Ministry of Environmental Protection and Agriculture of Georgia
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FOURTH NATIONAL COMMUNICATION OF GEORGIA

under the United Nations Framework Convention on Climate Change

2021

Fourth National Communication of Georgia

Under the United Nations Framework Convention on Climate Change

Tbilisi, 2021

The Ministry of Environmental Protection and Agriculture of Georgia has been in charge of coordinating the preparation of Georgia's Fourth National Communication.

The document was prepared and published with the assistance from the United Nations Development Programme (UNDP) and the Global Environmental Facility (GEF). The views expressed are those of the authors and do not necessarily reflect those of UNDP and GEF.

Foreword

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), Georgia is fully committed to the objectives of the Convention and acknowledges the necessity of urgent actions towards greenhouse gas (GHG) emissions reduction and climate change adaptation.

According to the commitments taken under the UNFCCC, the Government of Georgia ensures regular reporting of climate change related trends and developments through the national communication (NC) and the biennial update reports (BUR).

The Ministry of Environmental Protection and Agriculture of Georgia has an honor to submit Georgia's Fourth National Communication (FNC) to the UNFCCC that was prepared with close involvement of different state agencies. The FNC document includes the analysis of climate change impacts on the country's most important and vulnerable sectors such as agriculture, tourism, health, energy, also on the different components and resources of the environment such as forestry, biodiversity, protected territories, underground water and coastal zones, cultural heritage sites, etc. Noteworthy, that the report identifies existing initiatives and needs, which gives an opportunity to the country to plan concrete projects and processes accordingly.

The Georgia's FNC document, following the Article 12, paragraph 1, of the Convention, includes the information on greenhouse gas emissions not controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer; also, the general description of steps taken or envisaged by the Party to implement the Convention. The FNC document consists of five chapters: national circumstances, GHG inventory report, climate change mitigation policy, vulnerability and adaptation, and other information, that provides information on mainstreaming of climate change into economic, social and environmental policies, the bilateral agreements, studies and research relevant to climate change, policy documents linked to climate change and future needs analysis.

Finally, I would like to express my sincere gratitude to the United Nations Development Programme (UNDP) and to the Global Environment Facility (GEF) for support provided within the preparation process of the Fourth National Communication (FNC) document.

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List of Acronyms and Abbreviations

AD	Activity Data
AFOLU	Agriculture, Forestry, and other Land Use
BUR	Biennial Update Report
CAP	Climate Action Plan
CDM	Clean Development Mechanism
CH_4	Methane
CIS	Commonwealth of Independent States
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2-eq	CO2 equivalent
CRF	Common reporting format
DOC	degradable organic carbon
EF	Emission Factor
EU	European Union
FBUR	First Biennial Update Report
FNC	First/Initial National Communication
FOD	First order decay
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEOSTAT	National Statistics Office of Georgia
GHG	Greenhouse gas
GIZ	German Corporation for International Cooperation GmbH
GSL	Growing season length
GSP	UNDP-UNEP Global Support Programme
HFCs	Hydrofluorocarbons
LEDS	Low Emissions Development Strategy
LEPL	Legal Entity Under Public Law
LT LEDS	Long-Term LEDS
LULUCF	Land-Use, land-use change and forestry
MEPA	Ministry of Environmental Protection and Agriculture
MoU	Memorandum of understanding
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Plan of Action
NEA	National Environmental Agency
NECP	National Energy and Climate Plan
NGO	Non-governmental organization
NEHAP	National Environment and Health Action Plan 2018-2022
NIR	National Inventory report
NMVOCs	Non-Methane Volatile Organic Compounds

N_2O	Nitrous Oxide
NO_X	Nitrogen Oxides
PFCs	Perfluorocarbons
QA	Quality Assurance
QC	Quality Control
SBUR	Second Biennial Update Report
SF_6	Sulphur Hexafluoride
SNC	Second National Communication
SO_2	Sulphur Dioxide
SWMC	Solid Waste Management Company of Georgia
TNA	Technology Needs Assessment
TNC	Third National Communication
TJ	Tera joule
UNDP	United Nations Development Programme
UNFCCC	UN Framework Convention on Climate Change.

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EXECUTIVE SUMMARY

S.1. National Circumstances

State Structure. Georgia is a democratic state. The power in Georgia is distributed between legislative, executive and judicial branches. The president is the head of state. The parliament is the legislative body. The executive branch – the Government – includes the Prime Minister and the Ministers. Currently there are 11 ministries in Georgia. More than 20% of country's territory is occupied by Russia, namely, the Autonomous Republic of Abkhazia and Tskhinvali Region. The whole territory of country includes two autonomous republics – Adjara and Abkhazia Autonomous republics, 64 self-governing districts and 5 self-governing cities.

The occupation of Abkhazia and Tskhinvali by the Russian Federation is hampering the improvement of the environmental situation on the ground, as the Georgian government is deprived of the ability to exercise its jurisdiction over the occupied territories. Also, the Russian Federation, as an effective control force on the ground, prevents the entry of international mechanisms in the regions of Abkhazia and Tskhinvali.

Geography. Georgia is situated in the south-east of Europe, to the South of the Greate Caucasus Range. Georgia covers a territory of 76,284 square kilometers, including the Autonomous Republic of Abkhazia and Tskhinvali Region and the territorial waters. Georgia is very mountainous country – 54% of its territory is located at the altitude above 1000 m. The landscape of the country is quite varied with its mountains, plateaus, low-lands, glaciers, swamps and arid territories, lakes and rivers. With regard to land use, 15.8% represents the cropland, 70.6% is covered by forests, shrubs and grasslands, and 13.6% is used for agricultural activities.

Climate. In the western part of Georgia the climate is subtropical, while in the eastern part there is a dry moderate continental climate. The climate of Georgia is very diverse, with all climatic zones, except of desert, savanna and tropical forests. Annual precipitation in Georgia ranges from 400 to 4,500 mm. Due to its location at a relatively low latitude and moderate cloudiness, Georgia receives significant heat from the sun. The average annual duration of bright sunshine ranges from 1,350 to 2,520 hours.

Climate change process is considerably activated in Georgia. In 1986-2015, compared to 1956-1985, the mean annual ground air temperature in the country increased almost everywhere, depending on the regions – in the range of 0.25–0.58^{0}C. The average increase in the territory of Georgia is 0.470C. During the same period, the annual precipitation in western Georgia has mainly increased, while it decreased in some eastern regions.

Against the background of climate change, the increased trend to intensive and frequent natural hydrometeorological events is evident. The scale and quantitative indicators of landslide-gravity and avalanche processes have significantly increased in the territory of the country. Another indicator is intensive melting of glaciers. The wide specter of negative consequences of climate change are already visible in the country.

The negative effects will be even stronger in the future. The country's main goal is to improve its preparedness and adaptation capacity by developing climate-resilient practices that will reduce the vulnerability of the most sensitive communities to climate change.

Natural resources. Georgia is rich in natural resources. The main natural resources of the country are water and forests. In its territory there are deposits of mineral resources, including manganese, iron, copper, gold, marble and coal ores, also a smaller pools of oil and gas. Georgia's vegetation cover is very rich and diverse.

Georgia is home of about 100 species of mammals, more than 330 species of birds, about 48 reptiles, 11 amphibians and 160 species of fish. There are thousands of species of invertebrates, but their exact composition still requires to be established.

Population. By January 1, 2019 the population of Georgia was 3,723 thousand. 59% of the population is urban, and the rest 41% - rural. More than 30% of the whole population lives in Tbilisi. Male population is 48% of the total, and female population – 52%.

Health Care and Social welfare. Climate change has a significant impact on the human health, healthcare and social welfare systems. According to the data provided by the National Center for Disease Control and Public Health (NCDC) in 2017 the diseases of the cardiovascular system still remained as the leading cause of mortality in Georgia. Respiratory diseases were the second leading cause of mortality in 2005 and the 5th leading cause of death in 2017. However, a number of diseases (chronic obstructive pulmonary syndrome, asthma) that may be associated with climate change still remain in the leading positions. Between 2008-2017 cases of infectious and parasitic diseases doubled. Malaria cases have not been reported in Georgia since 2015. In 2012-2013 the Georgian Red Cross conducted a pilot study on Heat Waves, on the basis of which a National Action Plan on Heat Waves was developed.

Education. Over the recent years the number of activities aimed at awareness raising among the population on climate change has increased significantly, with the special focus on the youth. The issues directly or indirectly related to the climate change are being taught at the secondary and high schools, also in the format of informal education.

Culture. Georgia has very rich cultural heritage. In 2019 Georgia's unified data base of cultural heritage included 26,524 immovable and 5,322 movable objects. The cultural monuments are spread across entire Georgia, in each and every corner of the country.

Economy. Georgia is a country with transition economy. After 1990s its economy has gone through important structural changes. The scope of industry and intensive agriculture has decreased and Georgia's economy is becoming more devoted to services, tourisms, bank, and construction sectors. Significant reforms began after 2003, a number of macroeconomic parameters were improved, anti-corruption, privatization and tax reforms were carried out, the investment environment became relatively attractive, which led to economic growth.

In 2014 the European Union and Georgia signed an Association Agreement, constituent part of which is the Agreement on Deep and Comprehensive Free Trade Area (AA/DCFTA). Against this background the country harmonized its laws with the EU legislation. Georgia has one of the most liberal foreign trade policy, which implies the simplified foreign trade and customs procedures, relatively low import tariffs and a minimum non-tariff regulation.

According to the government program 2019-2020, for the long-term economic development of Georgia, it is important to establish a country as an international investment, communication, transport, logistics, energy, technology, education and financial hub. Under the program it is planned to rehabilitate and build the roads for international transit movement and for connecting the regions; application of European standards for waste management; preparation of spatial planning concepts, schemes and plans for the country and municipalities, land use regulation and development regulation plans for cities, towns and villages.

In 2018, foreign trade turnover amounted to $ 12.5 billion, with exports and imports accounting for $ 3.4 billion and $ 9.1 billion, respectively. The top exports of Georgia are: copper ores (re-export), cars (re-export), ferroalloys, wine and hard liquors, mineral water, fertilizers, tobacco (re-export) and medicines.

Petroleum products, natural gas, cars and food products have the largest share in imports, as well as medicinal remedies.

Priorities for National and Regional Development. Under the Paris Agreement, the countries shall elaborate and in 2020 submit to the UNFCCC Secretariat the Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy. This long-term strategy will be designed within the frame of the Project EU4Climate, which is financed by the European Union. The project aims to promote the goals and climate policies of the Paris Agreement and ensure low-emission and climate–resilient development in the Eastern Partnership countries, including Georgia.

On July 1, 2017 Georgia was admitted, as a full-fledge member, to the European Energy Community, within the framework of which important measures have to be taken in the field of climate change, namely, establishment of legislative and institutional framework for the promotion and development of energy efficiency and renewable energy sources and elaboration of action plans.

Among the national documents that should be mentioned is the Strategy "Georgia 2020", which, among many other priority issues, focuses on climate change mitigation and adaptation measures, promotion of energy efficiency and development of environmentally friendly technologies. Georgia's Strategy 2015-2020 for Agriculture Development envisages the introduction of climate-friendly agricultural practices in Georgia. With regard of sustainable development goals in the field of tourism, development of eco-tourism is one of its priorities.

At a local level 6 cities and 17 municipalities joined the EU initiative Covenant of Mayors. This process is of national importance, since the signatories represent about 60% of the total population and with even more share in the GDP. The signatories committed to achieve by 2030 40% reduction of GHG emission from 1990 level. In 2014, under the umbrella of the Covenant of Mayors, the European Commission launched the new initiative related to the climate change adaptation as one of the actions, which is aimed at engaging the cities in adaptation to the climate change. In 2015 the European Commission combined two initiatives in climate and energy fields for developing the integrated approach.

National Institutional Arrangement. State policy of climate change is developed and implemented by the Ministry of Environmental Protection and Agriculture of Georgia. Environment and Climate Change Department is a structural unit within the Ministry and it has a sub-unit – the Climate Change Division. In addition to other functions, the Division is entitled to coordinate, in cooperation with the stakeholders, the preparation of Georgia's National Communication to the Convention and the Biannual Updated Report, also to coordinate regular conduct of GHG emission national inventory and submit the report to the Secretariat of the Convention. The legal entity of public law - Environmental Information and Education Centre, is an agency under the Ministry. One of the functions of the Centre is to create a unified database of environmental information and promote its publicity. The process of preparing the Fourth National Communication is led and coordinated by the Climate Change Division. Separate chapters of the Communication have been designed by various organizations. UNDP Georgia acts as an implementing agency of the project of the Global Environmental Facility (GEF) and provides assistance to Georgia in the course of program. It also monitors and oversees the project on behalf of the GEF.

S.2. National Greenhouse Gas Inventory

The National GHG Inventory is based on the Intergovernmental Panel on Climate Change (IPCC) Methodology. Inventory Software Version 2.69 for energy sector and excel based worksheets for IPPU, Agriculture, LULUCF and Waste sectors were used for the compilation of the inventory. The inventory covers the following sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry, and other Land Use (AFOLU, in separate chapters); and Waste. The UNFCCC requires reporting the following gases: Carbon Dioxide (CO_2); Methane (CH_4); Nitrous Oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); Sulphur Hexafluoride (SF_6).

The Global Warming Potentials provided by the IPCC in its Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year time horizon was used for expressing GHG emissions and removals in CO_2 equivalents.

Institutional Arrangement of the National GHG Inventory

The Climate Change Division of the Ministry of Environmental Protection and Agriculture of Georgia (MEPA) is responsible for coordination of periodic compilation of inventory report and its submission to the Convention Secretariat. The LEPL Environmental Information and Education Centre of the Ministry prepared National GHG Inventory report with the assistance of independent international and local experts. UNDP Georgia operates as an implementing agency for the Global Environment Facility (GEF) project and assists Georgia during the whole program implementation process; it also monitors and supervises the project on behalf of the GEF. There is an active cooperation on data exchange between the MEPA and National Statistics Office of Georgia based on the MoU singed in 2014.

Quality Assurance and Quality Control

The QC is carried out through a system of routine technical activities that monitor and maintain the quality of the inventory, throughout its development process. The QC activities are carried out by a team of experts involved during the preparation of the National Inventory Report. Quality Assurance (QA) conducted by the personnel not directly involved in the inventory compilation/development process. The external review of this NIR was coordinated by the UNDP-UNEP Global Support Programme (GSP).

Key Categories

This sub-chapter provides the analysis of key source/sink of GHG emission/removals in Georgia for the period of 1990-2017, related to absolute values of emissions/removals (level analysis), as well as for the trends, Approach 1. The key category analysis was performed using excel worksheets.

Uncertainty Assessment

The uncertainty analysis of the National GHG inventory is based on the Tier 1 approach and covers all source/sink categories and all direct greenhouse gases. The year of 2017 was taken for the uncertainty assessment as the last year, and 1990 as the base year. The uncertainty estimation for the activity data and emission factors was based on typical values of the IPCC and on experts' judgment. The results revealed that the level of emissions' uncertainty (percentage uncertainty in total inventory) is within 22.85%, and the uncertainty trend – 11.99%.

Emission and Removal Trends by Categories

Emission trends by sectors over 1990-2017 years period are provided. Energy is the dominant sector, and it accounts for more than half of the total emissions over the entire period, excluding LULUCF. Following the disintegration of the Soviet Union, the contribution of the agricultural sector in the total emissions grows gradually, and it ranks second over the period of 1990-2017. IPPU and Waste sectors are on the third and fourth places in ranking, excluding LULUCF.

In Georgia, LULUCF sector had a net sink of greenhouse gases for 1990-2017 years period. The sink capacity of the LULUCF sector fluctuates between (-4,145) Gg CO_2-eq and (-6,625) Gg CO_2-eq. In 2017

GHG emissions in Georgia totaled 17,766 Gg in CO_2-eq without consideration of the LULUCF sector, and 12,842 Gg CO_2-eq when taking this sector into account.

Table: GHG Emission Trends by Sectors in 1990-2017 (in Gg CO_2-eq)

Sector	Energy	IPPU	Agriculture	Waste	LULUCF (Net removals)	Total (excluding LULUCF)	Total (including LULUCF)
1990	36,698	3,879	4,102	1,135	(6,353)	**45,813**	**39,460**
1991	28,529	3,038	3,713	1,106	(6,416)	**36,385**	**29,970**
1992	24,224	1,705	3,079	1,110	(6,312)	**30,118**	**23,805**
1993	19,678	776	2,831	1,112	(6,548)	**24,397**	**17,849**
1994	11,558	414	2,683	1,091	(6,625)	**15,745**	**9,120**
1995	8,319	447	2,805	1,125	(6,273)	**12,696**	**6,423**
1996	7,931	535	3,344	1,153	(6,022)	**12,963**	**6,941**
1997	6,783	504	3,526	1,180	(5,965)	**11,993**	**6,028**
1998	6,125	502	3,184	1,208	(5,521)	**11,019**	**5,498**
1999	4,849	710	3,560	1,237	(5,324)	**10,356**	**5,032**
2000	5,612	725	3,317	1,269	(5,031)	**10,923**	**5,892**
2001	4,391	439	3,474	1,288	(4,889)	**9,592**	**4,703**
2002	5,139	591	3,719	1,305	(4,778)	**10,754**	**5,976**
2003	5,763	699	3,833	1,321	(4,407)	**11,616**	**7,209**
2004	6,086	846	3,436	1,339	(4,145)	**11,707**	**7,562**
2005	5,396	957	3,461	1,354	(4,163)	**11,168**	**7,006**
2006	7,258	1,136	3,329	1,376	(4,257)	**13,099**	**8,843**
2007	7,888	1,314	3,022	1,400	(4,362)	**13,624**	**9,263**
2008	6,267	1,383	3,132	1,421	(4,357)	**12,203**	**7,846**
2009	6,580	1,106	3,061	1,456	(4,727)	**12,203**	**7,476**
2010	7,707	1,443	3,055	1,483	(4,537)	**13,688**	**9,151**
2011	9,743	1,794	2,981	1,509	(4,864)	**16,027**	**11,163**
2012	10,294	1,872	3,223	1,538	(4,750)	**16,927**	**12,178**
2013	8,949	1,892	3,582	1,542	(4,834)	**15,964**	**11,130**
2014	9,642	2,035	3,633	1,551	(4,609)	**16,861**	**12,252**
2015	10,849	2,058	3,745	1,562	(4,617)	**18,214**	**13,597**
2016	11,355	1,822	3,798	1,559	(4,797)	**18,534**	**13,738**
2017	10,726	1,990	3,488	1,562	(4,924)	**17,766**	**12,842**

Energy (CRF Sector 1)

In 2017, GHG emissions from the energy sector amounted to 10,726 Gg CO_2-eq, which is about 60% of Georgia's total GHG emissions (excluding LULUCF). In 2017, the following source categories had the largest shares in the total GHG emissions from the Energy Sector: Transport – 39%, Other Sectors – 24%, Oil and Natural Gas – 13%, Energy Industries – 14%, Manufacturing Industries and Construction – 9%. Compared to 1990, the total GHG emissions from the energy sector had decreased by 71%. A significant fall in GHG emissions in the 1990s is due to the collapse of the Soviet Union and fundamental changes in the economy of the country. However, the national economy started to grow since 2000 and the average annual growth of real GDP amounted to 8.4% prior to 2008. During 2008-2009, economic growth of Georgia has slowed down due to the Russian-Georgian war. Starting in 2010, the real GDP of the country began to increase again by 4.7% on average until 2018[1].

A large share of the emissions from the energy sector is due to fuel combustion (87% in 2017) and the remaining 13% is caused by fugitive emissions. Among emission source-categories, the highest growth relative to 2000 was noted in fugitive emissions from the transformation of solid fuel (5 Gg CO_2-eq. in 2000, 132 Gg CO_2-eq. in 2016), which took place as a result of the intensification of coal mining works in recent years. However, since 2017 coal mining has significantly decreased due to the technical inspection of safety norms of mines, following the deadly workplace accidents[2].

Industrial processes and product use (CRF Sector 2)

The GHG emissions from the sector cover emissions from the following categories: Mineral Products (2A), Chemical Industry (2B), Metal Production (2C), Non-Energy Products from Fuels and Solvent Use (2D), Electronics Industry (2E), Product Uses as Substitutes for ODS (2F) Other Product Manufacture and Use (2G) and Other Industries such as paper, drinks and food production (2H). In 2017, total GHG emissions from this sector amounted to approximately 1,990.2 GgCO_2-eq, accounting for 11% of national total emissions (excluding LULUCF) in Georgia. The emissions of CO_2, CH_4, and N_2O from this sector have decreased by 53% compared to 1990. The emissions of HFCs, PFCs, SF_6, and NF_3 from this sector have increased 712 times compared to 2001.

Agriculture (CRF Sector 3)

The agriculture sector of Georgia as source of GHG emissions comprises three subcategories: Enteric fermentation, Manure management and Agricultural Soils. The other IPCC subcategories of rice cultivation and prescribed burning of savannas are not relevant for Georgia and therefore are not considered. GHG emissions are estimated for 2016-2017 years period. For previous 1990-2015 years GHG emissions from agriculture sectors are recalculated applying specified data on cattle distribution by breeds

Enteric fermentation is the largest source for methane emissions within this sector, while "Agriculture soils" is the largest emitter of nitrous oxide. The emissions source category "enteric fermentation" consists of the following sub-sources: cattle, buffalos, sheep, goats, horses, asses, and swine (monogastricstomachs). Camels and mules are not relevant for Georgia. For 1900-2017 years period GHG emissions mainly varied according to the livestock population.

Land use, land-use change and forestry (CRF Sector 4)

The GHG inventory in the sector has been prepared in accordance with the 2006 IPCC Guidelines. The inventory for the LULUCF sector covers the following source/sink categories: 1) Forest land (5A); 2) Cropland (5B); 3) Grassland (5C); 4) Wetlands (5D); 5) Settlements (5E) and 6) Other land (5F). In this GHG inventory, emissions and absorptions have been estimated for three source/sink categories: forest land, cropland, and grassland. The above mentioned categories are the key source-categories in Georgia; in addition there is sufficient data available (e.g. databases) for carrying out calculations in these categories (unlike other source/sink categories); this allows to obtain the annual parameters for greenhouse gases emissions and absorptions in order to determine the trend of annual changes.

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[1] GEOSTAT – RealGrowthofGDP.
[2] Miners' Deaths Spark Protests In Georgia

The calculations of emissions and absorptions in the LULUCF sector have been carried out using default values of Emission Factors (Tier I approach), which correspond to the climatic conditions of Georgia according to the methodological explanations of IPCC guidelines.

Indicators of changes in land and land use are mainly based on data from the National Statistics Office and FAOSATA. Data from the Ministry of Environment and Agriculture of Georgia and the Adjara Forestry Agency are used as well.

In 1990 the accumulated volume was about 6,353.1 GgCO_2, while in 2017 net emissions decreased by 23 %, amounting to 4,923.8Gg CO_2.

Waste (CRF Sector 5)

Waste Management is still an environmental challenge for Georgia - poor waste management leads to one of the most important environmental problems. Untreated municipal wastewater is a major cause of surface water pollution in Georgia. Water used in households and industry contains a huge amount of toxins that gravely degrade the natural environment, flora and fauna, and the quality of life of the population.

Presently there are 56 municipal landfills in Georgia. Solid Waste Management Company of Georgia manages 54 landfills, 2 landfills are managed by Municipality of Batumi city in Adjara Autonomous Republic and Did Lilo landfill is managed by Tbilisi municipality. The methane emissions from landfills in Georgia are estimated based on the IPCC First order decay (FOD) method. The IPCC FOD method assumes that the degradable organic component/degradable organic carbon (DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are produced. The methane emission from landfills is key category.

The water used in households and industry contains a huge amount of toxins that significantly damage the environment. Wastewater handling systems transfer wastewater from its source to a disposal site. Wastewater treatment systems are used to biologically stabilize the wastewater prior to disposal. CH_4 is produced when wastewater or sludge is anaerobically treated. The methane emissions from aerobic systems are negligible. Wastewater treatment systems generate N_2O through the nitrification and denitrification of sewage nitrogen. Methane emission from wastewater handling is key category.

Consumption of foodstuffs by humans results in the production of sewage. Main source of nitrogen from human sewage is protein, a complex, high-molecular-mass, organic compound that consists of amino acids joined by peptide bonds. Assessment of CH_4 production potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater and the wastewater treatment system.

Recalculation of GHG emissions

During this inventory GHG emissions and removals were calculated using 2006 IPCC guidelines for the years 1991-1993, 1995-1999, 2001-2004, 2006-2009, 2016 and 2017, and figures were recalculated for all the previous years (1990, 1994, 2000, 2005, 2010-2015) in all sectors except for the IPPU sector where GHG emissions had been recalculated for all previous years during the last inventory.

S.3. Climate change mitigation policies and measures

Introduction

In accordance with the requirements of the Paris Agreement, Georgia is obliged to submit in 2020 an updated, more ambitious document of nationally defined contribution than the previous version. The Ministry of Environment and Agriculture of Georgia has prepared an updated NDC and will submit it to the

UNFCCC Secretariat in November 2020. According to the updated NDC, Georgia makes an unconditional commitment that by 2030 greenhouse gas emissions will be 35% lower than the levels in 1990. In the case of international support, Georgia is committed to reducing greenhouse gas emissions by 50% or 57% nationally by 2030 compared to 1990 levels if global greenhouse gas emissions follow the 20C and 1.50C scenarios, respectively.

Under the Paris Agreement, countries must develop and submit to the UNFCCC Secretariat a "Mid-Century, Long-Term Low Greenhouse Gas Emission Development Strategy" by 2020. This long-term strategy will be developed under the EU-funded EU4Climate project. The aim of the EU4Climate project is to promote the goals and policies of the Paris Agreement and to ensure low-emission and climate-friendly development in the Eastern Partnership countries, including Georgia.

Energy Sector

The largest share of greenhouse gas emissions in Georgia (60%) comes from the energy sector, which includes greenhouse gases emitted into the atmosphere by the combustion of fossil fuels and evaporates emissions from coal, oil and gas extraction, processing, transportation. Emissions from the energy sector, among other sub-sectors, include greenhouse gases released into the atmosphere as a result of the burning of fossil fuels in the transport and building sub-sectors. According to the National Greenhouse Gas Inventory in Georgia, the following key source categories were identified in the energy sector (excluding the transport sub-sector): gas consumption in buildings, volatile emissions from gas distribution, gas consumption in electricity generation, fossil fuel energy consumption in the industrial sector.

On July 1, 2017, Georgia became a full member of the European Energy Union, which requires the harmonization of the country's national legislation with the EU energy legislation within a strictly defined timeframe. Commitments to promote and develop energy efficiency and renewable energy sources are key to mitigating climate change. By 2020-2030, the country should develop targets for the share of renewable energy in final energy consumption and the amount of energy saved by energy efficiency. The Ministry of Economy and Sustainable Development of Georgia has started reforming the energy sector and developed new laws and action plans. In 2019-2020, Parliament passed the following laws: on energy and water supply, on energy efficiency, energy efficiency of buildings, and encouragement of production and use of energy from renewable sources.

On December 23, 2019, the Government of Georgia approved the "National Energy Efficiency Action Plan (2019-2020)" for the implementation of the energy efficiency policy by Decree N2680.

In accordance with the Law on Energy and Water Supply, energy policy includes the National Energy and Climate Plan (NECP). The NECP is a new initiative of the European Union and the member states of the Energy Union also have a recommendation to develop a unified, integrated policy and measures for energy and climate issues at the national level. The NECP development process should take place in parallel with the CAP and NDC development, so it is extremely important to coordinate these processes. The NECP should cover the period 2021-2030 and include a vision for 2050 in order to be in line with the policy objectives of the European Union, the Energy Community or the UNFCCC. The NECP covers 5 main areas: energy security; domestic energy market; energy efficiency; reducing greenhouse gas emissions and renewable energy sources; research, innovation and competitiveness.

Transportation Sector

Georgia is located at the crossroads of Europe and Asia, where strategic cargo is transported. The country's economic growth and sustainable development largely depends on the effective use of its potential as a transit country.

The number of vehicles registered in Georgia is characterized by an increasing trend. The number of vehicles in 2018 increased by 55% compared to 2007. Within the country, up to 25 million tons of cargo (approximately 59.9 percent of the total cargo transported) is transported annually by road and about 260 million passengers are transported. International shipping is large. Annual shipments in 2011-2018 were in the range of 30 million tons. In 2018, international shipments increased slightly compared to the previous year, amounting to 31.1 million tons. Due to such volumes, there is a large load on the main roads.

Most of the car fleet in the country is old and faulty private vehicles. In addition, the share of modern technologies and public transport in the sector is small. The fleet growth factor is important, which is directly related to the increase in emissions. The car fleet has doubled in the last 10 years, which is quite alarming, and does not indicate a focus on public transport.

It is noteworthy that the bus fleet in major municipalities is being gradually upgraded, as well as the development of various policy documents and strategies that will help increase the use of public transport and the consumption of non-motorized transport.

With the support of the German Society for International Cooperation, a strategy for the development of cycling in the city of Rustavi was prepared. Bakuriani multimodal transport strategy is being prepared (donor World Bank); Tbilisi Sustainable Urban Transport Mobility Plan (donor Asian Development Bank; $ 1.5 million); Restructuring of the bus network and introduction of an integrated, automated system for payment of fare (donors European Bank for Reconstruction and Development and Tbilisi Municipality; 0.8 million euros). Samgori-Vazisubani cableway is planned to be built (donor: French Development Agency; 0.5 million euros); Preparation of corporate development programs for 6 municipalities of Georgia and research on transport reform (donor: European Bank for Reconstruction and Development; 17 million Euros); Study on the Potential of Public and Tourism Transport Services on the Mtkvari River in Tbilisi Municipality (Donor: Asian Development Bank; $ 0.5 million)

With the help of the European Bank for Reconstruction and Development, new buses of 170 Euro 5 type will be purchased for 6 large municipalities in 2020-2022 and transport bodies/agencies and legislative regulations will be arranged and strengthened accordingly. This is also a great precondition for establishing a normal transport system in large municipalities and focusing on the people of the cities.

Industry Sector

According to the National Greenhouse Gas Inventory, the following key source categories were identified in the industrial processes sector: cement production, iron and steel production, ferroalloy production, ammonia production and nitric acid production. The industrial sector also emits greenhouse gas emissions into the atmosphere by burning fossil fuels used for energy purposes. The key source categories in this regard are the production of non-metallic mineral products (the most energy-intensive products are: cement production, glass container production, brick and block production, limestone production), iron and steel production, food industry and construction.

In the industrial sector in general, three types of mitigation measures can be considered:

- Increase energy efficiency in the industrial sector, which means replacing outdated technologies and processes with new energy-saving technologies and processes;
- Fuel replacement, which means replacing a currently used high-carbon energy signature with a low-carbon energy signature;
- Use of carbon dioxide capture and storage technologies.

Of these, the last two destinations are usually more expensive than the first. There are those in energy efficiency measures that are profitable for the enterprise and have a relatively short payback period. There are also less profitable measures, with a longer payback period. Energy efficiency measures can be divided into two types according to their ability to be disseminated and identified:

- A measure that is specific to a particular production process, the identification and assessment of economic viability of which requires a detailed production energy audit;
- Measures that are relatively general and that, even without prior energy auditing, are known to benefit a wide range of enterprises, such as energy efficient engines (electric motors with frequency regulators), efficient cooling/cooling systems, and so on.

It is important to promote both types of measures in Georgia. In the case of the first type of measures, it is necessary to identify them mainly in large enterprises, but it is also important that medium and small enterprises have the opportunity to conduct energy audits. This is reflected in access to relevant qualified staff and the ability to use financial instruments to identify enterprise-specific measures. As for the second type of measures, they can be implemented through the introduction of standards. There is also a need to train industry representatives and raise awareness so that they can see how energy efficiency measures can reduce production costs and product cost. It is important to create financial mechanisms that will make the first investment capital available to industrial facilities. These can be targeted energy efficiency cheap loans, energy efficiency fund and so on.

Agricultural Sector

The following source categories are considered in the agricultural sector: enteric fermentation, manure management, direct and indirect emissions from agricultural soil, and the incineration of agricultural waste in field conditions. Enteric fermentation is the main source of greenhouse gas emissions. Manure management includes all emissions from the operation of management systems such as anaerobic ponds, liquid systems, solid storage, and livestock feeding stalls.

According to the Georgian Low Emission Development Strategy (2017), lack of capital, land fragmentation, lack of modern technologies and rural poverty in the agricultural sector are significant challenges that make agricultural production inefficient and contribute to increased emissions into the environment.

One of the major challenges is also in the direction of climate-friendly agriculture and climate change. Low level of awareness. In 2020, the Ministry of Environment Protection and Agriculture of Georgia established a **working group on climate-friendly agriculture**. The aim of the group is to promote the introduction/popularization of climate-friendly agricultural practices in Georgia and to reflect the issues mentioned in the strategic directions/documents of agricultural policy. Also, one of the tasks of the established group is to promote awareness of climate-friendly agriculture for the various parties working in the agricultural sector.

The Rural Development Strategy of Georgia for 2017-2020 includes three priority directions: 1) Economy and competitiveness; 2) social status and standard of living; 3) Environmental protection and sustainable management of natural resources. The third priority includes three tasks, including climate change, implementation of mitigation measures for possible negative impacts caused by climate change, and risk management.

The Strategy of Agriculture and Rural Development of Georgia for 2021-2027 has three strategic goals, including the second strategic goal, which is the sustainable use of natural resources, conservation of ecosystems, adaptation to climate change. The presented strategic goal combines five tasks, one of which is to spread environmentally adapted, climate-friendly agricultural practices and promote the development of bio / organic production. The given task in the Agriculture and Rural Development Action Plan 2021-2023 involves the following activities: Identifying and promoting opportunities for adaptation to climate change.

Land use, Land use change and Forestry

Land use, land use change and forestry (LULUCF / Land Use, Land Use Change and Forestry) is one of the most important sectors of greenhouse gas emissions and absorption in Georgia. The key categories of the sector are forest lands and meadows, as well as arable lands, especially perennials.

Georgia's forests, which cover about 40% of the country's total area, play a crucial role in Georgia's greenhouse gas balance. The socio-economic situation in the country after gaining independence has had an extremely negative impact on the forestry sector and has had a direct impact on forests, leading to a significant reduction in their carbon dioxide absorption potential. Nevertheless, the National Greenhouse Gas Inventory Report in Georgia (1990-2017) shows that forests are a significant absorber of greenhouse gases and can make a significant contribution to climate change mitigation under consistent measures.

The same can be said for the other categories of the sector, the situation of the 1990s, like the forest sector, had a negative impact on the areas occupied by perennials, as well as on meadows and pastures. According to statistics, there is a decrease in the area occupied by both annual crops and perennials. For example, in 1990, perennials occupied 334 thousand hectares in the country, while in 2015, they decreased to 109.6 thousand hectares. Unfortunately, the current statistics do not show any land use categories or changes in them in terms of category change, however, a high rate of pasture and meadow degradation is evident. Due to the degradation of pastures and forests, the carbon sequestration potential of the LULUCF sector is significantly reduced.

The main challenge for the sector is forest degradation, which is mainly caused by unsustainable and inefficient use of forest resources. Timber still remains the main source of energy in rural areas, with 90% of the rural population partially or completely dependent on timber for space heating, water heating and food preparation. In addition, access to both energy efficient technologies and alternative energy resources is limited. In the wake of this and the socio-economic background of the country, the ongoing processes in the forestry sector over the years have been characterized by frequent institutional and legislative changes due to the instability of political and strategic priorities. Due to the lack of a clearly defined strategy and action plan, the processes failed to develop consistently, violating the necessary preconditions for the sustainable management of the sector, which implies a sound legal framework and adequate financial and human resources. Incomplete and outdated information on quantitative and qualitative indicators of forests did not allow for long-term planning of forest management and sustainable forest use in accordance with the functional purpose of forests.

To eliminate unsustainable forest management, the Georgian government launched a large-scale forest sector reform in 2013 and should complete it by 2020-21. The objectives of the forest sector reform are (a) to change current approaches to forest use and management, (b) to develop a unified forest management system, and (c) to improve the institutional and technical skills of forest management bodies.

The process was based on the "National Forest Concept" approved by the Parliament of Georgia, which is the main framework document defining the policy in the sector and which aims to introduce a sustainable forest management system in the country. Actions related to the development of the sector to ensure the implementation of the National Forest Concept are reflected in the documents of the Third National Environmental Action Program 2017-2021 (NEAP III), the Georgian Biodiversity Strategy and Action Plan (2014-2020), the Georgian Rural Development Strategy and Action Plan (2017-2020).

The importance of forest resources and their sustainable management is mentioned in the country's top-level climate policy: Georgia's National Defined Contribution (NDC) identifies forests as the main sector of national climate action, which has a quantitative commitment to make sustainable forest management broader. To mitigate climate change in the forestry sector, the Government of Georgia considers the following three measures as priorities: (a) establishing sustainable forest management practices; (b) Implement reforestation/forest restoration and promote natural restoration; and (c) increase protected areas.

Progress has been made in the country since the preparation of the Third National Communication, including the implementation of recommendations. In addition to improving the institutional and legislative framework, the scale of reforestation and the fight against forest pests and diseases has increased since 2015, responding to the Intended Nationally Determined Contribution (INDC) commitment (Implementation of reforestation measures by 2030 of predetermined 1500 ha and production of natural renewal promotion measures at 7500 ha). For example, 250 hectares of forest destroyed by fire in the Borjomi gorge were fully restored.

According to the Nationally defined contribution (NDC) document, the strategy for fulfilling the unconditional commitment to the forestry sector envisages sustainable forest management based on an ecosystem approach by 2030 as well as halting the degradation process; And consequently improving both quantitative and qualitative indicators of the forest. Georgia plans to increase its forest carbon sequestration capacity by 10% by 2030 compared to 2015 levels.

Like forests, there are a multitude of challenges for other categories in the LULUCF sector (arable land, especially perennials, meadows and pastures). The scarcity of data on agricultural land degradation hinders full-fledged assessment and forecasting. There is little data on the changes in categories and the reasons for the change. With the lack of data, there is a lack of knowledge and experience in the production of climate-friendly agriculture and new technologies. In response to the challenges, the country is working to improve the legislative framework, as well as to prepare a number of strategic documents and action plans, the consistent implementation of which will reduce emissions from land use change and forestry activities.

Waste Sector

In Georgia, waste management is associated with a number of financial and environmental problems of national, regional and local importance. The waste sector in the country (solid waste and wastewater) is an important source of greenhouse gas emissions. The waste sector in Georgia is represented by sub-sectors of solid waste disposal sites (landfills), solid waste biological treatment, solid waste incineration and wastewater treatment.

Landfills: To date, there are 57 official municipal landfills in the country, of which 23 are closed. Other landfills will also be sealed. They will be replaced by new, modern landfills in accordance with modern standards, the construction of which is planned until 2024. It is planned to install a system for collecting methane and burning it in torches at closed landfills.

The country lacks the technical and technological capabilities for biodegradable waste recycling, human resources with relevant skills. Fragmentation of organic waste is carried out in fragments. Only individual farmers and small-capacity composting plants in Marneuli produce compost from biodegradable waste.

Waste Water: Wastewater is one of the most important sources of greenhouse gas emissions from the waste sector.

United Water Supply Company of Georgia is implementing a project funded by the Asian Development Bank under the Urban Services Improvement Investment Program (loan: $ 500 million). provides for the improvement of water supply and sewerage systems in 9 cities and the construction of wastewater treatment plants in 7 cities. Within the framework of the same program, fesability study of Bakuriani and Didi Mitarb water supply, as well as Bakuriani and Chiatura town sewage systems and wastewater treatment facilities is underway.

All wastewater treatment plants will be treated with modern, biological treatment technology (active sludge method). On high-capacity buildings (Zugdidi, Poti, Marneuli, Kutaisi) anaerobic decomposition of precipitation in methane tanks and collection of released methane gas in gas storage (gas holders) is envisaged, part of which is used to maintain the fermentation process in methane tanks or recycled to generate electricity in gas generators that will be used during the operation of the treatment plant. As for small-capacity treatment plants where the methane output is low and cannot justify the high investment costs required for the productive use of gas, they do not provide for the collection and collection of methane and its subsequent use.

S.4. Vulnerability and Adaptation

The Climate change and its adverse impacts on ecosystems and economy pose severe threats to Georgia's sustainable development. Unique geographical location, complex dissected relief, land cover diversity and specific climate, containing almost every type of climatic zones, set conditions for wide variety of negative consequences of climate change in Georgia.

Adaptation to the adverse impacts of the climate change is one of the main priorities for the Government of Georgia. Georgia's main objective is to improve the country's preparedness and adaptive capacity by developing climate resilient practices reducing vulnerability of highly exposed communities. In this regard, Georgia takes steps to integrate climate risk and resilience into core development planning and implementation.

S.4.1 Current Climate Change

In order to assess the current climate change, the nature of changes in intensity and repeatability of mean and extreme values of meteorological

elements was studied based on observations of the 60-year period (1956-2015) of the Georgian Meteorological Network. Changes in meteorological elements between two 30-year periods (1986–2015 and 1956–1985) were assessed.

Annual mean air temperature in 1986–2015, compared to 1956–1985, has increased by almost 1 degree Celsius, with an average of 0.5^{0}C. The most significant warming was observed in Samegrelo-Zemo Svaneti, Kakheti and Samtskhe-Javakheti, where the temperature increase was 0.4-0.7^{0}C. Against the background of the observed warming, there is a significant increase in the probability and duration of heat waves.

The change in the total annual precipitation was of mosaic-pattern. In a significant part of western Georgia, precipitation increased within 5-15%. In most parts of eastern Georgia, in contrast to western Georgia, precipitation declined by about 5-15% over the last 30 years. Up to 20% precipitation growth was observed in certain areas. The upward trend in precipitation in western Georgia seems to be caused by the increase in rainfall. In the south and east of the country (especially in Kakheti and Mtskheta-Mtianeti) precipitation indices reflect a decrease in precipitation due to the increase in the duration of the dry periods.

Relative humidity is high throughout the area, with fluctuations (-1% to 5%). High humidity is observed in winter months in western Georgia and should be driven by extremely humid days (10-12 days/year), with decreasing trends most intensely observed in early summer-autumn.

Average annual wind speed significantly decreased on the whole territory of the country by about 1-2 m/s during all seasons of the year. It is noteworthy that the most significant decline with sustainable trend was observed on the stations considered in the Wind Atlas as the most prospective for the development of wind energy (Mta – Sabueti, Poti). At the same time, in the light of declining average speeds, there is an increase in the number of strong days in certain districts, which should be attributed to the increasing frequency of such days over the last 15 years, and is most frequently observed in Mtkvari Valley (Gori, Tbilisi).

In conclusion, it can be concluded that the study of climate change in the recent period in Georgia has revealed a very pronounced picture of warming, which is mainly caused by the increase of summer and autumn temperatures throughout the country and the by the increase of air temperature and wind speed. Against the backdrop of declining speeds, however, there has also been a marked increase in maximum wind speeds in certain areas. The identified climate change risks are therefore reflected in different socio-economic sectors.

S.4.2 Climate Change Scenario

RCP4.5 scenario is used to predict the expected climate change. Version 4.6.0 of RegCM Regional Climate Model was used to improve the global forecast scale. In this version a number of mechanisms for describing and parameterizing physical and chemical processes are refined. Dust and aerosols are also included in this model. In addition, RegCM 4.6.0 version allows for horizontal scale enhancement with the one-way nesting technique. All simulations of the regional climate model were run on an even coarser scale data (30 km) and over a relatively large area, and then calculated on a 10 km grid-spacing simulation.

Comparing two 30-year periods (2041-2070 and 2071-2100 years) with 30-year period of 1971-2000, future trends in climate change were assessed for 39 stations of the Georgian Meteorological Network. Scenarios were built for basic climatic parameters such as air temperature, precipitation totals, relative humidity and monthly and annual mean values. In addition, sector-specific climate parameters - indices that can assess the impact of climate change on individual sectors were calculated.

According to the scenario, the average annual temperature will increase from 1.6^0C to 3.0^0C throughout the country in the period of 2041-2070 compared to 1971-2000 years period. The average annual temperature continues to grow in the period of 2071-2100 and will rise to the range of 0.4^0C-1.7^0C. As a result, the temperature rise for this period is within the range of 2.1^0C-3.7^0C compared to the 1971-2000 average.

In the period of 2041-2070, the annual precipitation in Eastern Georgia is reduced by 9% on average. The largest decrease (12.3%) is noted in Pasanauri and smallest (5.3%) in Sagarejo. During the period of 2071-2100, compared to the period of 2041-2070, the precipitation change is insignificant, fluctuating within the range of 1-6%.

Changes in air temperature and precipitation total, as well as specialized indexes by season and region, affect different sectors, which is described in detail in the sectors-related sections.

S.4.3. Agriculture

S.4.3.1. Livestock farming

Environmental conditions are an integral part of the economic development of the livestock sector. The increase in productivity directly depends on the creation of livelihoods that are adapted to extreme conditions. The productivity of cattle of any breed is one of the indicators of adaptation of animals to environmental temperatures.

Visual observation of Holstein cattle behavior in the spring of 2016 in Pshaveli Village, Telavi Region, showed that it is sensitive to summer temperatures - the first signs of heat stress. Heat stress was manifested by an increase in arterial pulse and respiratory rate. Values of Temperature Humidity Index (THI) are measured on the basis of Telavi Meteorological Station data (temperatures and relative humidity). Practically during all August cattle are in discomfort, often $79 < THI \leq 84$, which can pose a serious threat to livestock health.

On the farm in Khornabuji Village, Alazani Valley, biological characteristics of Caucasian brown (in Latin: Bos Taurus) were studied. It was found that the pulse and respiration rate of cattle increased by 1.96 and 1.4 times, respectively, at 36.2^0C compared to 21.0^0C. At the same time, even though the sweating increases by 2.39 times, it is not sufficient for thermoregulation and the cows' (rectal) body temperature rises by 1.5^0C and skin temperature by 3.1^0C. Thus, at high temperatures, the Caucasian brown's thermoregulatory mechanism is unable to maintain the normal physiological state of the organism - heat stress causes milk yield decline.

The increase in temperatures also affects the morphological composition of the blood. It was found that in the afternoon, at extremely high temperatures, the amount of erythrocytes and leukocytes in the blood of dairy cows decreases, the concentration of hemoglobin also decreases, but the decrease is less significant. From noon to evening, the THI is above 80, which is a sign of a serious danger according to heat stress index rankings. In order to increase milk production in summer, measures to protect cows from the heat should be considered on pastures.

S.4.3.2. Perennials

Perennial crop production is one of the oldest, important and traditional branches of agriculture in Georgia. Current and projected climate change, as well as priority areas for adaptation, are discussed in relation to important perennial agricultural crops such as vines, nuts and tangerines.

An analysis of existing climate data and climate change scenarios shows that this climate dynamics, over the next few decades, in both eastern and western Georgia, will have a significant impact on changing important agro-meteorological parameters of perennial crops such as duration of vegetation period (increase), total of active temperatures (rise), critical winter temperatures (decrease), drought days (increase), carbon dioxide (CO2) concentrations (increase), etc.

With this in mind, it has been demonstrated that current and projected climate change will have a predominantly adverse impact, and in some cases a possible positive impact on vine, hazelnut and tangerine production.

Proposed adaptation recommendations for the crops under consideration include both primary and secondary measures, involving the use of financial support, institutional and scientific research approaches such as the allocation of new production zones and micro-zones, introduction and implementation of resource-saving conservative agriculture methods, support for drip irrigation, agro-meteorological network improvement, research related to new drought resistant genotypes, etc.

It is important to keep in mind that the expected social effects of adaptation measures, will be high, since these measures will significantly improve the social and economic well-being of farmers and rural residents producing the crops considered.

S.4.3.3. Cereals

The impact of climate change on wheat and maize production in Dedoplistskaro and Zugdidi regions is discussed.

A comparison of the meteorological elements of 1956-2015 revealed that current climate change is characterized by increased temperatures and increased total of active temperatures, as well as increase in the number of hot days in summer and a significant change in the seasonal distribution of annual precipitation.

Compared to the previous period (1956–1985), during the second period (1986–2015), wheat is more frequently subject to drought during tillering (drought stress), effect of elevated temperature on stem extension stage, and low heat and humidity during heading and the flowering periods. In particular, the negative effects of insufficient moisture and heat on grain formation and filling should be noted. In the second period, maize is less prone to spring frosts, which allows earlier sowing of this culture and can be considered as a positive influence of current climate change. However, high temperatures during the summer months increase the demand of maize for moisture, inhibit flowering and promote the response to light, which has a negative impact on crop yields.

It is expected that the stress caused by high temperatures and humidity will increase further in wheat and maize in 2071-2100 compared to the baseline period of 1971-2000. New species and new breeds of pathogens and pests causing diseases of wheat and maize will appear. Increase in carbon dioxide concentration will have a positive effect on wheat productivity if it is provided with sufficient moisture. The projected average annual temperature rise of 3.6 degrees Celsius during the period of 2071-2100 will result in 15-25% reduction wheat and maize yields under unchanged agro technology. These effects can be mitigated by increasing irrigation areas, introducing agro-technological measures to conserve moisture in irrigated areas, and developing seed rotation, and in the case of wheat, with spread of drought- and heat-resistant varieties.

S.4.3.4. Pastures

Information on Georgia's pastures and potential threats posed by the climate change is presented here. Species of natural meadows and vegetation in the country, as well as key habitat classes of Georgia's grasslands using the so called EUNIS Habitat Classification System of the European Nature Information System are discussed.

A review of recent pasture management practices and vegetation status is provided. Particular emphasis is placed on studies carried out in recent years to study anthropogenic and natural erosion and improve pasture management in Georgia's protected areas.

Significant attention is paid to the potential threats posed by climate change and the current or expected risks. Expert opinions based on climate indexes, forecasts and models collected over the last seventy years are also presented. Lastly, the conclusions and key recommendations concerning the expected threats, adaptation actions and mitigation measures are addressed.

S.4.3.5. Soil Erosion

Soil erosion in Georgia is one of the main causes of degradation of agricultural land as well as forest and alpine lands.

Water erosion is widespread throughout the country, in all natural-climate zones, ranging from humid subtropical to highland alpine. Wind erosion is only widespread in eastern Georgia, mostly in Outer (Gare) Kakheti and Shirak. The methodology of the European Research Center RUSLE (Revised Universal Soil Loss Equation) is used to assess the risks of water erosion. Surveys conducted according to the above methodology showed that 13.3% (43,414 hectares) of Zemo Imereti is eroded to varying degrees (Table 7).

The area of high and very severely degraded land in Zemo Imereti is 6,143 hectares, while the total area of weak and moderately degraded land is 16,260 hectares. Water erosion is particularly strong in Chiatura municipality, where 22.2% of the total area is degraded. The erosion processes of the rest of the municipalities are of approximately equal intensity and result in varying degrees of degradation of 10.7 - 12.3% of their total area.

An electronic map of the potential soil loss from water erosion in Upper Imereti has been developed as part of the project.

The expected decrease in precipitation in the future (2071–2100) does not necessarily mean a reduction in the exposure to erosive processes.

Wind erosion. Wind erosion equation (WEQ) was applied to estimate soil erosion. Studies have demonstrated that the soil erosion index (I, ton / ha / year) of Outer (Gare) Kakheti and Shiraki ranges from 67 to 544 ton/ha/yr. As a result of wind erosion in the region, the average area of heavy, highly degraded soils is 289, 357 ha, or 46.2% of the total area of the region, which is very high. The first electronic map of the project "Potential Soil Loss due to Wind Erosion in Outer Kakheti and Shiraki" was developed. In the wake of climate change, the manifestation of wind erosion by 2100 - its strength and frequency, will definitely increase in Outer (Gare) Kakheti and Dedoplistskaro-Shiraki.

S.4.4 Glaciers

Glacier degradation is an effective indicator of climate change. In order to support sustainable development of the country, it is necessary to develop a strategy for adaptation to glacier disasters and mitigation measures in the most vulnerable highlands. To this end, it is important to have the results of a scientifically justified glacier degradation study.

The characteristics of glaciers and their dynamics have been determined by high resolution data from Remote Sensing Satellite (IRS), based on centuries-old historical data, existing fieldwork, and complex, integrated use of expert knowledge.

Changes in the number of glaciers and the corresponding areas affected by climate change on glaciers and small glaciers were assessed. Determination of the likely glaciers retreat and their tentative melting dates are discussed.

It has been found that the glacial area and the number of glaciers in Georgia have decreased and this reduction is more intense in eastern Georgia than in western Georgia. It is demonstrated that climate change accelerates the retreat of large glaciers and sets the expected dates for complete melting of individual glaciers, and the interrelationship between large glaciers retreat and climate change has been established.

S.4.5. Water Resources

Georgia is rich in water resources - rivers, lakes, reservoirs, glaciers and groundwater. Georgia's rivers are fed by rainwater, groundwater, snow and glaciers. They are formed in wetlands, marshes and glaciers, on the territories of permanent snow. Most of the marshes and wetlands are in the lowlands of Kolkheti. There are about 860 lakes and 43 artificial reservoirs in the country.

In case of the Rioni Basin, an assessment of the impact of current and expected climate change on surface runoff has shown that the average normal rainfall value (ΔPr) of the upper reaches of the river between the two periods (1956–1985 and 1986–2015) increases by 2% (Shovi) and 5% (Ambrolauri), and average normal Rioni River discharge (ΔQ) increases by 19%. The normal mean value of sediment yield (ΔPr) in the lower reach of the Rioni River is increased by 3% (Kutaisi) and 13% (Poti), while the average value of the Rioni River basin increases by 21%. The Rioni Alpana and Rioni Chaladidi hydrologic cross-sectional river runoff forecast which was implemented according to the regional climate model RCP4.5 scenario within two prediction periods (2041–2070 and 2071–2100) based on the HBV-IHMS hydrological model showed that average normal Rioni River discharge at the Rioni Alpana of the total rainfall (ΔPr) is reduced by about 8% within the period of 2041-2070 and decreased by 5% within the period of 2071-2100; The average normal rainfall value (ΔPr) decreased by 7.6% and 5.1% (Shovi) and 12.3% and 16.1% (Ambrolauri), respectively. The average normal value of the Rioni River discharge (Q_{aver}) in the Rioni Chaladidi cross-section declines by 9% in 2041-2070 as compared to the period of 1971- 2000 and is reduced by 3% within the period of 2071-2100; The average normal rainfall value (ΔPr) decreases respectively by 17.6% and 16.1% (Kutaisi).

S.4.6. Groundwater

Assessment, protection and rational use of underground freshwater resources are the top priority for any country in the context of climate change in order to ensure adequate adaptation. Issues related to distribution and use of groundwater freshwater resources on the territory of Georgia have been described; In-depth analysis of the actions undertaken and ongoing in Georgia for protecting underground freshwater resources from effects of to the climate change was carried out; Based on actual materials, the vulnerability of groundwater to climate change has been assessed; Considering future climate scenarios, based on expert analysis it was possible to identify particularly vulnerable groundwater bodies; Recommendations were developed including strategic objectives for the protection of underground freshwater resources in Georgia and adaptation measures to address local, community-level threats of the climate change.

S.4.7. Coastal Zone

The three (3) factors having a direct influence on the formation of the eastern shores of the Black Sea are discussed: planetary and regional climate, tectonics and anthropogenic factors.

Coastal development in natural conditions: Consideration of sea level variability in the Upper Holocene; vertical movement and lithodynamic systems of beach structural blocks; Adjara and Kolkheti beach-ridge system.

Sea Storm Activity: The statistical analysis of the sea storm activity according to the data of the Hydrometeorology Department of Adjara Hydrometeorology Observatory and Maritime Transport Agency is provided.

Actual condition of the coastal zone: This section provides a description of beach parameters, erosion problems and solution thereof, challenges on the Black Sea coast of Georgia and the impact of the global warming, as well as some indicators of this impact. The effects of the global warming and anthropogenic impacts on the coast are compared. The accuracy of various time forecasts is evaluated.

The main adverse effect of the global warming for the coast is the sea-level rise, which will cause flooding and loss of territories; anthropogenic impacts accelerate the process of flooding and loss of coastal areas.

S.4.8. Natural Hazards

The complex relief of Georgia contributes to exacerbation of atmospheric circulatory processes and formation of various types of natural meteorological events (floods, overflows, snow avalanches, strong winds, droughts, etc.). In the wake of the climate change, there have been increasing trends in the frequency and intensity of natural disasters in recent decades, floods and freshet being the most damaging in terms of both economic losses and human casualties. Measures to prevent / mitigate adverse effects of floods / freshet are as follows:

1. Conducting hydrometric and topographic works at vulnerable areas; 2. Hydraulic and hydrological modeling; 3. Installation / maintenance of hydrological checkpoints for early notification; 4. Issue of relevant recommendations for taking coastal protection measures.

The following preventive measures to mitigate the adverse effects of snow avalanches include: 1. Arrangement of protective timber or metal construction in the area of avalanche; 2. Arrangement of avalanche dam (landfill) near settlements; 3. Conduct of high impact works for road safety.

S.4.9. Geological Processes

Georgia is one of the most difficult regions in the world in means of development of natural geological processes (landslides, mudslides, rockslide, stone fall, etc.), the degree of vulnerability of the area and the risk of danger. In recent years, the scale and quantification of landslide-gravitational and mudflow processes have significantly increased in the country. Geological disasters have caused major danger to the population and infrastructure of Georgia in recent years. Significant economic losses were attributed to human casualties.

Landslide-gravitational and mudflow phenomena should be noted among geological hazards due to magnitude of development and high risk of danger. The climatic factor has a decisive role in producing/reactivating modern geological processes. The issue is particularly relevant to Georgia, a complex region in means of geological structure and terrain-climatic features. Such as, where the provocation of much of the geological processes is directly linked to the climate factor. The study identifies the likely impact of the climate change on geological processes over two 30-year periods (2041–2070 and 2071–2100 years) with respect to the baseline 30-year period (1971–2000 years). Geological hazard zoning maps were prepared. The document also outlines recent geological hazard management projects and adaptation measures to be undertaken in the wake of the climate change.

S.4.10 Forests

Covering almost 40% of the country's area, forests play a vital role in the social, economic, and cultural development of the country. Forest groves are of paramount importance

in maintaining the biodiversity of typical landscapes and ecosystems of Georgia. In addition, many sectors of Georgia’s economy are directly linked to maintaining forest ecosystems. They also provide continuous direct or indirect benefits and resources to the country's population, which in its turn ensures the functioning of various sectors of the economy, human well-being, poverty eradication and creating the favorable environment for sustainable development of the country.

Forests of the country, for the recent almost 30 years, have experienced strong anthropogenic pressure, which directly affected the state of forests. At the same time, the negative impacts of the climate change on both the progress of existing pests and the emergence of new harmful insects and diseases are significant. Taking into account future climate scenarios, there is also an increased risk in change of the species and fire hazards. Consequently, the climate change, along with many challenges in the sector, should be considered as one of the major problems. Measures to mitigate the climate change impacts on Georgia's forests and adaptation of the forests to the climate change impacts should serve as a basis for actions planned for the development of the sector.

S.4.11. Protected Areas

Protected areas play a vital role in contributing to the climate change mitigation and adaptation. However, the climate change will have a significant impact on protected areas. The climate change will affect protected species on protected areas, which may be reflected by their scattering, new habitat capture, or extinction.

The climate change causes activation of the existing diseases and their carriers, as well as emergence and spread of the new diseases. Another important threat is invasive species that have not yet occupied their potential distribution areas. Protected areas, while maintaining ecosystem integrity help to reduce the risk and impact of natural disasters; however, natural disasters can significantly damage the habitats of protected species inhabiting the protected area, as well as their immigration corridors. The climate change is expected to have impact not just on the natural values of the protected areas, but also on the number of visitors of these areas, the period of visits, the shift of tourism-friendly places and generally, the economics of the sector. In view of the above, it is important to adopt appropriate adaptation measures to ensure that the system of protected areas is in place.

S.4.12. Human Health

The current trend of prevalence of climate-related diseases (diseases of the cardiovascular and respiratory system, infectious diseases) is established. Special attention is given to the analysis of the impact of heat waves on human health. Multi-criteria analysis was applied to compare Tbilisi, Kutaisi, Batumi, Zugdidi, Telavi and Poti in means of the level of vulnerability of these cities to the impacts of the climate change and in particular one of its challenges - to heat waves and their ability to adapt, both in the current situation, as well as for the two forecast periods (2041-2070 and 2071-2100). The analysis revealed that Telavi is most vulnerable in the present situation; Batumi - in the first forecast period;, and Telavi again - in the second forecast period. The Framework Document developed by the World Health Organization provides an opportunity to develop effective measures for adapting the health sector. This document is highly recommended for decision makers for guidance. The report also summarizes the results of a rapid assessment of the health sector's preparedness for climate change by filling in a simplified questionnaire by local experts and identifying needs for sector adaptation. Finally, recommendations are made for effective sector adaptation, which is desirable for national, local and non-governmental sectors.

S.4.13. Energy

Higher temperatures due to the climate change in Georgia, changes in precipitation patterns, melting glaciers, increased weather-related disasters, geological risks and other processes will have a significant impact on the country's energy sector. The climate change in the Enguri and Rioni basins is expected to reduce precipitation, which will affect river runoff. Increased melting of glaciers for certain period is expected to increase river runoff, after which glacier runoff will begin to decrease. As the runoff increases, the risk of floods will increase and the role of the reservoirs will become important. As temperature rises, evaporation from the reservoirs will increase, especially during the period May to September. Precipitation is expected to decrease in eastern Georgia, which is expected to reduce river runoff. Average air temperature is expected to rise at the site of the thermal power plants in Gardabani Region, which will adversely affect the efficiency of the stations. In Georgia, considering average wind speeds, the most attractive location for wind stations development within the period of 2041-2070 and 2071-2100 will be Sabueti Mountain, Kutaisi, Paravani, Batumi and Goderdzi Pass, where the average wind speed will be more than 4 m / s. According to the climate change scenario, the expected climate change in the potential areas of development of solar stations (Tbilisi, Gardabani, Udabno) will not cause serious problems for the development of solar stations. The problem with power transmission lines is the increase in temperature, which is particularly significant in the lowlands. Compared to the baseline period, the number of heating degree days will decrease, while the number of cooling degree days will increase significantly. Increased geological and weather-related risks will have a negative impact on critical energy infrastructure. Therefore, an in-depth analysis of the sector's sustainability and resilience is needed; its development strategy should also be developed, taking into account the principles of sustainable development and the risks posed by the climate change.

S.4.14. Transport

The climate change has a negative impact on the transport sector. In the future, these impacts are likely to be further enhanced. As a result of the climate change, transport infrastructure operation, maintenance, repair and rehabilitation costs will increase. Modernization of the transport infrastructure in order to better adapt to the climate change implies high costs; though economic losses are going to be much larger unless the adaptation measures are taken. Particular attention is paid to the potential effects of extreme heat events, which may pose risks to the transport infrastructure. Depending on the pace and scale of the development of transport infrastructure in the country, it is also important to develop adaptation measures and monitor their implementation.

S.4.15. Tourism

The tourism industry is one of the most important sectors of the economy, the development of which directly depends on the geographical location, topography, vegetation, ecology, weather and climate of the region. Weather and climate are the two key factors that determine the bioclimatic resources of a place. In order to study the impact of the climate change on the development of the tourism industry, the complex Tourism Climate Index (Holiday Climate Index - HCI) has been identified.

The research parameters were compared for two 30-year periods, I (1956–1985) and II (1986–2015). The consistency of changes in the HCI Index and its constituent parameters are defined for 12 tourist destinations in Georgia. Mathematical statistics methods were used for data analysis. It has been found that the climate change does not have a significant impact on tourism bioclimatic resources, it can only cause a change in the HCI index category, i.e. it can increase or decrease by one grade. So it can be said that the bioclimatic conditions in Georgia have not changed significantly and we should not expect any significant changes in the future either.

In order to study the snow conditions in winter tourist places (Mestia, Goderdzi, Gudauri, Bakuriani), the main climatic characteristics of snow cover, average, minimum and maximum values of snow cover duration and changes in maximum snow cover depth were determined. In the future, climate change may significantly affect the length of the ski season. According to the climate scenario, average temperature are expected to rise every month relative to the baseline 30-year period (2041–2070) compared to the baseline 30-year period (1971–2007). Precipitation throughout the whole territory of Georgia, with the exception of a few low-lying stations, has decreased. In the future, as temperature increases and precipitation drops, snow cover will likely decrease. As for the maximum depth of snow cover, it does not undergo significant changes at the resorts located in the study area and is not a barrier for the development of downhill skiing tourism in the future.

S.4.16. Biodiversity

Threats of the climate change impacts that may have a negative impact on Georgia's biodiversity are discussed. The global processes and the practices that are used worldwide for biodiversity conservation are analyzed. In addition, special attention is paid to the potential risks posed to Georgia's ecosystems and species as a result of the climate change.

Based on the expert data, special emphasis was made on the mountainous regions and the semiarid zone, as well as on the forest and wetland ecosystems of Georgia as endangered ecosystems. Studies in this field in recent years in Georgia are also reviewed.

Considerable attention is paid to the potential threats posed by the climate change and the current or expected risks. Expert opinions based on forecasts and models collected over the last seventy years are also presented.

The final section provides conclusions and key recommendations for biodiversity conservation, the climate change adaptation and mitigation.

S.4.17. Cultural Heritage

Georgia is a country rich in cultural heritage. As of 2019, there are 26,524 immovable and 5,322 movable objects of cultural heritage in the unified database of Georgia. On the basis of historical or cultural value, antiquity, uniqueness or authenticity, the status of immovable cultural heritage monument is granted to 7,689 sites and the status of movable monuments - to 4,221 items. 1,011 monuments with cultural heritage status were assigned the category of national significance due to its outstanding artistic, aesthetic value or historical significance, its links with the certain stage of developmental of the nation and its outstanding national values.

Due to the climate change, Georgia's cultural heritage (historical monuments) may be endangered by increased relative humidity, extreme precipitations accompanied by strong winds, as well as by increasing frequency and duration of heat waves.

S.5. Other information

This chapter provides summarized and analyzed information on how the climate change and related issues are integrated into key areas of the country's development, including research and education initiatives, also the efforts made to raise public awareness and change the climate behavior, and capacity building among representatives of different segments and professions of the society to ensure effective work on climate change issues.

The analysis of the information was carried out on the basis of sectoral and cross-sectoral strategic documents, educational and research initiatives, as well as the study of awareness-raising and capacity-building materials and interviews with experts involved in relevant processes. This analysis did not provide an in-depth assessment of the actual implementation and scale of the commitments set out in the sectoral or cross-sectoral strategic documents, or their impact; however, the existing gaps and needs were analyzed as much as possible.

It describes how and to what extent climate change is reflected in the country's social, economic and environmental strategies and other policies. It also provides the review of strategic documents related to the climate change that have been developed or are being developed since 2014. It includes the sectoral documents (like energy, agriculture, infrastructure, healthcare, education and other fields), as well as cross-sectoral documents. The review includes the documents elaborated at the central, regional and municipal levels.

The situation is reviewed in terms of type of ongoing research works on climate change at research / scientific institutes, as well as at sectoral technical institutions, such as the National Environment Agency. In addition to an overview of the current situation, the country needs in this area are also briefly described.

Formal and informal educational / informational initiatives to increase knowledge and awareness about climate change are discussed. In particular, it considers existing institutional framework to ensure that climate change issues are properly integrated into the formal education system and what needs still remain in this regard. Information on climate change actions and initiatives aimed at raising awareness in the community is provided.   It refers to the activities planned and implemented by the state, as well as by non-governmental and donor organizations. The mechanisms for exchanging / sharing information to study climate change issues and plan strategic measures among different sectoral agencies and key actors are briefly described.

Information is provided on the "larger" initiatives that, with the support of donors and partner organizations, help build capacity to honor commitments under the Climate Change Framework Convention and the Paris Agreement.

S.6. Constraints, gaps, and needs for financial and technical support and capacity building

According to Decision 17/CP.8 of the Conference of the Parties of United Nations Framework Convention on Climate Change (UNFCCC), non-Annex I parties to UNFCCC shall identify the constraints, gaps and development priorities, the needs for financial and technical support and capacity building in their countries, as well as the activities, measures and programs proposed and implemented to address the constraints and fill the gaps.

Constraints and gaps analyses is mainly based on the information provided in the Third National Communication of Georgia to UNFC, the First and Second Biennial Update Reports, and Technological Needs Assessment document. In addition, meetings were held with various stakeholders to obtain information on mitigation and adaptation projects implemented and planned by them, and to discuss the gaps and needs.

Georgia has received assistance from Annex II countries (including EU member states) and their development agencies, international financial institutions (World Bank, European Bank for Reconstruction and Development, Asian Development Bank), as well as financial and technological mechanisms of the Convention, such as the Global Environment Facility, the Green Climate Fund, the Adaptation Fund, the Climate Technology Center and Network, etc.

Since 2013, the number and price of projects implemented in Georgia in the field of climate change mitigation has been higher rather than in the field of adaptation. Besides, financial assistance in mitigation projects outweighs the technical support and capacity building assistance, while that in adaptation and pervasive projects is relatively smaller. In addition, most of the mitigation projects are implemented in the field of energy, and the adaptation projects are mostly dealing with natural disasters and agricultural problems.

The country’s efforts on climate change are growing and, importantly, covering a wide range of sectors and measures. The analysis revealed the following barriers that hinder the efforts to some extent: (a) weak coordination between public institutions; (b) poor institutional arrangement; (c) low awareness of projects and initiatives on promoting climate change mitigation and adaptation; and (d) lack of national financial resources.

The main barriers and needs that are relevant for projects and initiatives in greenhouse gas inventory and reporting, as well as for mitigation and adaptation have been identified. Mitigation and Adaptation chapters in Fourth National Communication provide the sectoral constraints and needs in each area and are grouped to identify strategic areas for capacity building and set out appropriate steps.

In recent years, Georgia has significantly intensified its efforts to seek technologies, to create and improve conditions to technology transfer and to make more active use of the various mechanisms of transfer.

Technology Needs Assessment (TNA) for climate change is a handbook for the country in this regard. TNA process has identified the priorities and technologies for the introduction of modern technologies. It serves as a guidance for donor countries and organizations in terms of technology transfer, taking into account Georgia's priorities. Action Plans for Climate Change Adaptation and Climate Change Mitigation Technologies have been developed based on TNA. This chapter provides information on technology transfer priorities and mechanisms.

In the past few years, Georgia has received significant assistance in transfer of technologies from Annex II countries to UNFCCC within the framework of technical cooperation projects. Some of the projects with the main goal or one of the components being technology/know-how transfer are categorized as technology transfer projects and serve the effective implementation of mitigation or adaptation measures.

One of the barriers to widespread adoption of modern technologies is the high initial cost of investment in technology and limited access to finances in Georgia. The increase in the initial investment cost is also caused by the need for outsourcing of technical staff to implement the technology due to the lack of relevant knowledge and trained staff. Therefore, the availability of international financing mechanisms for modern technologies is vital for the country. It is equally important whether Georgia can use these mechanisms and how effectively it will do it.

The country needs to raise awareness of financial sources for technology transfer and accreditation of institutions to obtain an access to financial assistance. It is also required to develop capacities for those institutions in project development, so that the projects they submit for funding are competitive.

Technology transfer projects implemented in the country allow Georgia to engage in the sharing of knowledge and experience between countries, which is crucial for the introduction and sustainable use of technologies.

Following the submission of the Third National Communication in 2016, Georgia has taken serious steps to overcome technology transfer barriers. Significant progress has been made in improving relevant regulatory framework. In recent years, related laws, strategic documents and action plans have been adopted, which greatly contributed to the technology transfer in the country.

1 National Circumstances

1.1 State Structure

Georgia is a democratic state. The power in Georgia is distributed between legislative, executive and judicial branches. The president is the head of state. The parliament is the legislative body with 150 members. The executive branch – the Government – includes the Prime Minister and the Ministers. Currently there are 11 ministries in Georgia. More than 20% of country's territory is occupied by Russia, namely, the Autonomous Republic of Abkhazia and Tskhinvali Region. The whole territory of country includes two autonomous republics – Adjara and Abkhazia Autonomous republics, 64 self-governing districts and 5 self-governing cities[3]. Judicial power is exercised by two branches – the Constitutional Court of Georgia and the Common Courts[4].

Currently, more than 20% of country's territory is occupied by Russia, namely, the Autonomous Republic of Abkhazia and Tskhinvali Region. The whole territory of country includes two autonomous republics – Adjara and Abkhazia Autonomous republics, 64 self-governing districts and 5 self-governing cities.

1.2 Geography

Georgia is located in the south-eastern part of Europe, south to the Great Caucasus Range. Georgia is bordered by Russia to the north, by Armenia to the south, by Azerbaijan to the southeast, by Turkey to the southwest and by the Black Sea to the west. Georgia covers a territory of 76,284 square kilometers, including the Autonomous Republic of Abkhazia and Tskhinvali Region and the territorial waters[5], of which the land area takes about 91%, and the water - 9%. Two third of country's territory is mountainous, with a complex relief. 54% of its territory is located at the altitude above 1000 m. The landscape of the country is quite varied with its mountains, plateaus, low-lands, glaciers, swamps and arid areas (semi-deserts), lakes and rivers. With regard of land use, 15.8% represents the cropland, 70.6% is covered by forests, shrubs and grasslands, and 13.6% is used for agriculture activities. Geographically Georgia is divided into two parts: East and West, naturally divided by the Likhi Range.

1.3 Climate

In the western part of Georgia the climate is subtropical, while in the eastern part there is a dry moderate continental climate. Almost every climate zone is represented in Georgia, except for deserts, savanna and tropical forests. The local climate is conditioned by the Caucasus, which protects Georgia from the direct influx of cold air masses from the north, and the Black Sea, which moderates temperature fluctuations and promotes a large amount of precipitation, especially in western Georgia. Annual precipitation in Georgia ranges from 400 to 4,500 mm. Due to its location at a relatively low latitude and moderate cloudiness, Georgia receives significant heat from the sun. The average annual duration of bright sunshine ranges from 1,350 to 2,520 hours[6].

Climate change process is considerably activated in Georgia. In 1986-2015, compared to 1956-1985, the mean annual ground air temperature in the country increased almost everywhere, depending on the regions

[3] Government of Georgia - www.gov.ge
[4] The Constitution of Georgia
[5] Geostat – Natural Resources of Georgia and Environmental Protection, 2017
[6] Geostat – Natural Resources of Georgia and Environmental Protection, 2017

– in the range of 0.25–0.58^{0}C. The average increase in the territory of Georgia is 0.47^{0}C. During the same period, the annual precipitation in western Georgia has mainly increased, while it decreased in some eastern regions.

Against the background of climate change, the increased trend to intensive and frequent natural hydrometeorological events is evident (floods/flash floods, snow avalanches, strong winds, droughts, etc.). The scale and quantitative indicators of landslide-gravity and avalanche processes have significantly increased in the territory of the country. Another indicator is intensive melting of glaciers.

The wide specter of negative consequences of climate change are already identified in the country. (1) Due to rising sea levels, the Black Sea has seized large areas of land, destroyed and/or damaged buildings and infrastructure; (2) frequent and intensified floods, flash floods, landslides and mudslides in highland areas cause great damage to the economy; (3) due to the reduced rainfall and increased evaporation, the semi-arid area of eastern Georgia is threatened by desertification; (4) frequent intense heat waves pose a threat to human health; (5) increased temperature altered rainfall structure, reduced access to water resources, increased wildfires, parasites, and diseases have degraded forest growth capacity and productivity.

The negative effects will be even stronger in the future. The country's main goal is to improve the country's preparedness and adaptation capacity by developing climate-resilient practices that will reduce the vulnerability of the most sensitive communities to climate change. In this regard, Georgia is taking steps to integrate climate risk and climate resilience issues into its key development plans and strategies

1.4 Natural Resources

Georgia is rich in natural resources. In its territory there are deposits of mineral resources, such as manganese, iron, copper, gold, marble, also a smaller pools of oil and gas. Georgia is rich in both groundwater and surface fresh and mineral water resources, which is due to its mountainous terrain. There are more than 2 thousand mineral and thermal springs in the country, which are successfully used to treat various diseases.

There are more than 850 lakes in Georgia with the total area of 170 km^2. Most of them belong to the fresh water lakes. As for the rivers, there are 26,060 rivers in Georgia with the total length of 60 thousand km. 18,209 rivers are located in western Georgia and 7,951 in in its eastern part. About 99.4% of the rivers belong to the type of small rivers (their length is less than 25 km). The rivers of Georgia are supplied with water by glaciers, snow, rain and groundwater. There are 44 reservoirs on the territory of Georgia with the total surface area of 163 km^2 and 3,315 million m^3 of volume.

On the territory of Georgia glaciers are located only in the Grater. In Georgia there are 725 glaciers with the total area of 370 km^2. Wetlands cover considerable area in Georgia – 627 km^2 and they are mostly located in Kolkheti Lowland. Coastline length of the Black Sea within Georgia is 330 km.

Georgia's plant world (flora) is rich and diverse owing to its physical-geographic diversity, including climatic conditions. More than 13,300 species of plants are registered in Georgia, among them 4,225 seed plants, 75 – ferns, 600 – mosses, 650 – lichens, 5,000 – fungi and 2,000 – algae. In Georgia there is a large diversity of fauna too. Georgia is home of about 100 species of mammals, more than 330 species of birds, about 48 reptiles, 11 amphibians and 160 species of fish. There are thousands of species of invertebrates, but their exact composition still requires to be established. About 40% of Georgia's total territory is covered by forest. The forests, in addition to their ecological importance, also bear energy and economic function in Georgia: they supply the population with firewood and timber.

1.5 Population

By January 1, 2019 the population of Georgia was 3,723 thousand - 6,000 less than in 2018. 59% of the population is urban, and the rest 41% - rural. 1,171 thousand people live in Tbilisi, i.e. more than 30% of the total population. Population density is 65.1 persons per 1 km^2. The population of the age group 65+ makes 14.8% and it has an increasing trend. Male population is 48% of the total, and female population – 52%. According to the National Census of 2014, ethnic Georgians comprise 86.8% of the total population, ethnic Azerbaijani - 6.3%, ethnic Armenians - 4.5%, ethnic Russians - 0.7%, Ossetians - 0.4%, Yezids - 0.3%, Ukrainians - 0.2%, Greeks - 0.1%, and others – 0.6%.[7]

1.6 Healthcare and Social Welfare

Climate change has a significant impact on the human health, health care and social welfare systems. According to the World Health Organization, climate change has a direct negative impact on health with the following three main manifestations: heat waves; natural disasters; and change in infectious background. Extremely high temperature is one of the leading causes of death from cardiovascular and respiratory diseases, especially in the elderly. Extremely high temperature increases the level of allergens (allergen-born particles) in the atmosphere. Natural disasters are accompanied by outbreaks of infectious diseases transmitted by water and food. Changes in the infectious background are also manifested by an increase in the number of insects that are capable to communicate infectious, and this is another development associated with the climate change and the increase of average temperatures.

According to the data provided by the National Center for Disease Control and Public Health (NCDC) in 2017 the diseases of the cardiovascular system still remained as the leading cause of mortality in Georgia, and it has retained such leading position since 1990. According to the data of 2017, cardiovascular diseases represent 17.2% of all diseases registered in Georgia, and the new cases make 9.4%. Within this group of diseases high morbidity and mortality is evident in hypertensive (high blood pressure), ischemic and cerebrovascular diseases. The incidence of circulatory diseases per 100,000 population increased from 500 in 2013 to 2,600 in 2017.

Respiratory diseases were the second leading cause of mortality in 2005 and the 5th leading cause of death in 2017. However, a number of diseases (chronic obstructive pulmonary syndrome, asthma) that may be associated with climate change still remain in the leading positions. Between 2008-2017 cases of infectious and parasitic diseases doubled (in 2017 first cases per 100,000 population – 2,400, and in 2008 – 1,200). Malaria cases have not been reported in Georgia since 2015[8].

On 29 December 2018, the Government of Georgia, by its Ordinance N680 approved the National Environment and Health Action Plan 2018-2022 (NEHAP)[9], one of the strategic tasks of which is the climate change component - the integration of health issues in climate change adaptation and mitigation policies. With this regard the following priorities have been identified in the aforementioned document:

- Promotion of health systems to strengthen and increase their capacity in assessing and monitoring health vulnerabilities to climate change;

[7] Demographic Situation in Georgia, 2014, Geostat. http://census.ge/ge/results/census/demo
[8] National Center for Disease Control and Public Health, Healthcare Statistical Reference
[9] National Environment and Health Action Plan

- Determination of risks posed by climate change and their adverse effects on human health, primarily for the most vulnerable groups of the population;
- Preparation and introduction of the relevant strategies and action plans;
- Disseminate and share the knowledge and the best practices.

In 2012-2013 the Georgian Red Cross conducted a pilot study on Heat Waves, on the basis of which a National Action Plan on Heat Waves was developed.

1.7 Coverage of Climate Change Issues

In Georgia the following entities work on the climate change issues:

National Environmental Agency[10] is a legal entity of the public law under the Ministry of Environmental Protection and Agriculture of Georgia, which independently implements the following activities under the state control:

Monitoring and assessment of meteorological, hydrological, geological processes and quality of the environment on the territory of Georgia; assessment and preparation of warnings about the expected natural events and environmental pollution and dissemination of relevant information; learning the physical processes of climate change, participate in the development of measures to mitigate the possible negative consequences caused by these changes, etc.

Vakhushti Bagrationi Institute of Geography[11] (was founded in 1933) is engaged in scientific studies on natural disasters. In 2013-2014 the Institute accomplished the glacier-geomorphological study of Georgian glaciers against the background of ongoing climate change.

1.8 Education

Over the recent years the number of activities aimed at awareness raising among the population on climate change has increased significantly, with the special focus on the youth. The issues directly or indirectly related to the climate change are being taught at the secondary and high schools, also within the format of informal education.

In 2016, Ilia State University (established in 2006 as a result of the merger of six institutes of high education), with the support of the Analytical Center World Experience for Georgia and the Heinrich Boell Foundation, established a course Climate Change and Sustainable Development providing h certificates for students, public officials and journalists. Climate change policy is taught in the Master's program in Environmental Management and Policy at the Georgian Institute of Public Affairs. The program was created in 2016 with the support of the Ministry of Environment and the GIZ. In regard of formal and non-formal education, the LEPL Environmental Education and Information Centre regularly conducts lectures, seminars and trainings to support environmental education and raise awareness on climate change.

1.9 Culture

Georgia has very rich cultural heritage. In 2019 Georgia's unified data base of cultural heritage included 26,524 immovable and 5,322 movable objects. The cultural monuments are spread across entire Georgia, in each and every corner of the country. Cultural monuments and their constituent materials located in both

[10] www.nea.gov.ge
[11] www.geography.tsu.ge

outdoor and indoor facilities are constantly exposed to the simultaneous impact of one or more climatic factors. The vulnerability of an object to the impact of climatic factors, including climate change threats, depends on its structure and the properties of the materials.

In 2016, the Climate Change Adaptation Guide[12] was prepared, which provides an analysis of the impact of climate change on Georgia's economic, environmental and social spheres, including cultural heritage, for the base periods 2021-2050 and 2071-2100, and provides relevant recommendations. The document is focused on the threats to the cultural heritage sites caused by increased frequency and scale of various natural disasters (debris/mudflow, floods, flashfloods, landslides, also gravitational processes: rockfalls, rockslide and stonefall, snow avalanche, erosion processes, land subsidence processes).

For prevention and mitigation of climate change risks it is important to develop appropriate policies and strategies; promote to and perform scientific researches; raise the awareness (knowledge) on climate change and preventive conservation requirements among the specialists working in the field of cultural heritage; and introduce the modern standards of preventive conservation.

1.10 Economy

Georgia is a country with economy in transition. It is replacing the Soviet centralized planned economy with a market economy. Since 1990s country's economy has undergone important structural changes. The scope of intensive industry and agriculture has decreased and the scale of services, tourisms, bank, and construction sectors increased. Significant reforms began in 2004, which resulted in a number of improved macroeconomic parameters; anti-corruption, privatization and tax reforms; more attractive investment environment - which led to economic growth.

In 2014 the European Union and Georgia signed an Association Agreement, constituent part of which is the Agreement on Deep and Comprehensive Free Trade Area. Against this background the country harmonized its laws with the EU legislation. Georgia has one of the most liberal foreign trade policy, which implies the simplified foreign trade and customs procedures, relatively low import tariffs and a minimum non-tariff regulation. Georgia has a free trade regime with the CIS countries (except of the Russian Federation), Turkey, the European Union, the People's Republic of China and with the European Free Trade Association[13].

According to the country's socio-economic development strategy "Georgia 2020" adopted in 2014, the economic policy of the Government is based on three basic principles[14]: (1) Fast and effective economic growth focused on the manufacturing sector, which leads to removing existing economic problems, creating jobs and eliminating poverty; (2) implementation of inclusive economic growth policies, which implies involvement of the general population (including diaspora, migrants, ethnic minority and other groups) in the process of economic development and ensuring welfare of each member of the society as a result of economic growth; (3) rational use of natural resources in the process of economic development, ensuring environmental safety and sustainability and prevention of risks related to the natural disasters.

[12] http://nala.ge/climatechange/uploads/RoadMap/RoadMap_Geo.pdf.
[13] www.economy.ge
[14] www.economy.ge

According to the Government Program[15] 2019-2020, for the long-term economic development of Georgia, it is important to establish a country as an international investment, communication, transport, logistics, energy, technology, education and financial hub.

Under the program it is planned to rehabilitate and build the roads for international transit movement and for connecting the regions; introduction of European standards for waste management; preparation of spatial planning concepts, schemes and plans for the country and municipalities, land use regulation and development regulation plans for cities, towns and villages.

The Government Program puts the stress on the economic policy for the following branches:

Energy - Main direction of the Energy Policy defined by the Government of Georgia is to improve the energy security of the country and degree of independence, along with a gradual reduction of dependence on the imported energy resources through the utilization of domestic energy resources, diversification of supply sources and routs. For the effective implementation of the Energy Policy the following will be done: infrastructure will be developed for the creation of a safe and stable transmission and distribution system of natural gas and power energy; project has been launched for the improvement of natural gas supply through a gas storage facility with a capacity of 210-280 million cubic meters; additional resources will be allocated for the provision of natural gas in rural areas, as a result of which 1.3 million subscribers will gain access to natural gas supply by the end of 2020; work will be continued for the best use of renewable energy, also the energy efficiency measures will be implemented in various directions. It is worth to mention that in 2017 Georgia acceded to the Energy Community, within the frame of which Georgia has to harmonize the national energy legislation with the EU Law.

In 2019-2020 the Parliament of Georgia adopted the following laws: on Energy and Water Supply[16]; on Energy Efficiency[17]; on Energy Efficiency of Buildings[18]; on Promoting the Generation and Consumption of Energy from Renewable Sources[19]; and the Government approved the updated National Action Plan for 2020 on Renewable Energy. With the aim to implement the Energy Efficiency Policy, the Government of Georgia approved the National Action Plan 2019-2020 under its Ordinance N 2680 of 23 December 2019.

Transport – for a further development of the transport system, the Government of Georgia will implement active policy to introduce and integrate environmentally clean and innovative technologies; in line with EU-Georgia Association Agreement and Agreement of Common Air Space, the legislation of Georgia will be approximated to the EU Directives and Regulations on transport; for achieving ensured road safety elaboration and implementation of the National Strategy and Action Plan on Road Safety will be continued; work will be continued for further improvements in the technical inspection system; restructuring is planned in the railway transportation, *inter alia*, through the development of new legal and regulation framework, which will be developed through the reform, thus facilitating the improved effectiveness in the sector and safety of transport operations; for the development of transit potential of the country the government services will be digitalized at every marine port of Georgia and the data will be collated into a common online platform; it is planned to modernize the state registry of vessels and attract high capacity ones under the Georgian flag, which will significantly improve the image of Georgia as a marine country.

[15] Government Program 2019-2020, www.gov.ge
[16] The law on Energy and Water Supply, 20 December 2019
[17] The law on Energy Efficiency, 21 May 2020
[18] The law on Energy Efficiency of Buildings, 21 May 2020
[19] The law on Promoting the Generation and Consumption of Energy from Renewable Sources, 20 December 2020

In recent years, the number of natural gas vehicles in Georgia is growing. Hybrid and electric vehicles also have become quite popular due to their cost-effectiveness and benefits established by the state.

Construction of Anaklia Deep Sea Port is a strategic project, which will create favourable conditions for the development of logistics services and industrial zone in the adjacent area. The Construction of new port gives the opportunity for development of value added services and shall result in significant increase in cargo turnover through the territory of Georgia. Today there are four functioning seaports under the control of Georgia, namely, Batumi and Poti seaports and the Black Sea (Kulevi) and Supsa oil terminals[20].

The Georgian railway network plays a vital role in the country's economy. The new Baku-Tbilisi-Kars railway, the main works of which have been completed, aims at creating an alternative Asia-Europe railway route, thus giving a new impetus to the restoration and development of the historic Silk Road and strengthen Georgia's role in economic relations between Europe and Asia.

In the field of civil aviation, the Government of Georgia promotes an "open sky" policy, which ensures the entry of new air companies into the Georgian market, the development of new direct flights, the increase of flight intensity and geographical area, access to air traffic, as well as maintaining growing trend of passengers' traffic. Three international (Tbilisi, Batumi and Kutaisi) and four local (Mestia, Ambrolauri, Natakhtari and Telavi) airports are operating in Georgia.

Environment Protection and Agriculture – protection of environment and rational use of natural resources, in parallel with a sustainable development of Agriculture, is a significant challenge for Georgia, especially against the background of the current process of climate change. Facilitation of climate-smart agriculture is one of the priorities of the Government of Georgia, which responds simultaneously to three crosscutting challenges, which are as follows: food security; adaptation with climate change; and mitigation of climate change. The following activities have been planned in the field of agriculture and environment protection: increase of irrigated land parcels; perform studies on degraded soils and take measures to recover and improve their fertility; create legal framework for windbreak management and development and plant the windbreaks; introduction of new rules of legislation for protection and maintenance of bio-diversity to ensure the sustainable use of biological resources; ensure the extension of protected areas and tourism promotion; introduction of and support to the sustainable forestry management practice through the establishment of effective mechanisms of forest care, protection and recovery, which will facilitate the maintenance and improvement of qualitative and quantitative forest indicators; extension and development of modelling capacity of the hydro meteorological surveillance network aimed at reducing the threats originated from natural disasters conditioned by the climate change, and introduction of national system of early warning; improvement of atmospheric air, water and soil quality monitoring and assessment system, along with the systems of atmospheric air pollution with harmful substances and recordings of water use; transition to the integrated water resource management system based on the sustainable management of water resources and European principles of basin management; improvement of waste and chemical substance management system, introduction of various mechanisms in line with the applicable EU standards, which will facilitate the prevention of waste generation and re-use of the waste.

Tourism – Tourism is a significant driving force of economic growth in the country and Government of Georgia plans to carry out the following measures for the further development of the priority sector: improvement and development of tourism infrastructure; intensification of marketing activities at the target

[20] www.economy.ge

and potential new markets; promotion and development of eco-tourism; facilitate investments for the development of business tourism; increase the quality of service to international standards; facilitate deeper cooperation between the public and private sectors for the creation and promotion of products in tourism.

In 2018 a number of international travelers trips reached 8.6 million in Georgia. The revenues from international tourism exceeded 3.2 billion USD. In 2018 the share of tourism in GDP made 7.6%[21].

GDP at constant 2018 prices amounted 17.6 billion USD with per-capita 4,722 USD. During the last 5 years the real annual GDP grew at an average annual rate of 4%[22]. More than half in GDP composition comes to the following sectors: trade (13.9%), activities related to the real estate (11.4%), processing industry (10.2%), construction (8.3%) and agriculture, forest and fish farming (7.8%).

In 2018 the external trade turnover achieved 12.5 billion USD, with 3.4 and 9.1 of export and import shares, respectively. The export goods are led by copper ore (re-export), cars (re-export), ferroalloys, wine and hard liquor beverages, mineral water, fertilizers, tobacco (re-export) and medicines. Among the imported goods the biggest shares come to oil products, natural gas, cars and food products.

The results of the evaluation of Georgia by various international organizations and agencies according to international ratings are summarized in the table below:

Table 1.10.1: Key indicators evaluated by the international organizations

Indicator	Rank	Number of countries	Source
Doing Business (2020)	6	190	World Bank[23]
Economic Freedom (2019)	16	186	Heritage Foundation[24]
World Economic Freedom (2018)	7	162	Fraser Institute[25]
Bertelsmann Transformation Index /BTI (2018)	42	129	Bertelsmann Foundation[26]
Global Competitiveness Index (2018)	66	140	World Economic Forum[27]
Global Innovation Index (2019)	48	129	Cornell University, The Business School for the World/ INSEAD, and World Intellectual Property Organization/WIPO [28]
Human Development Index (2017)	70	185	United Nations Development Programme[29]
Human Capital Index (2018)	60	157	World Bank[30]
Corruption Perceptions Index (2018)	41	180	Transparency International[31]
Rule of Law	41	126	World Justice Project 2018-2019
Open Government Index (2015)	29	102	World Justice Project

[21] Georgian Tourism in Figures 2018, www.gnta.ge
[22] Geostat - www.geostat.ge
[23] World Bank www.worldbank.org
[24] Heritage Foundation www.heritage.org
[25] Fraser Institute www.fraserinstitute.org
[26] German Bertelsmann Foundation www.bti-project.org
[27] World Economic Forum www.weforum.org
[28] Cornell University, The Business School for the World/ INSEAD, and World Intellectual Property Organization/WIPO www.globalinnovationindex.org
[29] United Nations Development Programme www.undp.org
[30] www.economy.ge
[31] www.transparency.org

1.11 National and Regional Development Priorities

Georgia acceded to the UN Framework Convention on Climate Change in 1994, and Kyoto Protocol to the Convention was ratified by the Parliament with the Resolution N1995 of 28 May 1999. By the ordinance N96 of February 21, 2017, the Government of Georgia approved the Paris Agreement.

On January 17, 2020, by Parliament Resolution No. 5700, Georgia joined the "Doha Amendment to the Doha Protocol to the UN Framework Convention on Climate Change"

In 2016 the EU-Georgia Association Agreement entered into force, emphasizing the need for cooperation in the following areas: climate change mitigation, climate change adaptation, emissions trading, climate change integration into sectorial policies, and the development of clean technologies. The agreement underlines the need for cooperation in the process of preparation of technology transfer measures based on the Low Emission Development Strategy, Nationally Appropriate Mitigation Actions (NAMA) and Technology Needs Assessment (TNA).

In accordance with the Paris Agreement, the countries shall elaborate “Mid-century, long-term low greenhouse gas emission development strategy” and submit it to the secretariat of the Convention by 2020.

The Long-term strategy will be prepared within the frame of EU4Climate Project financed by the European Union. The project has the aim to support the development and implementation of climate policies by the Eastern Partnership countries, including Georgia, contributing to low emission and climate resilient development.

On July 1, 2017 Georgia was admitted, as a full-fledge member, to the European Energy Community,[32] within the framework of which important measures have to be taken in the field of climate change, namely, establishment of legislative and institutional framework for the promotion and development of energy efficiency and renewable energy sources and elaboration of action plans. In 2020-2021, the Ministry of Economy and Sustainable Development of Georgia plans to draft the national action plan on energy and climate change.

Among the national documents that is worth to be mentioned is the Strategy “Georgia 2020”, which, among many other priority issues, focuses on climate change mitigation and adaptation measures, promotion of energy efficiency and development of environmentally friendly technologies. Climate change and adaptation is also underlined in Georgia’s Strategy 2015-2020 for Agriculture Development. The Strategy envisages the introduction of climate-friendly agricultural practices in Georgia. With regard of sustainable development goals in the field of tourism, development of ‘eco-tourism’ is one of its priorities.

From 2018, the United Nations Development Programme (UNDP), with financial support of the Green Climate Fund (GCF), assists the Government of Georgia to adopt a proactive integrated climate risk management approach[33] focused on climate risk reduction, prevention, and preparedness though establishment of a multi-hazard early warning system and an enhanced use of climate information in planning and decision-making across all sectors. The project will achieve transformative change in climate risk reduction and management in Georgia by development of a fully-integrated impact-based system of multi-hazard early warning system.

[32] Energy Community www.energy-community.org
[33] www.ge.undp.org

At a local level 6 cities and 17 municipalities joined the EU initiative Covenant of Mayors. This process is of national importance, since the signatories represent about 60% of the total population and with even more share in the GDP. The signatories committed to achieve by 2030 40% reduction of GHG emission from 1990 level. In 2014, under the umbrella of the Covenant of Mayors, the European Commission launched the new initiative related to the climate change adaptation as one of the actions, which is aimed at engaging the cities in adaptation to the climate change. In 2015 the European Commission combined two initiatives in climate and energy fields for developing the integrated approach. Within the frame of the Covenant of Mayors the municipalities should elaborate the Sustainable Energy and Climate Action Plans[34].

1.12 National Institutional Arrangement

The Government of Georgia is responsible for its relations with the UN Framework Convention on Climate Change. The Ministry of Environmental Protection and Agriculture (MEPA) of Georgia develops and implements the state policy in the field of climate change[35]. Environmental and Climate Change Department is a structural unit within the Ministry and it has a sub-unit – the Climate Change Division. In addition to other functions, the Division is entitled to coordinate, in cooperation with the stakeholders, the preparation of Georgia's National Communication to the Convention and the Biannual Updated Report, also to coordinate regular conduct of GHG emission national inventory and submit the report to the Secretariat of the Convention.

The legal entity of public law - Environmental Information and Education Centre, is an agency under the Ministry36. One of the functions of the Centre is to create a unified database of environmental information and promote its publicity. At the same time, in the last years, the Centre, through the support of independent experts, works on drafting the report on GHG national inventory.

In order to meet its obligations, Georgia has prepared and submitted three national communications and two biennial updated reports, along with inventory reports. Initial National Communication was filed in 1999; the Second National Communication in 2009; and the third national communication - in 2016; the first biennial updated report was submitted in 2016 and the second biennial updated report - in 2019.

The process of preparation of the Fourth National Communication was coordinated by the Climate Change Division of the Ministry of Environmental Protection and Agriculture of Georgia. UNDP Georgia operated as an implementing agency for the Global Environment Facility (GEF). At the initial stage of project implementation, a project executive board was established, headed by a national project director appointed by the Ministry of Environmental Protection and Agriculture. The Board was the main decision-making body and consisted of representatives of the Ministry of Environmental Protection and Agriculture, the Ministry of Economy and Sustainable Development, UNDP, GIZ and the non-governmental organization Georgian Green Movement / Friends of the Earth - Georgia. The Board was responsible for making important decisions related to the project, it reviewed and approved the work plan and budget changes, it was responsible for the timely and quality implementation of the project.

Separate components of the National Communication were prepared by: the National Environment Agency[37] - Vulnerability and Adaptation; the Environmental Information and Education Centre – the National

[34] www.covenantofmayors.eu
[35] The Decree N112 of the Government of Georgia on Approval of the Regulations of the Ministry of Environmental Protection and Agriculture of Georgia, 6 March 2018.
[36] www.eiec.gov.ge
[37] www.nea.gov.ge

Inventory of Greenhouse Gases; the analytical organization World Experience for Georgia[38] - National Circumstances and Mitigation Measures; and the non-governmental organization "Georgia's Environmental Outlook"[39] - "Constraints and Gaps" and "Other Information".

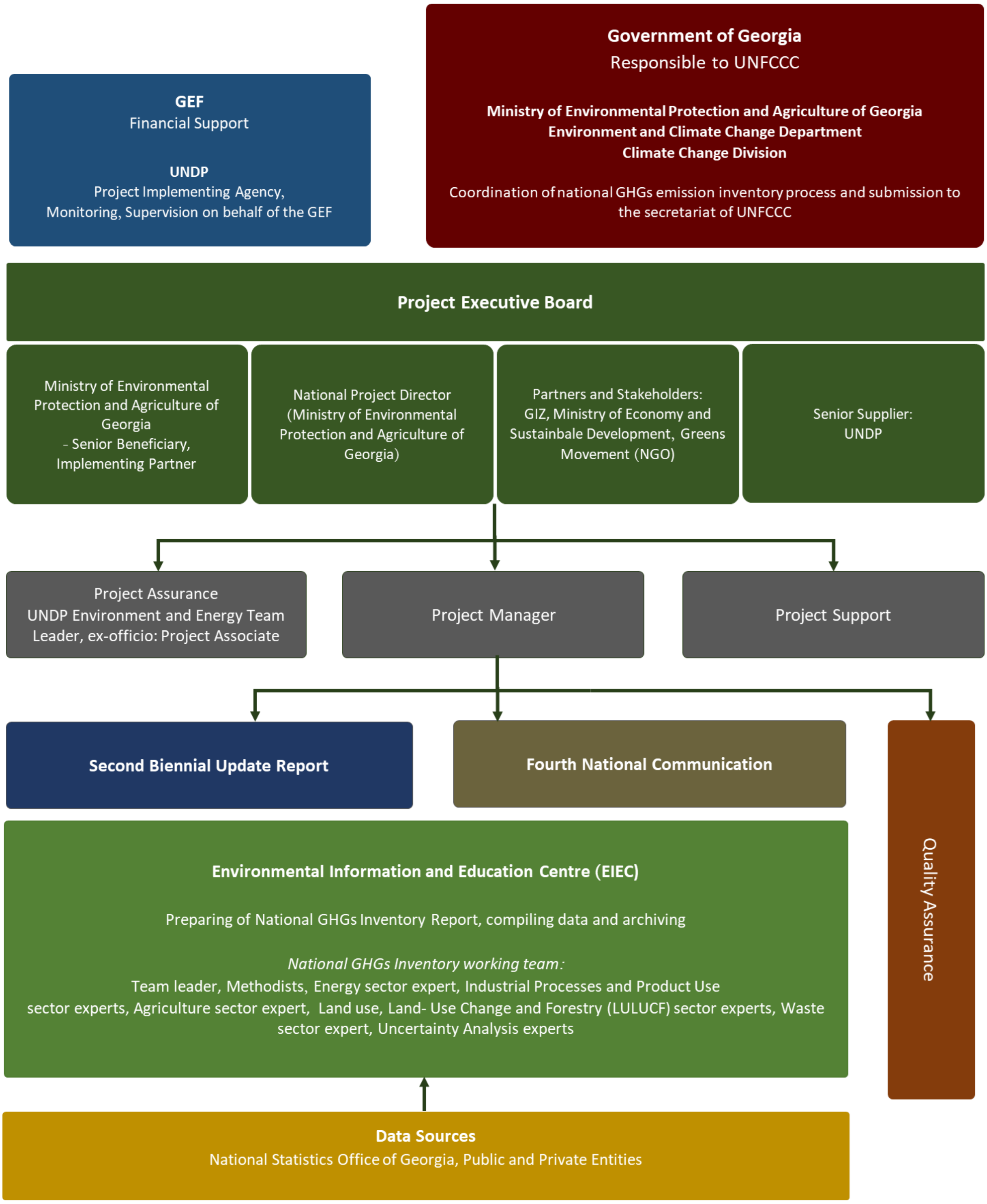

Figure 1.12.1: Institutional Framework of the National GHG Inventory in Georgia

[38] www.weg.ge
[39] www.geo.org.ge

The key sources of data necessary for the preparation of national communications and updated biennial reports are the National Statistics Office of Georgia (GEOSTAT) and the National Environmental Agency (NEA). In 2014 the Ministry of Environmental Protection and Natural Resources of Georgia and GEOSTAT formalized the Memorandum on Cooperation, according to which GEOSTAT provides statistics to the Ministry. By the Decree N502 of the Government of Georgia of August 18, 2014 and on the basis of the General Administrative Code of Georgia, the National Environment Agency provides the information in its possession to the Ministry free of charge.

2 National Greenhouse Gas Inventory

2.1 Overview

Georgia presents its sixth national inventory of greenhouse gas emissions by sources and removals by sinks in the Fourth National Communication to the UNFCCC over the period of 2016-2017. In Georgia, the first GHG inventory was performed based on the 1980-1996 data, as a part of the preparation of the First/Initial National Communication (FNC, during 1997-1999). The Second National Communication (SNC, during 2006-2009) comprised GHG inventory data for the period of 1997-2006. The 2007-2011 years GHG inventory was performed as a part of the Third National Communication (TNC, during 2012-2015). The First Biennial Update Report (FBUR, during 2015-2017) of Georgia to UNFCCC comprised GHG inventory data for the period of 2012-2013. The 2014-2015 years GHG inventory was prepared as a part of the Second Biennial Update Report (SBUR, during 2018-2019). The Fourth National Communication (during 2019-2021) comprised GHG inventory data for the period of 2016-2017.In the latest national GHG inventory the figures of the previous years were recalculated and adjusted in all the sectors, due to the use of IPCC 2006 guidelines and more reliable activity data.

The Inventory is based on the Intergovernmental Panel on Climate Change (IPCC) Methodology that is comprised of the following key documents (hereafter jointly referred to as the IPCC methodology). These are:

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories[40] (hereafter referred to as IPCC 2006);
- 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (hereafter referred to as IPCC GPG-LULUCF);
- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories[41] (hereafter referred to as IPCC 1996);
- IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)[42] (hereafter referred to as IPCC GPG).

[40] IPCC 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Egleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nGgip.iges.or.jp/public/2006gl/index.html

[41] IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories. Reference manual. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK. http://www.ipcc-nGgip.iges.or.jp/public/gl/invs1.html

[42] IPCC, 2000: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan. http://www.ipcc-nGgip.iges.or.jp/public/gp/english/

Inventory Software Version 2.69 (released in September 2019[43]) for energy sector and excel based worksheets (for IPPU, Agriculture, LULUCF, Waste sectors) were used for the compilation of the inventory. The inventory covers the following sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry, and other Land Use (AFOLU, in separate chapters); and Waste. The UNFCCC requires reporting the following gases: Carbon Dioxide (CO_2); Methane (CH_4); Nitrous Oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); Sulphur Hexafluoride (SF_6).

The Sixth National Inventory of Georgia reviews all the above-listed direct gases stipulated by the Convention as well as indirect greenhouse gases, such as: Nitrogen Oxides (NO_X), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) as well as Sulphur Dioxide (SO_2).

According to the UNFCCC reporting guidelines on annual inventories[44], the Global Warming Potentials (GWP) provided by the IPCC in its Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year time horizon was used for expressing GHG emissions and removals in CO_2 equivalents.

2.2 Overview Institutional Arrangement of the National GHG Inventory

The Climate Change Division of the Ministry of Environmental Protection and Agriculture of Georgia is responsible for coordination of periodic compilation of inventory report and its submission to the Convention Secretariat.

The LEPL Environmental Information and Education Centre [45] of the Ministry prepared National GHG Inventory report with the assistance of independent international and local experts. UNDP Georgia operates as an implementing agency for the Global Environment Facility (GEF) project and assists Georgia during the whole program implementation process; it also monitors and supervises the project on behalf of the GEF. There is an active cooperation on data exchange between the Ministry of Environmental Protection and Agriculture and National Statistics Office of Georgia based on the MoU singed in 2014.

2.3 Quality Assurance and Quality Control

The QC is carried out through a system of routine technical activities that monitor and maintain the quality of the inventory, throughout its development process. The QC activities are carried out by a team of experts involved during the preparation of the GHG NIR and by the project coordinator during the compilation and development of the GHG NIR of Georgia.

Quality Assurance (QA), as defined by the 2006 IPCC Guideline is a planned system of review procedures conducted by the personnel not directly involved in the inventory compilation/development process. The external review of this NIR was coordinated by the UNDP-UNEP Global Support Programme (GSP) and was conducted from 16 to 22 March 2020 by Dr. Carlos Lopez, consultant in national GHG emissions inventories.

2.4 Treatment of the Confidential Information

Part of the Activity Data (AD), Emission Factors (EF) and other parameters obtained from GEOSTAT or the private sector correspond to confidential information. These are listed and archived. At the stage of

[43] https://www.ipcc-nggip.iges.or.jp/software/index.html
[44] Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention, III B.
[45] www.eiec.gov.ge

obtaining and archiving data, as well as during the QC process, confidential files are distinguished from others, and restricted access is ensured. At the stage of UN reporting, the minimum level of aggregation of the above with other sub-categories is performed, and the notation key "C" (confidential) is used.

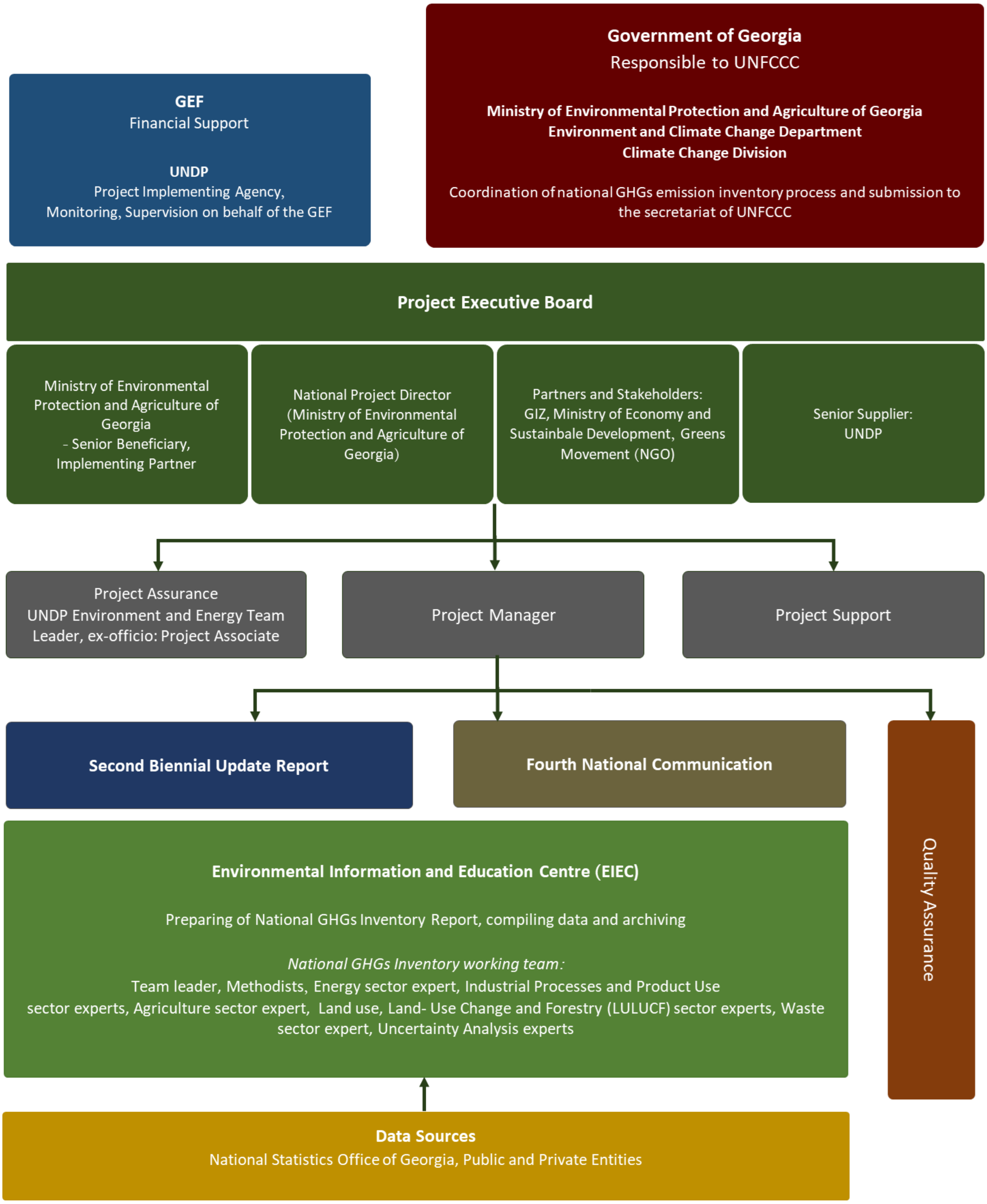

Figure 2.4.1: **Institutional Framework of the National GHG Inventory in Georgia**

2.5 Description of Key Categories

This sub-chapter provides the analysis of key source/sink of GHG emission/removals in Georgia for the period of 1990-2017, related to absolute values of emissions/removals (level analysis), as well as for the trends, Approach 1. The key category analysis was performed using excel worksheets.

Hence, 1990 was considered base year for trend assessment. The derived results were arranged in a descending order and cumulative totals were calculated. The sources with the cumulative total equaling to or higher than 95% of the overall emission (in CO_2-eq) were determined to be a key category in terms of the trend. The identified key categories are presented in the table below.

Table 2.5.1: Key Categories of Georgia's GHG Inventory According to Level and Trend Assessment

IPCC Category code	IPCC Category	Greenhouse gas	Reasons to select as Key-category
3.B.1.a	Forest land Remaining Forest land	CO_2	Level, Trend
1.A.3.b	Road Transportation	CO_2	Level, Trend
3.B.3.a	Grassland Remaining Grassland	CO_2	Level, Trend
1.A.4	Other Sectors - Gaseous Fuels	CO_2	Level, Trend
3.B.2.a	Cropland Remaining Cropland	CO_2	Level, Trend
3.A.1	Enteric Fermentation	CH_4	Level, Trend
1.B.2.b	Natural Gas	CH_4	Level, Trend
4.A	Solid Waste Disposal	CH_4	Level, Trend
1.A.1	Energy Industries - Gaseous Fuels	CO_2	Level, Trend
3.C.4	Direct N2O Emissions from managed soils	N_2O	Level, Trend
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO_2	Level, Trend
2.A.1	Cement production	CO_2	Level, Trend
1.A.1	Energy Industries - Solid Fuels	CO_2	Level, Trend
3.C.5	Indirect N2O Emissions from managed soils	N_2O	Level, Trend
2.C.2	Ferroalloys Production	CO_2	Level, Trend
2.B.1	Ammonia Production	CO_2	Level, Trend
4.D	Wastewater Treatment and Discharge	CH_4	Level, Trend
3.A.2	Manure Management	N_2O	Level, Trend
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	Level, Trend
2.B.2	Nitric Acid Production	N2O	Level, Trend
1.A.3.e	Other Transportation	CO_2	Level
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	Level
1.A.4	Other Sectors - Liquid Fuels	CO_2	Trend
2.C.1	Iron and Steel Production	CO_2	Trend
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	Trend
1.B.1	Solid Fuels	CH_4	Trend
1.A.1	Energy Industries - Liquid Fuels	CO_2	Trend

2.6 Uncertainty Assessment

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals. The uncertainty analysis of Georgia's sixth national GHG inventory is based on the Tier 1 approach and covers all source/sink categories and all direct greenhouse gases. The year of 2017 was taken for the uncertainty assessment as the last year, and 1990 as the base year. The uncertainty estimation for the activity data and emission factors was based on typical values of the IPCC and on experts' judgment. The results revealed that the level of emissions' uncertainty (percentage uncertainty in total inventory) is within 22.85%, and the uncertainty trend – 11.99%.

Table 2.6.1: Results of the Uncertainty Analysis

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	Gas	Emissions of 1990	Emissions of 2017	Uncertainty of activity data	Emission factor / estimation parameter uncertainty	Combined uncertainty $(E^2+F^2)^{0.5}$	Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$	A type sensitivity	B type Sensitivity I D/ΣC I	Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions K^2+L^2
			Input data	Input data	Input data (Note A)	Input data (Note A)			Note B		I * F Note C		
			Gg CO2-eq.	Gg CO2-eq.	%	%	%	%	%	%	%	%	%
1A1	Electricity and Heat Production - Liquid Fuels	CO_2	8,172.17	0.00	1	6.1	6.18	0.00	-0.08	0.00	0.00	-0.08	0.01
1A1	Electricity and Heat Production - Gaseous fuels	CO_2	4,604.23	1022.98	1	3.9	4.03	0.07	-0.02	0.03	0.14	-0.02	0.02
1A1	Heat Production and other Energy Industries - Solid Fuels	CO_2	955.46	506.90	1	12.4	12.44	0.17	0.00	0.01	0.22	0.00	0.05
1A2	Manufacturing Industries and Construction - solid fuels	CO_2	3,519.07	722.80	5	12.4	13.37	0.41	-0.02	0.02	0.32	-0.08	0.10
1A2	Manufacturing Industries and Construction - biomass	CO_2	0.00	5.20	5	18.7	19.36	0.00	0.00	0.00	0.00	0.00	0.00
1A2	Manufacturing Industries and Construction - liquid fuels	CO_2	2,008.10	14.70	5	6.1	7.89	0.00	-0.02	0.00	0.00	-0.09	0.01
1A2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	2,007.79	272.20	5	3.9	6.34	0.01	-0.01	0.01	0.04	-0.06	0.01
1A3a	Civil aviation	CO_2	0.00	1.80	5	4.2	6.53	0.00	0.00	0.00	0.00	0.00	0.00
1A3ai	International Aviation (International Bunkers) - Liquid Fuels	CO_2	608.63	292.23	5	4.2	6.53	0.02	0.00	0.01	0.04	0.01	0.00

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	Gas	Emissions of 1990	Emissions of 2017	Uncertainty of activity data	Emission factor / estimation parameter uncertainty	Combined uncertainty $(E^2+F^2)^{0.5}$	Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$	A type sensitivity	B type Sensitivity I D/ΣC I	Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions K^2+L^2
			Input data	Input data	Input data (Note A)	Input data (Note A)			Note B		I * F Note C		
			Gg CO2-eq.	Gg CO2-eq.	%	%	%	%	%	%	%	%	%
1A3b	Road Transportation - Liquid Fuels	CO_2	3,603.22	3353.65	5	3.1	5.88	1.69	0.05	0.08	0.37	0.25	0.19
1A3b	Road transportation - Gaseous Fuels	CO_2	0.00	492.84	5	3.9	6.34	0.04	0.01	0.01	0.07	0.06	0.01
1A3c	Other transportation	CO_2	141.32	195.70	5	5	7.07	0.01	0.00	0.00	0.03	0.02	0.00
1A3d	International water-borne navigation (International bunkers) - Liquid Fuels	CO_2	0.00	4.68	5	4.2	6.53	0.00	0.00	0.00	0.00	0.00	0.00
1A4a	Commercial/Institutional- solid fuels	CO_2	85.85	2.30	5	12.4	13.37	0.00	0.00	0.00	0.00	0.00	0.00
1A4a	Commercial/Institutional- liquid fuels	CO_2	762.45	30.33	5	6.1	7.89	0.00	-0.01	0.00	0.01	-0.03	0.00
1A4a	Commercial/Institutional- Gaseous Fuels	CO_2	228.21	384.45	5	3.9	6.34	0.03	0.01	0.01	0.05	0.04	0.00
1A4a	Commercial/Institutional- biomass	CO_2	122.19	17.71	5	18.7	19.36	0.00	0.00	0.00	0.01	0.00	0.00
1A4b	Residential - solid fuels	CO_2	73.83	2.29	5	12.4	13.37	0.00	0.00	0.00	0.00	0.00	0.00
1A4b	Residential - liquid fuels	CO_2	986.76	39.77	5	6.1	7.89	0.00	-0.01	0.00	0.01	-0.04	0.00
1A4b	Residential - Gaseous Fuels	CO_2	2,627.65	1735.73	5	3.9	6.34	0.53	0.02	0.04	0.24	0.09	0.07

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	**Gas**	**Emissions of 1990**	**Emissions of 2017**	**Uncertainty of activity data**	**Emission factor / estimation parameter uncertainty**	**Combined uncertainty $(E^2+F^2)^{0.5}$**	**Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$**	**A type sensitivity**	**B type Sensitivity I D/ΣC I**	**Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions K^2+L^2**
			Input data	**Input data**	**Input data (Note A)**	**Input data (Note A)**			**Note B**		**I * F Note C**		
			Gg CO2-eq.	**Gg CO2-eq.**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1A4b	Residential - biomass	CO_2	1,605.97	1679.00	5	18.7	19.36	4.58	0.03	0.04	1.10	0.13	1.24
1A4c	Stationary - solid fuels	CO_2	56.76	1.05	5	12.4	13.37	0.00	0.00	0.00	0.00	0.00	0.00
1A4c	Stationary - Liquid Fuels	CO_2	390.99	42.50	5	6.1	7.89	0.00	0.00	0.00	0.01	-0.01	0.00
1A4c	Stationary - Gaseous Fuels	CO_2	70.48	248.94	5	3.9	6.34	0.01	0.01	0.01	0.03	0.03	0.00
1A4c	Stationary - biomass	CO_2	421.12	0.12	5	18.7	19.36	0.00	0.00	0.00	0.00	-0.02	0.00
1B1	Fugitive Emissions from Solid Fuel Mining and transformation	CO_2	62.20	10.10	5	300	300.04	0.04	0.00	0.00	0.11	0.00	0.01
1B2	Fugitive Emissions from Fuels – Oil and Natural Gas (Flaring, production, distribution)	CO_2	11.68	2.09	5	300	300.04	0.00	0.00	0.00	0.02	0.00	0.00
2A1	Cement Production	CO_2	504.97	658.74	5	5	7.07	0.09	0.01	0.02	0.12	0.06	0.02
2A2	Lime Production	CO_2	36.66	53.39	20	15	25.00	0.01	0.00	0.00	0.03	0.02	0.00
2A3	Glass production	CO_2	30.30	15.12	5	10	11.18	0.00	0.00	0.00	0.01	0.00	0.00
2B1	Ammonia Production	CO_2	524.78	404.32	5	6	7.81	0.04	0.01	0.01	0.09	0.03	0.01
2C1	Cast Iron and Steel Production	CO_2	2,492.08	43.25	10	25	26.93	0.01	-0.02	0.00	0.04	-0.22	0.05
2C2	Ferroalloys Production	CO_2	142.87	420.50	5	25	25.50	0.50	0.01	0.01	0.37	0.05	0.14
2D1	Lubricant Use	CO_2	0	10.25	5	50	50.25	0.00	0.00	0.00	0.02	0.00	0.00
5A	Forest land	CO_2	-6,224.20	-5,578.10	5	20	20.62	57.38	-0.08	-0.14	-3.92	-0.40	15.55

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	Gas	Emissions of 1990	Emissions of 2017	Uncertainty of activity data	Emission factor / estimation parameter uncertainty	Combined uncertainty $(E^2+F^2)^{0.5}$	Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$	A type sensitivity	B type Sensitivity I D/ΣC I	Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions K^2+L^2
			Input data	Input data	Input data (Note A)	Input data (Note A)			Note B		I * F Note C		
			Gg CO2-eq.	Gg CO2-eq.	%	%	%	%	%	%	%	%	%
5B	Cropland	CO_2	-3,029.90	-2257.80	10	75	75.66	126.64	-0.03	-0.06	-5.95	-0.28	35.53
5C	Grassland	CO_2	901.00	2912.10	10	75	75.66	210.68	0.06	0.07	7.68	0.64	59.38
1A1	Stationary fuel combustion	CH_4	8.59	0.48	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1A2	Fuel combustion	CH_4	9.44	1.69	5	100	100.12	0.00	0.00	0.00	0.01	0.00	0.00
1A3a	Civil aviation	CH_4	0.09	0.00	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1A3b	Road transportation	CH_4	20.60	35.36	5	40	40.31	0.01	0.00	0.00	0.05	0.00	0.00
1A3c	Other transportation	CH_4	0.07	0.13	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1A4a	Commercial/Institutional	CH_4	9.50	1.81	5	100	100.12	0.00	0.00	0.00	0.01	0.00	0.00
1A4b	Residential	CH_4	102.61	98.00	5	100	100.12	0.42	0.00	0.00	0.34	0.01	0.12
1A4c	Stationary	CH_4	28.72	0.66	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1B1	Fugitive Emissions from Solid Fuel Mining and transformation	CH_4	676.51	0.00	5	300	300.04	0.00	-0.01	0.00	0.00	-0.03	0.00
1B2	Fugitive Emissions from oil Extraction	CH_4	66.89	96.53	5	300	300.04	3.64	0.00	0.00	1.02	0.01	1.04
1B2	Fugitive Emissions from oil and natural gas production	CH_4	142.02	24.43	5	300	300.04	0.23	0.00	0.00	0.26	0.00	0.07
1B2	Fugitive Emissions from oil and natural gas Transmission and distribution	CH_4	5,126.65	1293.79	10	100	100.50	73.36	-0.02	0.03	4.55	-0.16	20.72

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	**Gas**	**Emissions of 1990**	**Emissions of 2017**	**Uncertainty of activity data**	**Emission factor / estimation parameter uncertainty**	**Combined uncertainty $(E^2+F^2)^{0.5}$**	**Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$**	**A type sensitivity**	**B type Sensitivity I D/ΣC I**	**Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions K^2+L^2**
			Input data	**Input data**	**Input data (Note A)**	**Input data (Note A)**			**Note B**		**I * F Note C**		
			Gg CO2-eq.	**Gg CO2-eq.**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
4A	Enteric fermentation	**CH_4**	1,883.0	1656.0	10	30	31.62	11.90	0.02	0.04	1.75	0.23	3.11
4B	Manure management	**CH_4**	122.0	74.0	10	50	50.99	0.06	0.00	0.00	0.13	0.01	0.02
3F	Field burning of Agricultural Residues (3.F)	**CH_4**	11.0	12.0	10	50	50.99	0.00	0.00	0.00	0.02	0.00	0.00
6A	Solid Waste Disposal Sides	**CH_4**	619.0	1073.0	30	30	42.43	8.99	0.02	0.03	1.13	0.63	1.67
6B1	Industrial Waste Water handling	**CH_4**	186.0	219.0	50	30	58.31	0.71	0.00	0.01	0.23	0.18	0.09
6B2	Domestic Waste Water handling	**CH_4**	240.0	167.0	5	30	30.41	0.11	0.00	0.00	0.18	0.01	0.03
1A1	Stationary fuel combustion	**N_2O**	26.89	2.77	5	100	100.12	0.00	0.00	0.00	0.01	0.00	0.00
1A2	Fuel combustion	**N_2O**	21.56	3.67	5	100	100.12	0.00	0.00	0.00	0.01	0.00	0.00
1A3a	Civil aviation	**N_2O**	0.00	0.00	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00
1A3ai	International Aviation	**N_2O**	5.28	2.53	5	150	150.08	0.00	0.00	0.00	0.01	0.00	0.00
1A3b	Road transportation	**N_2O**	54.90	59.50	5	50	50.25	0.04	0.00	0.00	0.10	0.00	0.01
1A3c	Other transportation	**N_2O**	2.55	4.09	5	100	100.12	0.00	0.00	0.00	0.01	0.00	0.00
1A4a	Commercial/Institutional	**N_2O**	3.70	0.49	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00
1A4b	Residential	**N_2O**	22.49	19.71	5	150	150.08	0.04	0.00	0.00	0.10	0.00	0.01
1A4c	Stationary	**N_2O**	5.33	0.14	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00
2B2	Nitric Acid Production	**N_2O**	147.50	228.94	5	20	20.62	0.10	0.00	0.01	0.16	0.02	0.03

	A	B	C	D	E	F	G	H	I	J	K	L	M
	2006 IPCC Categories	**Gas**	**Emissions of 1990**	**Emissions of 2017**	**Uncertainty of activity data**	**Emission factor / estimation parameter uncertainty**	**Combined uncertainty $(E^2+F^2)^{0.5}$**	**Contribution to Variance by Category in Year 2017 $(GxD)^2/(\sum D)^2$**	**A type sensitivity**	**B type Sensitivity I D/ΣC I**	**Uncertainty in trend in national emissions introduced by emission factor /estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions K^2+L^2**
			Input data	**Input data**	**Input data (Note A)**	**Input data (Note A)**			**Note B**		**I * F Note C**		
			Gg CO2-eq.	**Gg CO2-eq.**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
2G3	Medical Surgeries	**N_2O**	11.06	14.884	5	10	11.18	0.00	0.00	0.00	0.01	0.00	0.00
4B	Manure management	**N_2O**	365.0	313.0	50	100	111.80	5.31	0.00	0.01	1.10	0.22	1.26
4D1	Direct soil emissions	**N_2O**	1,080.0	884.0	10	25	26.93	2.46	0.01	0.02	0.78	0.12	0.62
4D3	Indirect soil emissions	**N_2O**	637.0	530.0	50	50	70.71	6.09	0.01	0.01	0.93	0.36	1.00
3F	Field burning of Agricultural Residues	**N_2O**	26.0	29.0	10	50	50.99	0.01	0.00	0.00	0.05	0.00	0.00
6B2	Domestic Waste Water handling	**N_2O**	55.0	59.0	5	70	70.18	0.07	0.00	0.00	0.15	0.00	0.02
2F	Consumption of halocarbons and sulfur hexafluoride (Refrigeration and Air Conditioning Equipments)	**HFC**	0.00	155.33	5	25	25.50	0.07	0.00	0.00	0.14	0.02	0.02
2F	Consumption of halocarbons and sulfur hexafluoride (Emissions from Appliances (electrical equipment)	**SF6**	0.00	355.76	5	100	100.12	5.51	0.01	0.01	1.25	0.04	1.57
Total emissions			**40,222**	**15,181**		**Percentage uncertainty in total inventory:**		**522.10**					**143.79**
								22.85				**Trend uncertainty:**	**11.99**

Table 2.6.2: Uncertainty values of Activity Data and Emission Factors

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
1A1	Electricity and Heat Production - Liquid Fuels	CO_2	According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%.	According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected.
1A1	Electricity and Heat Production - Gaseous fuels	CO_2	According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%.	According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected.
1A1	Heat Production and other Energy Industries - Solid Fuels	CO_2	According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%.	According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected.
1A2	Manufacturing Industries and Construction - solid fuels	CO_2	According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies, and was not fully in line with EU requirements. Therefore, the uncertainty was set at 5%.	According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected
1A2	Manufacturing Industries and Construction - biomass	CO_2	According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%.	According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected
1A2	Manufacturing Industries and Construction - liquid fuels	CO_2	According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was developed by the National	According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
			Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%.	
1A2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%.	According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected
1A3a	Civil aviation	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected.	According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected
1A3ai	International Aviation (International Bunkers) - Liquid Fuels	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected.	According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected
1A3b	Road Transportation - Liquid Fuels	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected.	According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 3.1% was selected
1A3b	Road transportation - Gaseous Fuels	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected.	According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 3.9% was selected
1A3c	Other transportation	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected.	Typical 5%.

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
1A3d	International water-borne navigation (International bunkers) - Liquid Fuels	CO_2	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected.	According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected
1A4a	Commercial/Institutional - solid fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected
1A4a	Commercial/Institutional - liquid fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected
1A4a	Commercial/Institutional - Gaseous Fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected
1A4a	Commercial/Institutional - biomass	CO_2	According IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected
1A4b	Residential - solid fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected
1A4b	Residential - liquid fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is	According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
			about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	
1A4b	Residential - Gaseous Fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected
1A4b	Residential - biomass	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected
1A4c	Stationary - solid fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected
1A4c	Stationary-Liquid Fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected
1A4c	Stationary - Gaseous Fuels	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected
1A4c	Stationary - Biomass	CO_2	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
1B1	Fugitive Emissions from Solid Fuel Mining and transformation	CO_2	Coal mining data provided by GEOSTAT is reliable and, therefore, the uncertainty value of 5% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16)	According to the IPPC methodology, using the typical emission factor for this category has a huge uncertainty value. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16)
1B2	Fugitive Emissions from Fuels - Oil and Natural Gas (Flaring, production, distribution)	CO_2	Data on Oil and Natural Gas was provided by the Oil and Gas Corporation and is reliable. Therefore, an uncertainty value of 5% was chosen	According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5)
2A1	Cement Production	CO_2	Activity data is quite accurate; therefore, its uncertainty value is within 5%.	Major source for emission factor uncertainty is associated with determining the CaO content of clinker. If clinker data are available, the uncertainty of the emission factor is equal to the uncertainty of the CaO fraction and the assumption is that it was all derived from CaCO3 (Table 2.3)46. According to the methodology, it is assumed that the content of CaO is standard, associated with 4-8% of uncertainty. That's why, the uncertainty of emission factors is about 5%.
2A2	Lime Production	CO_2	In Georgia, as far as lime production is scattered in many small enterprises, there is certain risk regarding full coverage. However, the National Statistics Office of Georgia (GEOSTAT),being the source for these data, has significantly improved data coverage in this area; nevertheless, according to the IPCC methodology the uncertainty could still be quite high. Consequently, based on the experts' assessment, the uncertainty of activity data from this source is estimated as 20%.	The stoichiometric ratio is a precise number and, therefore, the uncertainty of the emission factor is the uncertainty of lime composition, in particular of the share of hydraulic lime that has 15% uncertainty in the emission factor (2% uncertainty in the types). Therefore, the total uncertainty value is 15%
2A3	Glass production		Glass production data are typically measured fairly accurately (+/-5 percent) for Tier 1 and Tier 2 approaches.	Because emissions are estimated based on quantity of melted glass in each manufacturing process and default emission factors, the uncertainty of Tier 2 is higher than Tier 3. The emission factors can be expected to have an uncertainty of +/- 10 percent.

[46] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.17)

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
2B1	Ammonia Production	CO_2	Activity data was collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the enterprise Rustavi Chemical Fertilizers Plant, which are rather accurate data. Emissions are calculated based on the volume of consumed natural gas, as well as based on the produced ammonia amount. Based on the expert judgment, their uncertainty is within 5%.	Based on the 2006 IPCC, the only required fuel uncertainty is estimated from determining the parameters of the CO_2 emissions coefficient for manufacturing the unit weight ammonia, which is about 6-7%, when using the Tier 1 approach. In Georgia's case, based on the expert assessment, the overall uncertainty of the CO_2emission coefficient is around 6%.
2C1	Cast Iron and Steel Production	CO_2	According to guideline, the most important type of activity data is the amount of steel produced; each method is applicable and national statistics should be available and likely have an uncertainty of ± 10 percent. Therefore, uncertainty value of 10% was selected.	According to the 2006 IPCC methodology[47] the default emission factors for iron and steel production used may have an uncertainty of ± 25 percent (see table 4.4).
2C2	Ferroalloys Production	CO_2	According to IPCC methodology, the most important type of activity data is the amount of ferroalloy production by product type and national statistics should be available and likely have an uncertainty less than 5 percent. The activity data were collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the Metallurgy research Institute of Georgia. Therefore, the data are rather accurate. Based on the expert assessment, their uncertainty value is 5%.	In case of using the Tier 1 method, the uncertainty of emission standard coefficients is estimated within the25% range.
2D1	Lubricant Use	CO_2	Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries, for which a default of 5 percent may be used in countries with well-developed energy statistics and 10-20 percent in other countries (PG. 5.10) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf	The default ODU factors developed are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of 50 percent.
5A	Forest land	CO_2	According to the IPCC methodology, uncertainties vary between 1-15% in 16 European countries (Laitat et al. 2000). Area data should be obtained using the guidance in Chapter 3 or from FAO (2000). Industrialized countries estimated an uncertainty in forest area as approximately 3%. In Georgia's case 5% uncertainty was selected.	In Finland, the uncertainty of basic wood density of pine, spruce and birch trees is up to 20% in studies of Hakkila (1968, 1979). The variability between forest stands of the same species should be lower or at most the same as for individual trees of the same species. In Finland, the uncertainty of biomass expansion factors for pine, spruce, and birch was approximately 10% (Lehtonen et al., 2003). In eight Amazon tropical forest inventory plots, combined measurement errors led to errors of 10-30% in estimates of basal area change over periods of less than 10 years (Phillips et al., 2002).

[47] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf (pg. 4.30)

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
				The overall uncertainty of country-specific basic wood density values should be about 20%
5B	Cropland	CO_2	Activity data are quite accurate. Based on the expert assessment, its uncertainty value is within 10%.	The sources of uncertainty when using the Tier 1 method include the degree of accuracy in land area estimates and in the default biomass carbon increment and loss rates. Uncertainty is likely to be low (<10%) in estimates of area under different cropping systems since most countries annually estimate cropland area using reliable methods. A published compilation of research on carbon stocks in agroforestry systems was used to derive the default data provided in Table 5.1 (Schroeder, 1994). While defaults were derived from multiple studies, their associated uncertainty ranges were not included in the publication. Therefore, a default uncertainty level of +75% of the parameter value has been assigned based on IPCC methodology and expert judgment.
5C	Grassland	CO_2	Activity data are quite accurate. Based on the expert assessment, its uncertainty value is within 10%.	According to the IPCC methodology and based on the expert judgment, the default uncertainty value of 75% was selected.
1A1	Stationary fuel combustion	CH_4	Typical 5%.	According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
1A2	Fuel combustion	CH_4	Typical 5%.	According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
1A3a	Civil aviation	CH_4	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected.	According to IPCC GHG methodology, the uncertainty of the CH4 emission factor may range between -57 and +100 percent. In Georgia's case, uncertainty value of 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69)

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
1A3b	Road transportation	CH_4	Typical 5%	Methane usually contributes less than 1% of the CO2-equivalent emissions from the transportation sector. Experts believe that there is an uncertainty of ±40% in the CH4 estimate. That's why uncertainty value of 40% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.29)
1A3c	Other transportation	CH_4	Typical 5%.	Typical 100%.
1A4a	Commercial/Institutional	CH_4	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38)
1A4b	Residential	CH_4	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38)
1A4c	Stationary	CH_4	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38)
1B1	Fugitive Emissions from Solid Fuel Mining and transformation	CH_4	Coal mining data provided by GEOSTAT are reliable and, therefore, the uncertainty value of 5% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16), (table 4.2.4, table 4.2.5)	According to the IPPC methodology, using the typical emission factor for this category has a huge uncertainty value. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16), (table 4.2.4, table 4.2.5)
1B2	Fugitive Emissions from oil Extraction	CH_4	Data on Oil extraction are provided by the Oil and Gas Corporation and are reliable. Therefore, the uncertainty value of 5% was chosen.	According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
				overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5)
1B2	Fugitive Emissions from oil and natural gas production	CH_4	Data on gas production were provided by the Oil and Gas Corporation and are reliable. Therefore, an uncertainty value of 5% was chosen.	According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5)
1B2	Fugitive Emissions from oil and natural gas Transmission and distribution	CH_4	The data were calculated using analytical method, they were based on estimation and, therefore, an uncertainty value of 10% was chosen.	According to the IPPC methodology, 100% value of uncertainty was chosen for emission factors. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.49, 4.50)
4A	Enteric fermentation	CH_4	The activity data were taken from the official statistical publication and are reliable. Classification and distribution of cattle is not entirely consistent with the IPCC standard on dairy and non-dairy cattle, however, it could be assumed, that the data provided by GEOSTAT about "cows" and "other cattle" are in conformity with the classification of "dairy" and "non-dairy cattle", as cows were intended for exactly dairy purpose in the case of Georgia, and the rest for beef production. Therefore, the uncertainty of activity data is moderate and does not exceed of 10%.	As the emission factors for the Tier 1 method are not based on country-specific data, they may not accurately represent a country's livestock characteristics, and may be highly uncertain as a result. Emission factors estimated using the Tier 1 method are unlikely to be known more precisely than ± 30% and may be uncertain to ± 50%. In case of Georgia uncertainty of 30% was selected, as for activity data (heads of cattle by species), they should be considered as reliable, since they are based on Official Statistical Data from GEOSTAT.
4B	Manure management	CH_4	The uncertainty of activity data related to animal number is estimated at 10%, as it is based on official statistical data.	According to the IPCC GPG, 50% is taken for methane emissions-related uncertainty.
3F	Field burning of Agricultural Residues (3.F)	CH_4	According to IPCC 2006 methodology and based on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 10% was selected.	According to IPCC 2006 methodology and based on the expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 50% was selected.

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
6A	Solid Waste Disposal Sides	CH_4	Calculations were made based on the IPCC 2006 methodology, Table 3.5; The final uncertainty of the activity data was estimated at 30%. https://www.ipccnggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf (pg. 3.27)	Calculations were made based on the IPCC 2006 methodology, Table 3.5; and similar calculations were performed in the SNC. The value of uncertainty for emission factor 30% was chosen.
6B1	Industrial Waste Water handling	CH_4	Calculations were made based on the IPCC 2006 methodology, Table 6.10 and similar calculations were performed in the SNC. The final uncertainty of the activity data was set at 50%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (pg. 6.23)	Calculations were made based on the IPCC 2006 methodology, Table 6.10 and similar calculations were performed in the SNC. The final uncertainty in emission factors was set at 30%.
6B2	Domestic Waste Water handling	CH_4	Calculations were made based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 6.7; The final uncertainty of the activity data was set at 5%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf V5_6_Ch6_Wastewater.pdf (pg. 6.17)	Calculations were made based on the 2006 IPCC Guidelines (Table 6.7) and similar calculations were performed in the SNC. The final uncertainty in emission factors was set at 30%.
1A1	Stationary fuel combustion	N_2O	Typical 5%.	According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
1A2	Fuel combustion	N_2O	Typical 5%.	According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate of 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
1A3a	Civil aviation	N_2O	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent). Therefore, a value of 5% was selected.	According to IPCC GHG methodology, the uncertainty of the N2O emission factor may range between -70 and +150 percent. Based on the expert assessment, uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69)
1A3ai	International aviation	N_2O	According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent). Therefore, a value of 5% was selected.	According to IPCC GHG methodology, the uncertainty of the N2O emission factor may range between -70 and +150 percent. Based on the expert assessment, uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69)

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
1A3b	Road transportation	N_2O	Typical 5%.	Typical 50% https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.29). Nitrous oxide usually contributes approximately 3% to the CO2-equivalent emissions from the transportation sector. The expert judgment suggests that the uncertainty of the N2O estimate may be more than ±50%. The major source of uncertainty is related to the emission factors.
1A3c	Other transportation	N_2O	Typical 5%	Typical 100%
1A4a	Commercial/Institutional	N_2O	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC GPG document, Table 2.12, uncertainty ranges from one-tenth of the mean value, to ten times the mean value that should be applied. In this case, an uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38)
1A4b	Residential	N_2O	According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014.	According to the IPCC GPG document, Table 2.12, uncertainty ranges from one-tenth of the mean value, to ten times the mean value that should be applied. In this case, an uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38)
1A4c	Stationary	N_2O	uncertainty of 5% was chosen	According to the IPCC methodology https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38), an uncertainty value of 150% was selected.
2B2	Nitric Acid Production	N_2O	The activity data are rather accurate. Based on the expert judgment its uncertainty value does not exceed 5%.	A new IPCC manual allows standard boundaries of 20% uncertainty assessment for medium-pressure technology plants
2G3	Medical Surgeries	N_2O	According to IPCC 2006 manual, activity data uncertainties are estimated based on the expert judgment. Uncertainty value of 5% was estimated https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf (pg. 8.37)	According to IPCC 2006 manual, uncertainties are estimated based on the expert judgment. Uncertainty value was estimated at 10%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf (pg. 8.37)
4B	Manure management	N_2O	The uncertainty of activity data for nitrous oxide emissions calculation in the manure management sector were estimated at 50%, as there is no exact information about the management systems.	According to IPCC GPG, the uncertainty for emission factors was estimated at 100%

	IPCC source-category	Gas	Uncertainty values in activity data and its selection reasons	Uncertainty in emission factors and its selection reasons
4D1	Direct soil emissions	**N_2O**	The activity data were collected from National Statistics Office of Georgia (GEOSTAT), which is a competent source and quite accurate. Therefore, 10% was selected as the indicator of uncertainty.	The uncertainty for emission factors were taken from the standard range of the IPCC GPG, there were also based on the expert assessment and are equal to 25%.
4D3	Indirect soil emissions	**N_2O**	The uncertainty of activity data is also quite high and related to the assumption on the percentage leached. In addition, the nitrogen content in fertilizers also has uncertainty. Finally, the uncertainty of activity data was set at 50%.	According to IPCC methodology and expert judgment emission factor uncertainties are at least in order of magnitude and volatilisation fractions of about +/−50%.
3F	Field burning of Agricultural Residues (3.F)	**N_2O**	According to IPCC 2006 methodology and based on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 10% was selected.	According to IPCC 2006 methodology and based the on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 50% was selected.
6B2	Domestic Waste Water handling	**N_2O**	The only national value for the emission calculation formula is the number of the populations, for which the uncertainty is estimated within 5% limits. Consequently, 5% of uncertainty value was chosen.	According to IPCC methodology and the expert judgment, emission factor uncertainties are estimated at 70%.
2F	Consumption of halocarbons and sulfur hexafluoride (Refrigeration and Air Conditioning Equipment)	**HFC**	Activity data are relatively accurate. Based on the expert judgment, its uncertainty value is 5%	According to the IPCC GPG, the uncertainty level for standard coefficients of emission is estimated at 25%.
2F	Consumption of halocarbons and sulfur hexafluoride (Emissions from Appliances (electrical equipment)	**SF6**	Activity data are relatively accurate. Based on the expert judgment, its uncertainty value is 5%	According to the IPCC GPG, tier 1 estimates are set at an uncertainty level of 100% or more, representing an estimate of actual emissions. Therefore, the value of 100% was selected.

2.7 Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

GHG (CO_2, CH_4, N_2O, HFCs and SF_6) emission trends for 1990-2017, without consideration of the LULUCF sector, are provided in table below. In 1990, these emissions totaled 45,813 Gigagrams in CO_2 equivalent (Gg CO_2-eq). Due to the collapse of the economic system of the Soviet period, emissions started to fall sharply. In 2017, GHG emissions amounted to 17,766 Gg CO_2-eq[48].

Table 2.7.1: GHG Emission Trends in Georgia during 1990-2017 (Gg CO_2-eq) excluding LULUCF

Gas/Year	CO_2	CH_4	N_2O	HFC-134a	HFC-125	HFC-143a	HFC-32	PFCs	SF_6	NF_3	Total
1990	34,097.77	9,288.91	2,426.51	NA	NA	NA	NA	NA	NE	NA	**45,813**
1991	25,692.44	8,540.44	2,152.57	NA	NA	NA	NA	NA	NE	NA	**36,385**
1992	20,496.33	7,819.22	1,802.06	NA	NA	NA	NA	NA	NE	NA	**30,118**
1993	15,726.21	6,972.08	1,698.80	NA	NA	NA	NA	NA	NE	NA	**24,397**
1994	10,255.88	4,057.05	1,432.52	NA	NA	NA	NA	NA	NE	NA	**15,745**
1995	7,208.45	3,944.06	1,543.04	NA	NA	NA	NA	NA	NE	NA	**12,696**
1996	6,332.33	4,521.04	2,109.23	NA	NA	NA	NA	NA	C	NA	**12,963**
1997	5,385.22	4,373.06	2,234.49	NA	NA	NA	NA	NA	C	NA	**11,993**
1998	4,776.89	4,405.12	1,836.76	NA	NA	NA	NA	NA	C	NA	**11,019**
1999	4,371.96	3,830.09	2,153.86	NA	NA	NA	NA	NA	C	NA	**10,356**
2000	4,874.75	4,204.08	1,844.25	NA	NA	NA	NA	NA	C	NA	**10,923**
2001	3,741.50	3,953.12	1,896.87	0.11	0.05	0.06	0.00345	NE	C	NA	**9,592**
2002	3,278.30	5,326.10	2,149.07	0.46	0.19	0.20	0.01	NE	C	NA	**10,754**
2003	3,458.88	5,924.18	2,230.22	1.46	0.64	0.47	0.07	NE	C	NA	**11,616**
2004	3,870.84	5,914.30	1,917.07	2.43	1.42	0.99	0.17	NE	C	NA	**11,707**
2005	4,759.76	4,459.33	1,940.05	4.59	2.33	1.73	0.27	NE	C	NA	**11,168**
2006	5,441.69	5,638.35	2,010.66	4.69	2.22	1.53	0.27	NE	C	NA	**13,099**
2007	6,499.91	5,340.34	1,774.80	5.31	2.14	1.45	0.26	NE	C	NA	**13,624**
2008	5,837.42	4,511.38	1,840.29	7.81	3.09	2.71	0.30	NE	C	NA	**12,203**
2009	6,192.01	4,133.36	1,856.39	12.84	4.07	3.61	0.39	NE	C	NA	**12,203**
2010	7,004.96	4,798.58	1,830.52	26.41	12.86	13.91	0.89	NE	C	NA	**13,688**
2011	8,898.12	5,276.69	1,787.43	30.54	17.31	14.54	1.82	NE	C	NA	**16,027**
2012	9,320.10	5,587.74	1,926.17	56.77	19.06	15.01	2.14	NE	C	NA	**16,927**
2013	8,711.96	4,957.75	2,190.26	65.07	21.33	15.24	2.62	NE	C	NA	**15,964**
2014	9,582.52	5,034.74	2,122.72	68.38	30.71	16.94	4.52	NE	C	NA	**16,861**
2015	10,250.94	5,645.66	2,177.69	77.83	37.61	17.98	5.97	NE	C	NA	**18,214**
2016	10,507.79	5,739.05	2,151.97	73.16	40.16	14.61	7.13	NE	C	NA	**18,534**
2017	10,688.51	4,941.06	1,980.96	81.69	48.85	15.92	8.87	NE	C	NA	**17,766**

2.8 Description and Interpretation of Emission and Removal Trends by Categories

Emission trends by sectors over 1990-2017years period are provided in the table below. As it is clear from the table, energy is the dominant sector, and it accounts for more than half of the total emissions over the entire period, excluding LULUCF. Following the disintegration of the Soviet Union, the contribution of the agricultural sector in the total emissions grows gradually, and it ranks second over the period of 1990-2017. IPPU and Waste sectors are on the third and fourth places in ranking, excluding LULUCF.

In Georgia, LULUCF sector had a net sink of greenhouse gases for 1990-2017 years period. The sink capacity of the LULUCF sector fluctuates between (-4,145) Gg CO_2-eq and (-6,625) Gg CO_2-eq. In 2017

[48] The discrepancies may appear in total values due to rounding effect.

GHG emissions in Georgia totaled 17,766 Gg in CO_2-eq without consideration of the LULUCF sector, and 12,842 Gg CO_2-eq when taking this sector into account.

Table 2.8.1: GHG Emission Trends by Sectors in 1990-2015 (Gg CO_2-eq)

Sector	Energy	IPPU	Agriculture	Waste	LULUCF (Net removals)	Total (excluding LULUCF)	Total (including LULUCF)
1990	36,698	3,879	4,102	1,135	(6,353)	**45,813**	**39,460**
1991	28,529	3,038	3,713	1,106	(6,416)	**36,385**	**29,970**
1992	24,224	1,705	3,079	1,110	(6,312)	**30,118**	**23,805**
1993	19,678	776	2,831	1,112	(6,548)	**24,397**	**17,849**
1994	11,558	414	2,683	1,091	(6,625)	**15,745**	**9,120**
1995	8,319	447	2,805	1,125	(6,273)	**12,696**	**6,423**
1996	7,931	535	3,344	1,153	(6,022)	**12,963**	**6,941**
1997	6,783	504	3,526	1,180	(5,965)	**11,993**	**6,028**
1998	6,125	502	3,184	1,208	(5,521)	**11,019**	**5,498**
1999	4,849	710	3,560	1,237	(5,324)	**10,356**	**5,032**
2000	5,612	725	3,317	1,269	(5,031)	**10,923**	**5,892**
2001	4,391	439	3,474	1,288	(4,889)	**9,592**	**4,703**
2002	5,139	591	3,719	1,305	(4,778)	**10,754**	**5,976**
2003	5,763	699	3,833	1,321	(4,407)	**11,616**	**7,209**
2004	6,086	846	3,436	1,339	(4,145)	**11,707**	**7,562**
2005	5,396	957	3,461	1,354	(4,163)	**11,168**	**7,006**
2006	7,258	1,136	3,329	1,376	(4,257)	**13,099**	**8,843**
2007	7,888	1,314	3,022	1,400	(4,362)	**13,624**	**9,263**
2008	6,267	1,383	3,132	1,421	(4,357)	**12,203**	**7,846**
2009	6,580	1,106	3,061	1,456	(4,727)	**12,203**	**7,476**
2010	7,707	1,443	3,055	1,483	(4,537)	**13,688**	**9,151**
2011	9,743	1,794	2,981	1,509	(4,864)	**16,027**	**11,163**
2012	10,294	1,872	3,223	1,538	(4,750)	**16,927**	**12,178**
2013	8,949	1,892	3,582	1,542	(4,834)	**15,964**	**11,130**
2014	9,642	2,035	3,633	1,551	(4,609)	**16,861**	**12,252**
2015	10,849	2,058	3,745	1,562	(4,617)	**18,214**	**13,597**
2016	11,355	1,822	3,798	1,559	(4,797)	**18,534**	**13,738**
2017	10,726	1,990	3,488	1,562	(4,924)	**17,766**	**12,842**

In the table below GHG emissions and removals from LULUCF sector are provided in Gg CO_2-eq.

Table 2.8.2: GHG Emissions and Removals from LULUCF sector

Source	Emission (Gg CO_2-eq)	Removal (Gg CO_2)	Net removals (Gg CO_2)
1990	3,394	-9,747	**-6,353**
1991	3,432	-9,848	**-6,416**
1992	3,519	-9,831	**-6,312**
1993	3,398	-9,946	**-6,548**
1994	3,435	-10,061	**-6,625**
1995	3,546	-9,819	**-6,273**
1996	3,579	-9,601	**-6,022**
1997	3,532	-9,498	**-5,965**
1998	3,750	-9,270	**-5,521**
1999	3,702	-9,025	**-5,324**
2000	3,747	-8,779	**-5,031**
2001	3,726	-8,615	**-4,889**
2002	3,673	-8,451	**-4,778**
2003	3,881	-8,288	**-4,407**
2004	3,977	-8,122	**-4,145**
2005	4,050	-8,213	**-4,163**
2006	4,083	-8,340	**-4,257**
2007	4,090	-8,452	**-4,362**

Source	Emission (Gg CO_2-eq)	Removal (Gg CO_2)	Net removals (Gg CO_2)
2008	4,160	-8,517	**-4,357**
2009	3,879	-8,606	**-4,727**
2010	4,016	-8,554	**-4,537**
2011	3,825	-8,689	**-4,864**
2012	3,754	-8,503	**-4,750**
2013	3,835	-8,669	**-4,834**
2014	3,866	-8,475	**-4,609**
2015	3,905	-8,522	**-4,617**
2016	3,772	-8,569	**-4,797**
2017	3,813	-8,737	**-4,924**

2.9 Description and Interpretation of Emission Trends for Precursors

Tables below show direct GHG emissions and precursors by sectors and sub-sectors for 1990 and 2017.

Table 2.9.1: **Direct GHG Emissions and Precursors by Sectors and Sub-Sectors in 1990 (Gg)**

Greenhouse Gas Source and Sink Categories	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)	NMVOCs (Gg)	SOx (Gg)
Total National Emissions and Removals for 1990	**37,492**	**9,747**	**1,438**	**63**	**115**	**386**	**72**	**106**
1. Energy	**30,368.23**	**NO**	**294.84**	**0.46**	**103.81**	**354.44**	**59.86**	**105.23**
A. Fuel Combustion (sectoral approach)	30,294		8.56	0.46	103.81	354.44	59.86	105.23
1. Energy Industries	13,731.86		0.41	0.09	36.46	3.43	0.99	51.95
2. Manufacturing Industries and Construction	7,534.96		0.45	0.07	20.65	6.37	0.98	27.11
3. Transport	3,744.54		0.99	0.19	35.06	237.63	44.84	11.84
4. Other Sectors	5,282.99		5.58	0.09	11.64	107.01	13.05	14.33
5. Non-Specified	0		1.13	0.02	0	0	0	0
B. Fugitive Emissions from Fuels	73.88		286.28		NE	NE	NE	NE
1. Solid Fuels	62.20		32.21		NE	NE	NE	NE
2. Oil and Natural Gas	11.68		254.07		NE	NE	NE	NE
C. CO2 transport and storage	NO	NO						
2. Industrial Processes	**C**	**NA**	**0.04**	**C**	**NO**	**1.58**	**11.92**	**0.39**
A. Mineral Products	571.93				NA	NA	NA	0.39
B. Chemical Industry	C		NA	C	NA	1.58	0.94	0.01
C. Metal Production	2,633.05		0.04	NA	NA	NA	NA	NA
D. Non-Energy Products from Fuel and Solvent Use	0		NA	NA	NA	NA	NA	NA
E. Electronic Industry	NO		NO	NO	NO	NO	NO	NO
F. Product Uses as Substitutes for ODS								
G. Other Product Manufacture and Use	C		NA	C	NA	NA	NA	NA

Greenhouse Gas Source and Sink Categories			CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)	NMVOCs (Gg)	SOx (Gg)
	H. Other (please specify)		NA		NA	NA	NA	NA	10.98	NA
3. Agriculture			**NA**	**NA**	**95.98**	**6.72**	**10.70**	**0.50**	**NE**	**NE**
	A. Enteric Fermentation				89.67					
	B. Manure Management				5.80	1.17			NE	
	C. Rice Cultivation				NO				NO	
	D. Agricultural Soils				NE	5.54			NE	
	E. Prescribed Burning of Savannahs				NO	NO	NO	NO	NO	
	F. Field Burning of Agricultural Residues				0.51	0.01	10.70	0.50	NE	
	G. Other				NO	NO	NO	NO	NO	
4. Land-use Change and Forestry			**3,393.66**	**9,746.73**	**2.01**	**0.02**	**0.16**	**29.07**	**NA**	**NA**
	A. Changes in Forest and Other Woody Biomass Stocks		492.67	6,716.84						
	B. Forest and Grassland conversion		NE	NE	NE	NE	NE	NE		
	C. Abandonment of Managed Lands			NE						
	D. CO2 Emissions and Removals from Soil		2,900.99	3,029.89						
	E. Other		NE	NE	2.01	0.02	0.16	29.07		
5. Waste			**NA**	**NA**	**1,045.00**	**55.00**	**NE**	**NE**	**NE**	**NO**
	A. Solid Waste Disposal on Land				619.00		NE		NE	
	B. Waste-water Handling				426.00	55.00	NE	NE	NE	
	C. Waste Incineration						NO	NO	NO	NO
	D. Other				NO	NO	NO	NO	NO	NO
6. Other			**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo items										
	International Bunkers		**608.63**		**0.00**	**0.02**	**NE**	**NE**	**NE**	**NE**
		Aviation	608.63		0.004	0.017	NE	NE	NE	NE
		Marine	NE		NE	NE	NE	NE	NE	NE
	CO2 Emissions from Biomass		**2,149**							

Table 2.9.2: Anthropogenic Emissions of HFCs, PFCs and SF6 in 1990 (Gg)

Greenhouse Gas Source and Sink Categories			HFCs (Gg)				PFCs (Gg)			SF_6 Gg)
			HFC-23	HFC-134	HFC-125	HFC-143a	CF4	C2F6	Other	
Total National Emissions and Removals 1990			**NE**	**NE**	**NE**	**NO**	**NE**	**NE**	**NE**	**NE**
1. Energy										
	A. Fuel Combustion (sectoral approach)									
		1. Energy Industries								

Greenhouse Gas Source and Sink Categories			HFCs (Gg)				PFCs (Gg)			SF_6 Gg)
			HFC-23	HFC-134	HFC-125	HFC-143a	CF4	C2F6	Other	
		2. Manufacturing Industries and Construction								
		3. Transport								
		4. Other Sectors								
		5. Other								
	B. Fugitive Emissions from Fuels									
		1. Solid Fuels								
		2. Oil and Natural Gas								
	C. CO2 transport and storage									
2. Industrial Processes			**NO, NA, NE**	**NO, NA, NE**	**NO, NA, NE**	**NO, NA**	**NO, NE**	**NO, NE**	**NO, NE**	**NO, NE**
	A. Mineral Products									
	B. Chemical Industry									
	C. Metal Production		NO	NO	NO	NO	NO	NO	NO	NO
	D. Non-Energy Products from Fuel and Solvent Use									
	E. Electronic Industry		NO	NO	NO	NO	NO	NO	NO	NO
	F. Product Uses as Substitutes for ODS		NA	NA	NA	NA	NE	NE	NE	NE
	G. Other Product Manufacture and Use		NE	NE	NE		NE	NE		NE
	H. Other (please specify)									
3. Agriculture										
	A. Enteric Fermentation									
	B. Manure Management									
	C. Rice Cultivation									
	D. Agricultural Soils									
	E. Prescribed Burning of Savannahs									
	F. Field Burning of Agricultural Residues									
	G. Other									
4. Land-use Change and Forestry										
	A. Changes in Forest and Other Woody Biomass Stocks									
	B. Forest and Grassland Conversion									
	C. Abandonment of Managed Lands									
	D. CO2 Emissions and Removals from Soil									
	E. Other									
5. Waste										
	A. Solid Waste Disposal on Land									

Greenhouse Gas Source and Sink Categories	HFCs (Gg)				PFCs (Gg)			SF_6 Gg)
	HFC-23	HFC-134	HFC-125	HFC-143a	CF4	C2F6	Other	
B. Waste-water Handling								
C. Waste Incineration								
D. Other								
6. Other (please specify)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items								
International Bunkers								
Aviation								
Marine								
CO2 Emissions from Biomass								

Table 2.9.3: Direct GHG Emissions and Precursors by Sectors and Sub-Sectors in 2017

Greenhouse Gas Sources and Sink Categories	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)	NMVOCs (Gg)	SOx (Gg)
Total National Emissions and Removals for 2017	**14,501**	**8,737**	**1,702**	**66**	**61**	**1,439**	**54**	**19**
1. Energy	**9,083**	**NO**	**74**	**0.2920**	**50**	**296**	**50**	**18**
A. Fuel Combustion (sectoral approach)	9,070.91		6.58	0.29	49.96	296.42	49.88	18.00
1. Energy Industries	1,529.88		0.02	0.01	2.93	0.38	0.09	0.30
2. Manufacturing Industries and Construction	1,009.68		0.08	0.01	4.22	1.97	0.26	5.37
3. Transport	4,044.00		1.69	0.21	38.58	215.60	40.11	11.58
4. Other Sectors	2,487.35		4.78	0.07	4.23	78.47	9.42	0.75
5. Non-Specified	NO		NO	NO	NO	NO	NO	NO
B. Fugitive Emissions from Fuels	12.15		67.37		NE	NE	NE	NE
1. Solid Fuels	10.06		0		NE	NE	NE	NE
2. Oil and Natural Gas	2.09		67.37		NE	NE	NE	NE
C. CO2 transport and storage	NO	NO						
2. Industrial Processes	**C**	**NA**	**NA**	**C, NA, NO**	**NA, NO**	**1.67**	**4.10**	**0.60**
A. Mineral Products	727.25				NA	NA	0.36	0.59
B. Chemical Industry	C		NA	C	NA	1.66	0.99	0.01
C. Metal Production	463.69		0.003	NA	NA	NA	NA	NA
D. Non-Energy Products from Fuel and Solvent Use	10.25		NA	NA	NA	0.01	0.04	NA
E. Electronic Industry	NO		NO	NO	NO	NO	NO	NO
F. Product Uses as Substitutes for ODS								
G. Other Product Manufacture and Use	C		NA	C	NA	NA	NA	NA
H. Other (please specify)	NA		NA	NA	NA	NA	2.71	NA
3. Agriculture	**NA**	**NA**	**89.78**	**5.17**	**4.80**	**0.20**	**NE**	**NA**
A. Enteric Fermentation			87.12					
B. Manure Management			2.43	1.09			NE	
C. Rice Cultivation			NO				NO	
D. Agricultural Soils			NE	4.07			NE	

Greenhouse Gas Sources and Sink Categories	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)	NMVOCs (Gg)	SOx (Gg)
E. Prescribed Burning of Savannahs			NO	NO	NO	NO	NO	
F. Field Burning of Agricultural Residues			0.23	0.01	4.80	0.20	NE	
G. Other			NO	NO	NO	NO	NO	
4. Land-use Change and Forestry	**3,812.72**	**8,736.57**	**78.97**	**0.97**	**6.14**	**1,140.66**	**NA**	**NA**
A. Changes in Forest and Other Woody Biomass Stocks	900.62	6,478.75						
B. Forest and Grassland conversion	NE	NE	NE	NE	NE	NE		
C. Abandonment of Managed Lands		NE						
D. CO2 Emissions and Removals from Soil	2,912.10	2,257.82						
E. Other	NE	NE	78.97	0.97	6.14	1,140.66		
5. Waste	**NA**	**NA**	**1,459.00**	**59.00**	**NE**	**NE**	**NE**	**NO**
A. Solid Waste Disposal on Land			1,073.00		NE		NE	
B. Waste-water Handling			386.00	59.00	NE	NE	NE	
C. Waste Incineration					NO	NO	NO	NO
D. Other			NO	NO	NO	NO	NO	NO
6. Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo items								
International Bunkers	**296.92**		**0.002**	**0.008**	**NE**	**NE**	**NE**	**NE**
Aviation	292.23		0.0020	0.0082	NE	NE	NE	NE
Marine	4.69		0.0004	0.0001	NE	NE	NE	NE
CO2 Emissions from Biomass	**1,702**							

Table 2.9.4: Anthropogenic Emissions of HFCs, PFCs and SF6 in 2017

Greenhouse Gas Source and Sink Categories	HFCs (Gg)				PFCs (Gg)			SF_6 (Gg)
	HFC-23	HFC-134	HFC-125	HFC-143a	CF4	C2F6	Other	
Total National Emissions and Removals 2017	**0.063**	**0.017**	**0.004**	**0.014**	**NE**	**NE**	**NE**	**C**
1. Energy								
A. Fuel Combustion (sectoral approach)								
1. Energy Industries								
2. Manufacturing Industries and Construction								
3. Transport								
4. Other Sectors								
5. Other								
B. Fugitive Emissions from Fuels								
1. Solid Fuels								

Greenhouse Gas Source and Sink Categories			HFCs (Gg)				PFCs (Gg)			SF6 (Gg)
			HFC-23	HFC-134	HFC-125	HFC-143a	CF4	C2F6	Other	
		2. Oil and Natural Gas								
	C. CO2 transport and storage									
2. Industrial Processes			**0.06**	**0.02**	**0.004**	**0.01**	**NO, NE**	**NO, NE**	**NO, NE**	**NO, NE, C**
	A. Mineral Products									
	B. Chemical Industry									
	C. Metal Production		NO	NO	NO	NO	NO	NO	NO	NO
	D. Non-Energy Products from Fuel and Solvent Use									
	E. Electronic Industry		NO	NO	NO	NO	NO	NO	NO	NO
	F. Product Uses as Substitutes for ODS		0.06	0.02	0.004	0.01	NE	NE	NE	NE
	G. Other Product Manufacture and Use		NE	NE	NE		NE	NE		C
	H. Other (please specify)									
3. Agriculture										
	A. Enteric Fermentation									
	B. Manure Management									
	C. Rice Cultivation									
	D. Agricultural Soils									
	E. Prescribed Burning of Savannahs									
	F. Field Burning of Agricultural Residues									
	G. Other									
4. Land-use Change and Forestry										
	A. Changes in Forest and Other Woody Biomass Stocks									
	B. Forest and Grassland Conversion									
	C. Abandonment of Managed Lands									
	D. CO2 Emissions and Removals from Soil									
	E. Other									
5. Waste										
	A. Solid Waste Disposal on Land									
	B. Waste-water Handling									
	C. Waste Incineration									
	D. Other									
6. Other (please specify)			**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items										
	International Bunkers									
		Aviation								
		Marine								
	CO2 Emissions from Biomass									

2.10 Energy (CRF Sector 1)

In 2017, GHG emissions from the energy sector amounted to 10,726 Gg CO_2-eq, which is about 60% of Georgia's total GHG emissions (excluding LULUCF). In 2017, the following source categories had the largest shares in the total GHG emissions from the Energy Sector: Transport – 39%, Other Sectors – 24%, Oil and Natural Gas – 13%, Energy Industries – 14%, Manufacturing Industries and Construction – 9%. Compared to 1990, the total GHG emissions from the energy sector had decreased by 71%.

Table 2.10.1: **Energy Sectoral Table for 1990 and 2017**

Category	1990 Emissions (Gg)			2017 Emissions (Gg)		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1 – Energy	30,368.23	294.84	0.44	9,083.06	73.95	0.29
1.A - Fuel Combustion	30,294.35	8.55	0.44	9,070.91	6.58	0.29
1.A.1 - Energy Industries	13,731.86	0.41	0.09	1,529.88	0.02	0.01
1.A.2 - Manufacturing Industries & Construction	7,534.96	0.45	0.07	1,009.68	0.08	0.01
1.A.3 – Transport	3,744.54	0.99	0.19	4,044.00	1.69	0.21
1.A.4 - Other Sectors	5,282.99	5.58	0.09	2,487.35	4.78	0.07
1.A.4.a - Commercial/Institutional	1,076.52	0.45	0.01	417.08	0.09	0.00
1.A.4.b – Residential	3,688.24	4.89	0.07	1,777.79	4.67	0.06
1.A.4.c - Agriculture/Forestry/ Fishing	518.23	0.24	0.00	292.47	0.03	0.00
1.A.5 Non-Specified	0.00	1.13	0.02	NO	NO	NO
1.B - Fugitive Emissions from Fuels	73.88	286.29	0.00	12.15	67.369	0.00
1.B.1 - Solid Fuels	62.20	32.21	0.00	10.06	0.00	0.00
1.B.2 - Oil and Natural Gas	11.68	254.07	0.00	2.09	67.369	0.00
1.B.3 - Other emissions from Energy Production	NO	NO	NO	NO	NO	NO
1.C - CO2 Transport and Storage	NO	NO	NO	NO	NO	NO

A significant fall in GHG emissions in the 1990s is due to the collapse of the Soviet Union and fundamental changes in the economy of the country. However, the national economy started to grow since 2000 and the average annual growth of real GDP amounted to 8.4% prior to 2008. During 2008-2009, economic growth of Georgia has slowed down due to the Russian-Georgian war. Starting in 2010, the real GDP of the country began to increase again by 4.7% on average until 2018[49].

In 2010, hydro generation reached its maximum capacity, while the generation from thermal power plants was the lowest in the past decade. Since 2011 the GHG emissions in the energy sector increased mainly due to the increased thermal power generation and improvement of the economic situation. Table below shows the CO_2 equivalent of the emissions in the energy sector. The Global Warming Potentials used to convert from GHG to CO_2-eq are reflected in the IPCC Second Assessment Report.

Table 2.10.2: **GHG Emissions from the Energy Sector (Gg CO_2-eq.)**

1B - Fugitive Emissions from Fuels	Year	1A - Fuel Combustion	1C - CO2 Transport and Storage	Total from Energy Sector
6,086	1990	30,612	NO	36,698
5,499	1991	23,030	NO	28,529
5,033	1992	19,191	NO	24,225
4,224	1993	15,454	NO	19,678
1,527	1994	10,032	NO	11,559
1,256	1995	7,063	NO	8,319

[49] GEOSTAT – RealGrowthofGDP.

1B - Fugitive Emissions from Fuels	Year	1A - Fuel Combustion	1C - CO2 Transport and Storage	Total from Energy Sector
1,676	1996	6,255	NO	7,930
1,529	1997	5,254	NO	6,782
1,528	1998	4,598	NO	6,125
820	1999	4,030	NO	4,850
1,104	2000	4,508	NO	5,611
810	2001	3,580	NO	4,390
2,112	2002	3,027	NO	5,138
2,653	2003	3,110	NO	5,762
2,697	2004	3,390	NO	6,087
1,274	2005	4,123	NO	5,397
2,600	2006	4,659	NO	7,259
2,331	2007	5,558	NO	7,889
1,446	2008	4,822	NO	6,267
1,111	2009	5,470	NO	6,581
1,693	2010	6,014	NO	7,707
2,180	2011	7,565	NO	9,745
2,363	2012	7,932	NO	10,295
1,554	2013	7,394	NO	8,949
1,489	2014	8,154	NO	9,643
2,032	2015	8,818	NO	10,849
2,103	2016	9,252	NO	11,355
1,427	2017	9,300	NO	10,726

As can be seen from the Table, a large share of the emissions from the energy sector is due to fuel combustion (87% in 2017) and the remaining 13% is caused by fugitive emissions. Among emission source-categories, the highest growth relative to 2000 was noted in fugitive emissions from the transformation of solid fuel (5 Gg CO_2-eq. in 2000, 132 Gg CO_2-eq. in 2016), which took place as a result of the intensification of coal mining works in recent years. However, since 2017 coal mining has significantly decreased due to the technical inspection of safety norms of mines, following the deadly workplace accidents[50].

During 2000-2017, GHG emissions from the manufacturing industry and transport sectors increased about 1.5 and 4.4 times, respectively. In the transport sector, GHG emissions increased due to the growing auto-park and a majority share of second-hand cars in the park. In Georgia, the number of motor vehicles in 2002-2016 period increased from 319,600 to 1,126,470[51]. Since 2006, the development of energy transit pipelines (South Caucasus Gas Pipeline, Baku-Tbilisi-Erzurum oil Pipeline) through Georgia required additional gas and diesel for the pipeline operation.

Non-CO_2 Emissions from Energy Sector

Non-CO_2 emissions, such as CO, NOx, NMVOC and SO_2, were calculated using the Tier 1 approach in fuel combustion. The Tier 1 methodology for non-CO_2 gases estimates emissions by applying Emission Factors to fuel statistics, which are organized by sector. Emissions of these gases depend on the fuel type used, combustion technology, operating conditions, control technology, and on maintenance and age of the equipment. However, since Georgia does not have such detailed data, the Tier 1 methodology was used,

[50] Miners' Deaths Spark Protests In Georgia

[51] MinistryofInternalAffairs, 2016

ignoring these refinements. Table below provides estimates of non-CO_2 emissions from fuel combustion for the period of 1990-2017.

Table 2.10.3: Precursor Gas Emissions in Energy Sector

Non-CO_2 From Fuel Combustion (Tier 1) Gg	CO	NOx	NMVOCs	SO_2
1990	354	104	60	105
1991	310	71	52	42
1992	305	63	47	51
1993	358	53	52	40
1994	157	37	25	34
1995	201	30	28	27
1996	444	40	70	14
1997	354	32	55	13
1998	260	26	39	14
1999	244	22	36	11
2000	209	22	30	10
2001	245	19	37	5
2002	249	18	38	5
2003	251	18	38	4
2004	239	19	36	5
2005	200	23	33	7
2006	205	25	33	7
2007	242	28	40	9
2008	215	23	35	9
2009	225	28	36	12
2010	246	32	41	15
2011	227	37	38	16
2012	308	39	47	17
2013	257	40	41	16
2014	262	46	42	16
2015	266	50	44	18
2016	326	54	55	19
2017	296	50	50	18

In 2017, the transport and the residential sectors contributed about 73% and 26% respectively in CO emissions. While transport sector (77%) was a key contributor in NO_x emissions. 80% and 18% respectively was the share of the transport and the residential sectors in NMVOC emissions in the same year. Manufacturing industry and the transport sectors had 30% and 64% shares respectively in SO_2 emission.

2.10.1 Fuel Combustion (1.A.)

Emissions of greenhouse gases from the Fuel Combustion source-category totaled 9,300 Gg in CO_2-eq in 2017. In that year, carbon dioxide, methane and nitrous oxide accounted for 85%, 14%, and 1% of emissions from fuel combustion source-category, respectively. The transport sector has the highest share (39%) in GHG emissions from the source. The residential sector has the highest contribution in methane emissions, and transport sector - in nitrous oxide emissions.

2.10.2 The Sectoral Approach vs the Reference Approach

This chapter explains a comparison between the reference approach and the sectoral approach in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I, paragraph 40). The table below shows carbon dioxide emissions in 2016-2017, calculated using these two approaches for different types of fuel, followed by the explanation of differences.

Table 2.10.2.1: Comparison of CO_2 Emissions (in Gg) Calculated using the Reference and the Sectoral Approaches

Fuel type	Year	2016	2017
Liquid Fuel	Reference approach	3,935	3,479
	Sectoral approach	3,967	3,489
	Difference	-0.82%	-0.28%
Solid Fuel	Reference approach	1,113	1,237
	Sectoral approach	1,114	1,235
	Difference	-0.09%	0.15%
Gas Fuel	Reference approach	4,192	4,310
	Sectoral approach	3,925	4,347
	Difference	6.81%	-0.85%
Other Fossil Fuels	Reference approach	0	0
	Sectoral approach	0	0
	Difference	0.00%	0.00%
Peat	Reference approach	0	0
	Sectoral approach	0	0
	Difference	0.00%	0.00%
Total	Reference approach	9,240	9,026
	Sectoral approach	9,007	9,071
	Difference	2.60%	-0.49%

6.81% difference in gas fuel in 2016 is due to the natural gas losses at the time of transportation and distribution, which is treated as methane emission, while under the reference approach it is treated as combusted and transformed into carbon dioxide.

2.10.3 International Bunker Fuels

All emissions from fuels used for international aviation and water-borne navigation (bunkers) are to be excluded from national totals and reported separately as memo items. Emissions from international aviation are defined as emissions from flights that depart in one country and arrive in a different country, including take-offs and landings for these flight stages.

Emissions from international water-borne navigation are sourced from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. It includes emissions from journeys that depart in one country and arrive in a different country.

Table below provides emissions from the International Aviation and Marine Bunkers.

Table 2.10.3.1: GHG emissions from international bunkers

Year	International Aviation Bunkers					International Marine Bunkers				
	Jet Kerosene, TJ	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total in Gg CO_2-eq	Diesel, Fuel Oil, TJ	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total in Gg CO_2 eq
1990	8,512	609	0.004	0.017	**614**	NE	NE	NE	NE	NE
1991	8,256	590	0.004	0.017	**596**	5,102	392	0.04	0.01	**395**
1992	7,095	507	0.004	0.014	**512**	3,644	280	0.03	0.01	**282**
1993	5,418	387	0.003	0.011	**391**	2,466	189	0.02	0.01	**191**
1994	2,765	198	0.001	0.006	**200**	2,168	166	0.02	0.00	**168**
1995	172	12	0.00	0.000	**12**	2,061	158	0.01	0.00	**160**
1996	3,354	240	0.002	0.007	**242**	NE	NE	NE	NE	NE
1997	2,967	212	0.001	0.006	**214**	NE	NE	NE	NE	NE
1998	4,128	295	0.002	0.008	**298**	NE	NE	NE	NE	NE
1999	3,483	249	0.002	0.007	**251**	NE	NE	NE	NE	NE

Year	International Aviation Bunkers					International Marine Bunkers				
	Jet Kerosene, TJ	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total in Gg CO_2-eq	Diesel, Fuel Oil, TJ	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total in Gg CO_2 eq
2000	648	46	0.000	0.001	**46**	NE	NE	NE	NE	NE
2001	559	40	0.000	0.001	**40**	NE	NE	NE	NE	NE
2002	989	71	0.000	0.002	**71**	809	60	0.01	0.00	**61**
2003	1,118	80	0.001	0.002	**81**	NE	NE	NE	NE	NE
2004	1,591	114	0.001	0.003	**115**	NE	NE	NE	NE	NE
2005	1,599	114	0.001	0.003	**115**	NE	NE	NE	NE	NE
2006	1,591	114	0.001	0.003	**115**	NE	NE	NE	NE	NE
2007	2,021	145	0.001	0.004	**146**	NE	NE	NE	NE	NE
2008	1,720	123	0.001	0.003	**124**	NE	NE	NE	NE	NE
2009	1,720	123	0.001	0.003	**124**	NE	NE	NE	NE	NE
2010	1,673	120	0.001	0.003	**121**	NE	NE	NE	NE	NE
2011	1,512	108	0.001	0.003	**109**	NE	NE	NE	NE	NE
2012	2,949	211	0.001	0.006	**213**	NE	NE	NE	NE	NE
2013	3,656	261	0.002	0.007	**263**	NE	NE	NE	NE	NE
2014	3,470	248	0.002	0.007	**250**	41	3	0.00	0.00	**3**
2015	3,002	215	0.002	0.006	**217**	61	5	0.00	0.00	**5**
2016	3,048	218	0.002	0.006	**220**	24	2	0.00	0.00	**2**
2017	4,087	292	0.002	0.008	**295**	63	5	0.00	0.00	**5**

Due to the lack of data, information on GHG emissions from the consumption of fuel by international marine bunkers is only available for 1991-1995- and 2014-2017-years periods. Data for the 1991-1995 period were provided by IEA, while the data for the latest period were obtained from the Transport and Logistics Development Policy Department of the Ministry of Economy and Sustainable Development.

2.10.4 Fugitive Emissions from Fuels (1.B.)

Fugitive emissions include all intentional or unintentional release of greenhouse gases (mainly methane) during the extraction, processing, and transportation of fossil fuels to the point of final use. Fugitive emissions were calculated from the following categories and sub-categories:

Solid fuels (coal mining and handling, underground mines)

- Coal mining
- Post-mining seam gas emissions
- Abandoned underground mines.

Oil

- Venting
- Flaring
- Oil production and upgrading
- Oil transportation
- Natural Gas
- Venting
- Flaring
- Production
- Transmission and storage
- Distribution.

GHG emissions trend from the fugitive emissions in subsectors are provided in the **Error! Reference source not found.**.1.

Table 2.10.4.1: **Fugitive Emissions (in Gg)**

Year / Category	1B1 Solid fuel total in CO_2-eq	CO_2	CH_4 in CO_2-eq	1B2a Oil total in CO_2-eq	CO_2	CH_4 in CO_2-eq	N_2O in CO_2-eq	1B2b Natural Gas total in CO_2-eq	CO_2	CH_4 in CO_2-eq	N_2O in CO_2-eq	Total fugitive emissions in CO_2-eq
1990	**738.70**	62.20	676.50	**160.46**	11.41	149.00	0.05	**5,186.87**	0.27	5,186.60	0.0005	**6,086**
1991	**23.07**	23.07	0.00	**18.06**	11.54	6.47	0.05	**5,457.83**	0.30	5,457.53	0.0005	**5,499**
1992	**8.35**	8.35	0.00	**112.19**	8.08	104.08	0.04	**4,912.87**	0.26	4,912.61	0.0004	**5,033**
1993	**5.98**	5.98	0.00	**35.62**	2.55	33.06	0.01	**4,182.32**	0.23	4,182.09	0.0004	**4,224**
1994	**81.98**	6.90	75.08	**39.23**	2.82	36.39	0.01	**1,405.85**	0.05	1,405.80	0.0000	**1,527**
1995	**15.67**	1.32	14.35	**42.05**	3.04	39.00	0.01	**1,198.54**	0.04	1,198.50	0.0001	**1,256**
1996	**7.39**	0.62	6.77	**102.71**	3.03	99.67	0.01	**1,565.53**	0.06	1,565.47	0.0000	**1,676**
1997	**2.31**	0.19	2.11	**112.58**	8.14	104.41	0.04	**1,413.65**	0.05	1,413.60	0.0000	**1,529**
1998	**6.92**	0.58	6.33	**99.98**	7.23	92.72	0.03	**1,420.84**	0.05	1,420.79	0.0000	**1,528**
1999	**7.39**	0.62	6.77	**76.47**	5.53	70.92	0.03	**735.71**	0.03	735.69	0.0000	**820**
2000	**4.91**	0.41	4.49	**93.34**	6.75	86.56	0.03	**1,005.42**	0.15	1,005.27	0.0006	**1,104**
2001	**2.31**	0.19	2.11	**83.18**	6.01	77.14	0.03	**724.97**	0.08	724.89	0.0003	**810**
2002	**2.78**	0.23	2.54	**62.19**	4.49	57.67	0.02	**2,047.00**	0.11	2,046.89	0.0001	**2,112**
2003	**3.70**	0.31	3.38	**117.63**	8.50	109.09	0.04	**2,531.44**	0.13	2,531.31	0.0001	**2,653**
2004	**3.70**	0.31	3.38	**82.36**	5.95	76.38	0.03	**2,610.47**	0.12	2,610.35	0.0001	**2,697**
2005	**2.23**	0.19	2.04	**56.86**	4.11	52.73	0.02	**1,214.70**	0.07	1,214.63	0.0001	**1,274**
2006	**4.14**	0.35	3.79	**53.78**	3.89	49.87	0.02	**2,542.15**	0.12	2,542.02	0.0001	**2,600**
2007	**10.61**	0.89	9.72	**51.77**	3.48	48.27	0.02	**2,268.75**	0.12	2,268.63	0.0001	**2,331**
2008	**14.76**	1.24	13.51	**49.14**	3.24	45.89	0.02	**1,381.69**	0.10	1,381.59	0.0001	**1,446**
2009	**56.74**	4.78	51.96	**48.60**	3.12	45.46	0.01	**1,005.99**	0.08	1,005.92	0.0001	**1,111**
2010	**119.27**	10.04	109.23	**49.36**	3.18	46.17	0.01	**1,524.34**	0.10	1,524.24	0.0001	**1,693**
2011	**157.23**	13.24	143.99	**47.55**	3.09	44.45	0.01	**1,975.14**	0.11	1,975.03	0.0000	**2,180**
2012	**187.93**	15.82	172.11	**42.41**	2.73	39.67	0.01	**2,132.58**	0.11	2,132.47	0.0000	**2,363**
2013	**184.00**	15.20	168.80	**45.66**	2.96	42.69	0.01	**1,324.49**	0.10	1,324.39	0.0000	**1,554**
2014	**133.52**	11.23	122.29	**41.45**	2.64	38.80	0.01	**1,313.90**	0.11	1,313.78	0.0001	**1,489**
2015	**136.28**	11.47	124.80	**39.41**	2.49	36.91	0.01	**1,856.10**	0.13	1,855.97	0.0001	**2,032**
2016	**132.10**	11.12	120.98	**37.93**	2.39	35.53	0.01	**1,933.08**	0.13	1,932.95	0.0001	**2,103**
2017	**10.06**	10.06	0.00	**32.27**	1.98	30.28	0.00	**1,384.57**	0.10	1,384.47	0.0001	**1,427**

As can be seen from the table, natural gas is the dominant subsector, where high emissions are caused by high losses of natural gas in the process of transportation and distribution. Over the years, emissions from the mining and processing of coal also increased, as a result of intensification of mining of this fuel in Georgia. Below all source subcategories are described separately.

2.11 Industrial processes and product use (CRF Sector 2)

The GHG emissions from the sector cover emissions from the following categories: Mineral Products (2A), Chemical Industry (2B), Metal Production (2C), Non-Energy Products from Fuels and Solvent Use (2D), Electronics Industry (2E), Product Uses as Substitutes for ODS (2F) Other Product Manufacture and Use (2G) and Other Industries such as paper, drinks and food production (2H).

Table 2.11.1: **Emissions from the Industrial Processes and Product use in Georgia in 1990-2017 ($GgCO_2$-eq)**

Year	Mineral Products	Chemical Industry	Metal Production	Non-Energy Products from Fuels and Solvent Use	Electronics industry	Product Uses as Substitutes for ODS	Other Product Manufacture and Use	Other Industries such as paper, drinks and food production	Total
	2A	2B	2C	2D	2E	2F	2G	2H	
1990	572	C	2635	0	NA	NA	C	NO	3,879
1991	357	C	2035	0	NA	NA	C	NO	3,038
1992	211	C	1053	0	NA	NA	C	NO	1,705
1993	110	C	276	0	NA	NA	C	NO	776
1994	45	C	116	0	NA	NA	C	NO	414
1995	32	C	94	0	NA	NA	C	NO	447
1996	48	C	81	0	NA	NA	C	NO	535
1997	42	C	106	0	NA	NA	C	NO	504
1998	84	C	111	0	NA	NA	C	NO	502
1999	138	C	62	0	NA	NA	C	NO	710
2000	143	C	46	0	NA	NA	C	NO	725
2001	146	C	71	0	NA	0.2	C	NO	439
2002	161	C	61	0	NA	0.9	C	NO	591
2003	161	C	111	0	NA	2.6	C	NO	699
2004	188	C	187	0	NA	5.0	C	NO	846
2005	226	C	200	0	NA	8.9	C	NO	957
2006	332	C	214	0	NA	8.7	C	NO	1,136
2007	521	C	207	0	NA	9.2	C	NO	1,314
2008	585	C	235	0	NA	14	C	NO	1,383
2009	328	C	224	0	NA	21	C	NO	1,106
2010	413	C	362	0	NA	54	C	NO	1,443
2011	625	C	438	0	NA	64	C	NO	1,794
2012	625	C	473	0	NA	93	C	NO	1,872
2013	639	C	465	9	NA	104	C	NO	1,892
2014	752	C	482	10	NA	121	C	NO	2,035
2015	759	C	438	11	NA	139	C	NO	2,058
2016	714	C	387	12	NA	135	C	NO	1,822
2017	727	C	464	10	NA	155	C	NO	1,990

Table 2.11.2: **Emissions from the Industrial Processes and Product use by gases in Georgia in 1990-2017 (Gg)**

Year	CO_2	CH_4		N_2O		HFCs	PFCs	SF_6		NF_3	
			CO_2-eq		CO_2-eq	CO_2-eq	CO_2-eq		CO_2-eq		CO_2-eq
1990	3,730	0.0433	0.9094	C	C	NA	NA	C	C	NE	NE
1991	2,889	0.0208	0.4361	C	C	NA	NA	C	C	NE	NE
1992	1,602	0.0107	0.2248	C	C	NA	NA	C	C	NE	NE
1993	673	0.0037	0.0773	C	C	NA	NA	C	C	NE	NE
1994	369	0.0023	0.0477	C	C	NA	NA	C	C	NE	NE
1995	388	0.0027	0.0573	C	C	NA	NA	C	C	NE	NE
1996	438	0.0020	0.0416	C	C	NA	NA	C	C	NE	NE
1997	417	0.0028	0.0586	C	C	NA	NA	C	C	NE	NE
1998	425	0.0057	0.1198	C	C	NA	NA	C	C	NE	NE

Year	CO_2	CH_4		N_2O		HFCs	PFCs	SF_6		NF_3	
			CO_2-eq		CO_2-eq	CO_2-eq	CO_2-eq		CO_2-eq		CO_2-eq
1999	576	0.0044	0.0930	C	C	NA	NA	C	C	NE	NE
2000	585	0.0036	0.0755	C	C	NA	NA	C	C	NE	NE
2001	382	0.0055	0.1155	C	C	0.22	NE	C	C	NE	NE
2002	474	0.0047	0.0986	C	C	0.86	NE	C	C	NE	NE
2003	568	0.0086	0.1803	C	C	2.64	NE	C	C	NE	NE
2004	702	0.0145	0.3035	C	C	5.01	NE	C	C	NE	NE
2005	783	0.0155	0.3254	C	C	8.91	NE	C	C	NE	NE
2006	938	0.0165	0.3474	C	C	8.71	NE	C	C	NE	NE
2007	1,116	0.0160	0.3363	C	C	9.16	NE	C	C	NE	NE
2008	1,178	0.0182	0.3822	C	C	13.91	NE	C	C	NE	NE
2009	892	0.0173	0.3635	C	C	20.91	NE	C	C	NE	NE
2010	1,165	0.0276	0.5799	C	C	54.07	NE	C	C	NE	NE
2011	1,486	0.0329	0.6907	C	C	64.20	NE	C	C	NE	NE
2012	1,538	0.0354	0.7429	C	C	92.99	NE	C	C	NE	NE
2013	1,542	0.0343	0.7209	C	C	104.26	NE	C	C	NE	NE
2014	1,670	0.0351	0.7380	C	C	120.56	NE	C	C	NE	NE
2015	1,660	0.0313	0.6574	C	C	139.38	NE	C	C	NE	NE
2016	1,488	0.0024	0.0514	C	C	135.06	NE	C	C	NE	NE
2017	1,606	0.0030	0.0620	C	C	155.33	NE	C	C	NE	NE

In 2017, total GHG emissions from this sector amounted to approximately 1,990.2 GgCO_2-eq, accounting for 11% of national total emissions (excluding LULUCF) in Georgia. The emissions of CO_2, CH_4, and N_2O from this sector have decreased by 53% compared to 1990. The emissions of HFCs, PFCs, SF_6, and NF_3 from this sector have increased 712 times compared to 2001.

The main driving factors for the reduction of emissions in this sector since 1990 are the decrease in steel production due to economic transition. However, HFC emissions from the product uses as ODS substitutes have largely increased.

Information on emissions of indirect GHG such as non-methane volatile organic compounds (NMVOCs), carbon monoxide, nitrogen oxides are provided in the **Error! Reference source not found.**.

Table 2.11.3: **Precursor Emissions from the Industrial Processes and Product use in Georgia in 1990-2017 (in Gg)**

Year	CO	NOx	NMVOC	SO_2	Year	CO	NOx	NMVOC	SO_2
1990	1.6	2.85	11.92	0.40	2004	1.0	2.69	2.04	0.13
1991	1.5	2.86	12.93	0.26	2005	1.2	3.19	2.16	0.17
1992	0.9	1.98	9.22	0.14	2006	1.4	3.67	2.29	0.25
1993	0.8	1.99	7.65	0.07	2007	1.4	3.65	2.41	0.39
1994	0.4	0.86	5.92	0.03	2008	1.5	3.68	2.02	0.42
1995	0.5	1.12	3.79	0.02	2009	1.4	3.72	2.22	0.27
1996	0.7	1.86	3.38	0.03	2010	1.6	4.33	2.87	0.28
1997	0.0	1.67	2.25	0.03	2011	1.7	4.69	3.29	0.46
1998	0.6	1.49	2.31	0.06	2012	1.8	4.65	3.22	0.47
1999	1.0	2.59	1.90	0.10	2013	1.7	4.73	3.34	0.50
2000	1.1	2.71	1.90	0.10	2014	1.7	4.72	3.58	0.50
2001	0.5	1.08	1.27	0.10	2015	1.9	4.99	3.59	0.54
2002	0.9	2.25	1.52	0.10	2016	1.5	3.85	3.81	0.56
2003	1.0	2.48	1.64	0.10	2017	1.7	4.43	4.10	0.63

2.12 Agriculture (CRF Sector 3)

According to the "Agriculture census 2014", in Georgia 73.1% of farms manage land lots up to 1 ha, 25% land lots from 1 ha to 5 ha and only 1.5% of the farms manage land lots larger than 5 ha. The agricultural lands area of Georgia comprises 2.55 million hectares, which is about 37% of the total territory (forestry is about 39%, other area- about 22%). The shares of various agricultural activities are as follows: Land under annual crops – 377,400 ha, Permanent cropland – 109,600 ha, Pastures, and grasslands – 300,000 ha.

The agriculture sector of Georgia as source of GHG emissions comprises three subcategories: Enteric fermentation, Manure management and Agricultural Soils. The other IPCC subcategories of rice cultivation and prescribed burning of savannas are not relevant for Georgia and therefore are not considered. GHG emissions are estimated for 2016-2017 years period. For previous 1990-2015 years GHG emissions from agriculture sectors are recalculated applying specified data on cattle distribution by breeds (provided by Head of the Department of Zootechny of the Agrarian University of Georgia Mr. Levan Tortladze), using tier 2 approach for methane emissions from manure management, estimating GHG emissions from enteric fermentation in donkeys and horses (during 2006-2017 years) and estimating GHG emissions from field burning of agricultural residues.

The GHG emissions from the agricultural sector are presented in **Error! Reference source not found.**. It clearly shows that enteric fermentation is the largest source for methane emissions within this sector, while "Agriculture soils" is the largest emitter of nitrous oxide.

Table 2.12.1: Methane and Nitrous Oxide emissions (in Gg) from agriculture sector in 1990-2017

Year	CH_4				N_2O												
	Enteric fermentation (3.A)	Manure management (3.B)	Field burning of Agricultural Residues (3.F)	CH4 total	Manure management – direct (3.B)	Manure management – indirect (3.B)	Agricultural soils (3.D)	Direct soil emissions (3.D.a)	Synthetic fertilizers (3.D.a.1)	Organic N fertilizers (3.D.a.2)	Urine & dung from grazing animals (3.D.a.3)	Crop residue decomposition (3.D.a.4)	Indirect soil emissions (3.D.b)	Atmospheric deposition (3.D.b.1)	Nitrogen leaching & run-off (3.D.b.2)	Field burning of Agricultural Residues (3.F)	N_2O total
1990	89.67	5.80	0.51	95.99	0.96	0.22	5.54	3.49	1.19	3.40	3.77	0.20	2.05	0.33	1.72	0.01	6.73
1991	83.28	5.05	0.44	88.77	0.88	0.20	4.87	3.07	0.98	2.92	3.23	0.17	1.80	0.30	1.50	0.01	5.96
1992	68.96	3.55	0.39	72.90	0.71	0.16	4.11	2.59	0.90	2.54	2.82	0.15	1.52	0.25	1.28	0.01	4.99
1993	63.25	3.00	0.32	66.56	0.66	0.15	3.81	2.39	0.90	0.30	1.08	0.12	1.42	0.23	1.19	0.01	4.63
1994	63.53	3.01	0.38	66.92	0.67	0.15	3.30	2.08	0.61	0.30	1.04	0.13	1.22	0.20	1.01	0.01	4.13
1995	65.16	3.01	0.38	68.54	0.69	0.15	3.56	2.24	0.76	0.31	1.06	0.12	1.32	0.22	1.11	0.01	4.41
1996	67.06	2.98	0.46	70.50	0.71	0.15	5.14	3.18	1.66	0.31	1.06	0.14	1.96	0.29	1.67	0.01	6.01
1997	68.13	3.01	0.64	71.79	0.72	0.16	5.61	3.47	1.87	0.32	1.07	0.21	2.15	0.31	1.84	0.02	6.51
1998	69.84	3.04	0.44	73.32	0.73	0.16	4.40	2.74	1.21	0.32	1.05	0.16	1.66	0.25	1.41	0.01	5.30
1999	74.78	3.33	0.57	78.67	0.79	0.17	5.18	3.21	1.56	0.34	1.13	0.19	1.97	0.29	1.67	0.02	6.16
2000	78.26	3.50	0.31	82.07	0.82	0.18	4.13	2.59	0.93	0.35	1.17	0.13	1.54	0.25	1.29	0.01	5.14
2001	78.88	3.55	0.56	82.98	0.83	0.18	4.56	2.85	1.13	0.36	1.20	0.17	1.71	0.27	1.44	0.01	5.58
2002	81.42	3.60	0.50	85.52	0.86	0.19	5.15	3.21	1.43	0.37	1.24	0.17	1.94	0.30	1.64	0.01	6.21
2003	83.37	3.76	0.56	87.68	0.88	0.19	5.34	3.33	1.49	0.38	1.27	0.18	2.02	0.31	1.71	0.02	6.43
2004	79.96	3.76	0.51	84.23	0.84	0.18	4.34	2.73	0.94	0.37	1.26	0.16	1.61	0.26	1.35	0.01	5.37
2005	80.89	3.61	0.53	85.03	0.85	0.19	4.36	2.74	0.91	0.37	1.26	0.21	1.62	0.26	1.36	0.01	5.41
2006	73.40	2.95	0.24	76.60	0.76	0.17	4.62	2.88	1.32	0.33	1.13	0.10	1.74	0.27	1.47	0.01	5.56
2007	71.24	1.99	0.31	73.54	0.72	0.15	3.88	2.43	0.92	0.31	1.09	0.11	1.45	0.23	1.21	0.01	4.76

Year	CH_4				N_2O												
	Enteric fermentation (3.A)	Manure management (3.B)	Field burning of Agricultural Residues (3.F)	CH4 total	Manure management – direct (3.B)	Manure management – indirect (3.B)	Agricultural soils (3.D)	Direct soil emissions (3.D.a)	Synthetic fertilizers (3.D.a.1)	Organic N fertilizers (3.D.a.2)	Urine & dung from grazing animals (3.D.a.3)	Crop residue decomposition (3.D.a.4)	Indirect soil emissions (3.D.b)	Atmospheric deposition (3.D.b.1)	Nitrogen leaching & run-off (3.D.b.2)	Field burning of Agricultural Residues (3.F)	N_2O total
2008	73.14	1.94	0.33	75.41	0.74	0.16	4.08	2.56	1.01	0.31	1.11	0.12	1.53	0.24	1.28	0.01	4.99
2009	69.45	2.06	0.27	71.78	0.71	0.15	4.15	2.59	1.13	0.30	1.05	0.10	1.56	0.24	1.32	0.01	5.02
2010	72.32	2.01	0.18	74.51	0.74	0.16	3.90	2.44	0.99	0.31	1.07	0.07	1.46	0.24	1.22	0.01	4.81
2011	71.61	1.96	0.30	73.87	0.73	0.16	3.71	2.33	0.85	0.31	1.06	0.11	1.38	0.22	1.16	0.01	4.61
2012	76.24	2.44	0.28	78.95	0.79	0.17	4.09	2.56	0.97	0.33	1.15	0.11	1.52	0.25	1.28	0.01	5.06
2013	81.54	2.50	0.35	84.38	0.84	0.18	4.81	3.00	1.27	0.36	1.24	0.13	1.80	0.28	1.52	0.01	5.84
2014	87.69	2.50	0.26	90.46	0.91	0.19	4.48	2.82	1.00	0.38	1.32	0.11	1.67	0.27	1.39	0.01	5.59
2015	91.08	2.56	0.27	93.91	0.94	0.20	4.57	2.87	0.98	0.40	1.37	0.12	1.69	0.28	1.42	0.01	5.72
2016	92.47	2.48	0.32	95.27	0.96	0.20	4.63	2.91	1.00	0.40	1.39	0.12	1.72	0.28	1.43	0.01	5.80
2017	87.12	2.43	0.23	89.78	0.90	0.19	4.07	2.57	0.78	0.38	1.32	0.09	1.50	0.26	1.24	0.01	5.17

Table 2.12.2: **GHG emissions (in Gg CO_2-eq) from agriculture sector in1990 -2017 years**

Year	CH_4				N_2O													Total Agriculture sector
	Enteric fermentation (3.A)	Manure management (3.B)	Field burning of Agricultural Residues (3.F)	CH_4 total	Manure management – direct (3.B)	Manure management – Indirect (3.B)	Agricultural soils (3.D)	Direct soil emissions (3.D.a)	Synthetic fertilizers (3.D.a.1)	Organic N fertilizers (3.D.a.2)	Urine & dung from grazing animals (3.D.a.3)	Crop residue decomposition (3.D.a.4)	Indirect soil emissions (3.D.b)	Atmospheric deposition (3.D.b.1)	Nitrogen leaching & run-off (3.D.b.2)	Field burning of Agricultural Residues (3.F)	N_2O total	
1990	1,883	122	11	2,016	297	68	1,717	1,080	370	140	508	62	637	103	534	4	2,086	4,102
1991	1,749	106	9	1,864	274	62	1,509	952	303	129	467	52	557	92	466	4	1,849	3,713
1992	1,448	75	8	1,531	221	50	1,274	801	279	102	375	45	473	76	396	3	1,548	3,079
1993	1,328	63	7	1,398	204	45	1,181	741	278	92	335	36	440	71	369	3	1,433	2,831
1994	1,334	63	8	1,405	207	46	1,022	645	189	93	324	40	377	62	314	3	1,278	2,683
1995	1,368	63	8	1,439	213	47	1,103	694	235	95	327	36	409	67	343	3	1,366	2,805
1996	1,408	63	10	1,480	220	48	1,592	985	513	97	330	45	607	90	517	4	1,864	3,344
1997	1,431	63	14	1,508	224	49	1,740	1,075	580	99	330	66	666	95	571	5	2,018	3,526
1998	1,467	64	9	1,540	227	49	1,364	850	376	98	327	49	515	78	436	4	1,644	3,184
1999	1,570	70	12	1,652	244	53	1,606	997	482	105	351	58	609	90	519	5	1,908	3,560
2000	1,643	74	7	1,723	256	56	1,279	803	289	109	363	41	477	77	400	3	1,594	3,317
2001	1,656	74	12	1,743	257	56	1,413	884	349	111	371	54	530	83	447	5	1,731	3,474
2002	1,710	76	11	1,796	265	58	1,596	994	443	114	385	51	602	92	510	4	1,923	3,719
2003	1,751	79	12	1,841	272	59	1,656	1,031	462	117	395	57	625	95	530	5	1,992	3,833
2004	1,679	79	11	1,769	260	57	1,346	846	290	114	392	50	500	81	420	4	1,667	3,436
2005	1,699	76	11	1,786	262	57	1,351	849	281	113	390	65	502	80	422	5	1,675	3,461
2006	1,541	62	5	1,609	235	51	1,432	892	409	101	351	30	540	84	456	2	1,720	3,329
2007	1,496	42	6	1,544	224	48	1,203	755	285	95	339	35	448	72	376	3	1,478	3,022

Year	CH_4				N_2O													Total Agriculture sector
	Enteric fermentation (3.A)	Manure management (3.B)	Field burning of Agricultural Residues (3.F)	CH_4 total	Manure management – direct (3.B)	Manure management – Indirect (3.B)	Agricultural soils (3.D)	Direct soil emissions (3.D.a)	Synthetic fertilizers (3.D.a.1)	Organic N fertilizers (3.D.a.2)	Urine & dung from grazing animals (3.D.a.3)	Crop residue decomposition (3.D.a.4)	Indirect soil emissions (3.D.b)	Atmospheric deposition (3.D.b.1)	Nitrogen leaching & run-off (3.D.b.2)	Field burning of Agricultural Residues (3.F)	N_2O total	
2008	1,536	41	7	1,584	230	49	1,266	793	312	97	345	38	473	75	398	3	1,548	3,132
2009	1,459	43	6	1,507	220	47	1,285	802	351	93	326	31	483	76	408	2	1,554	3,061
2010	1,519	42	4	1,565	229	49	1,210	757	306	97	333	22	453	73	379	2	1,490	3,055
2011	1,504	41	6	1,551	228	48	1,151	722	264	96	328	34	429	69	359	3	1,430	2,981
2012	1,601	51	6	1,658	244	52	1,267	794	301	104	356	33	473	76	396	2	1,565	3,223
2013	1,712	52	7	1,772	261	56	1,490	931	393	111	385	41	560	88	472	3	1,810	3,582
2014	1,842	53	6	1,900	281	60	1,390	874	309	119	410	35	517	85	432	2	1,733	3,633
2015	1,913	54	6	1,972	293	62	1,416	891	304	124	425	38	525	87	439	2	1,773	3,745
2016	1,942	52	7	2,001	297	63	1,434	902	311	125	430	36	532	88	444	3	1,797	3,798
2017	1,830	51	5	1,885	280	60	1,261	796	242	119	408	27	465	79	386	2	1,603	3,488

Enteric Fermentation (3.A.)

The emissions source category "enteric fermentation" consists of the following sub-sources: cattle, buffalos, sheep, goats (multi-chamberstomachs), horses, asses, and swine (monogastricstomachs). Camels and mules are not relevant for Georgia. For 1900-2017 years period GHG emissions mainly varied according to the livestock population.

Georgian Mountain and Red Mingrelian are native cattle breeds prevailing in Georgia. Georgian Mountain and Red Mingrelian are late maturing breeds, characterized by small weight, low productivity, and high fattiness of milk. Since the 30-ies of the 20th century several high-productive early maturing breeds have been imported. According to estimations, the characteristics and accordingly the emission factors of early maturing breeds are slightly (by 3-4%) different. Therefore, averaged value of emission factors has been applied and 3 breeds have been considered: Early maturing, Georgian Mountain and Red Mingrelian. Specified data on cattle distribution by breeds are provided by Head of the Department of Zootechny of the Agrarian University of Georgia Mr. Levan Tortladze.

Manure Management (3.B.)

During handling or storage of livestock manure, both CH_4 and N_2O are emitted. The magnitude of the emissions depends upon the quantity of manure handled, the manure properties, and the type of manure management system. Typically, poorly aerated manure management systems generate large quantities of CH_4 but smaller amounts of N_2O, while well-aerated systems generate little CH_4 but larger volume of N_2O.

Agricultural Soils (3.D.)

Nitrous oxide emissions from agricultural soils consist of direct and indirect sources. Direct source emissions result from nitrogen that has entered the soil from synthetic fertilizer, nitrogen from animal manure, nitrogen from crop residue decomposition and nitrogen deposited by grazing animals on fields (pasture range and paddock). Emissions from indirect sources are emitted off site through volatilization and leaching of synthetic fertilizer and manure nitrogen.

Field Burning of Agricultural Residues (3.F.)

Burning of agricultural residues (crop residues is not thought to be a net source of carbon dioxide because the carbon released to the atmosphere during burning is reabsorbed during the next growing season). Calculations are carried out applying 1996 IPCC methodology.

Crop residue burning is a net source of CH_4 and N_2O. CH_4 and N_2O emissions from field burning of agriculture residues are not key sources for Georgia. In 1990-2017 share of methane emissions from this source in sectoral emissions was within 0.3–0.6% and share of Nitrous oxide emissions was within 0.1–0.3%. Carbon monoxide and nitrogen oxides are also emitted during field burning of crop residues.

2.13 Land use, land-use change and forestry (CRF Sector 4)

The greenhouse gas inventory in the sector has been prepared in accordance with the new 2006 IPCC Guidelines. The old (1990-2015) and the new (2016-17) emissions / absorption estimates have also been updated.

The greenhouse inventory (GHGI) for the LULUCF sector covers the following source/sink categories: 1) Forest land (5A); 2) Cropland (5B); 3) Grassland (5C); 4) Wetlands (5D); 5) Settlements (5E) and 6) Other land (5F). In this GHG inventory, emissions and absorptions have been estimated for three source/sink categories: forest land, cropland, and grassland. The above mentioned categories are the key source-categories in Georgia; in addition there is sufficient data available (e.g. databases) for carrying out calculations in these categories (unlike other source/sink categories); this allows to obtain the annual parameters for greenhouse gases emissions and absorptions in order to determine the trend of annual changes.

The calculations of emissions and absorptions in the LULUCF sector have been carried out using default values of Emission Factors (Tier I approach), which correspond to the climatic conditions of Georgia according to the methodological explanations of IPCC guidelines. Carbon dioxide emissions and absorptions for each source/sink category, as well as the total values for 1990-2017 years period are provided in the tables below. Indicators of changes in land and land use are mainly based on data from the National Statistics Office and FAOSATA. Data from the Ministry of Environment and Agriculture of Georgia and the Adjara Forestry Agency are used as well.

Table 2.13.1: Carbon Stock Changes and Net CO_2 Emissions and Absorptions in the LULUCF Sector

Year	Forest lands		Croplands				Grasslands		Net emission/absorption	
			Perennial crops		Arable lands					
	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2
1990	-1,697.5	-6,224.2	748.9	-2,746.0	77.4	-283.9	-791.2	2901.0	1,732.7	-6,353.1
1991	-1,697.7	-6,224.8	730.0	-2,676.5	114.5	-419.9	-792.5	2,905.8	1,749.6	-6,415.4
1992	-1,704.1	-6,248.4	663.4	-2,432.4	148.0	-542.6	-793.9	2,911.0	1,721.6	-6,312.5
1993	-1,701.0	-6,237.0	697.2	-2,556.4	181.5	-665.4	-793.8	2,910.5	1,785.9	-6,548.2
1994	-1,692.0	-6,204.0	695.1	-2,548.7	214.9	-788.1	-795.1	2,915.3	1,806.9	-6,625.5
1995	-1,711.6	-6,276.0	592.2	-2,171.4	201.5	-739.0	-794.5	2,913.3	1,710.8	-6,273.0
1996	-1,696.2	-6,219.5	552.3	-2,025.1	188.1	-689.8	-794.3	2,912.4	1,642.4	-6,022.0
1997	-1,677.0	-6,149.1	569.1	-2,086.7	174.7	-640.7	-794.0	2,911.4	1,626.8	-5,965.1
1998	-1,660.9	-6,089.9	477.2	-1,749.6	161.3	-591.6	-793.8	2,910.5	1,505.6	-5,520.5
1999	-1,673.7	-6,136.9	423.8	-1,553.8	147.9	-542.4	-793.5	2,909.5	1,451.9	-5,323.5
2000	-1,661.2	-6,091.0	370.5	-1,358.4	134.6	-493.7	-794.1	2,911.7	1,372.2	-5,031.3
2001	-1,666.1	-6,109.1	317.1	-1,162.6	143.3	-525.5	-793.3	2,908.6	1,333.3	-4,888.6

Year	Forest lands		Croplands				Grasslands		Net emission/absorption	
			Perennial crops		Arable lands					
	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2	Gg C	Gg CO_2
2002	-1,681.0	-6,163.7	263.8	-967.1	152.0	-557.4	-793.6	2,910.0	1,303.2	-4,778.2
2003	-1,624.4	-5,956.2	210.5	-771.7	160.7	-589.2	-793.8	2,910.6	1,201.8	-4,406.6
2004	-1,598.9	-5,862.5	156.2	-572.9	169.4	-621.1	-794.0	2,911.2	1,130.5	-4,145.3
2005	-1,499.2	-5,497.2	252.0	-924.0	178.1	-653.1	-794.1	2,911.8	1,135.2	-4,162.5
2006	-1,490.3	-5,464.5	256.2	-939.4	208.6	-764.8	-794.2	2,912.1	1,160.9	-4,256.6
2007	-1,488.5	-5,457.8	235.2	-939.4	239.0	-876.5	-794.2	2,912.1	1,189.5	-4,284.7
2008	-1,469.4	-5,387.9	243.6	-893.2	269.5	-988.2	-794.2	2,912.1	1,188.3	-4,357.2
2009	-1,546.0	-5,668.6	237.3	-870.1	300.0	-1,099.9	-794.2	2,912.1	1,289.1	-4,593.9
2010	-1,466.1	-5,375.6	235.2	-862.4	330.4	-1,211.4	-794.2	2,912.1	1,237.4	-4,537.3
2011	-1,564.6	-5,736.7	228.9	-839.3	327.3	-1,200.1	-794.2	2,912.1	1,326.6	-4,864.0
2012	-1,531.9	-5,616.9	228.9	-839.3	328.8	-1,205.6	-794.2	2,912.1	1,295.4	-4,749.7
2013	-1,580.3	-5,794.3	231.0	-847.0	301.3	-1,104.8	-794.2	2,912.1	1,318.4	-4,834.0
2014	-1,499.5	-5,498.3	231.0	-847.0	320.6	-1,175.4	-794.2	2,912.1	1,256.9	-4,608.6
2015	-1,495.7	-5,484.3	231.0	-847.0	326.6	-1,197.5	-794.2	2,912.1	1,259.1	-4,616.8
2016	-1,532.0	-5,617.4	231.0	-847.0	339.4	-1,244.4	-794.2	2,912.1	1,308.2	-4,796.6
2017	-1,521.3	-5,578.1	276.4	-1,013.4	339.4	-1,244.4	-794.2	2,912.1	1,342.8	-4,923.8

In 1990 the accumulated volume was about 6,353.1 GgCO_2, while in 2017 net emissions decreased by 23 %, amounting to 4,923.8Gg CO_2.

Forest land (4.A.)

Within the framework of this report, greenhouse gas inventories for Georgian forests were carried out on an entire forest area, regardless of forest management regime (active or passive). Specifically, the calculations include part of the forest area within protected areas where any forest use measures (e.g. Nature strict reserve IUCN category 1) are prohibited by Georgian legislation, since these areas are considered to be managed forests despite passive management. Exceptions are forests in areas not controlled by Georgia (Abkhazia, so called South Ossetia), which are not included in the calculation due to the lack of relevant data.

The aim of calculations is to elucidate what a forest is – an absorber or, on the contrary, an emitter of carbon dioxide, which determines balance of volume of reduction of biomass, the biomass growth and volume of reforestation, forest yield.

Calculations were made according to the Tier 1 approach, and calculations were made for living biomass. Calculations were not carried out in relation of dead organic material and soil carbon reservoirs. This is in line with the forest management system in Georgia, in other words in most cases clear logging does not take place in forests of Georgia and accordingly no significant changes occur in the mentioned two pools.

Cropland (4.B)

The quantity of carbon that is accumulated on croplands depends on the kinds of crops grown, the management practices (e.g. fallow lands) and climatic conditions. Harvesting of annual crops (cereals, vegetables) takes place every year, therefore, in accordance with IPCC guidelines there is no net accumulation of biomass carbon stocks. In the case of perennial crops (fruit gardens, vineyards etc.) carbon is accumulated annually, that allows accumulation of carbon stock over the long period.

Regarding carbon stock changes in soils, those depend on operating practices on cultivable lands ploughing of soil, drainage, use of organic and mineral fertilizers.

Grassland (4.C)

In accordance with the IPCC methodology Grassland comprises rangelands and pastureland that are not considered cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pasture systems, consistent with national definitions.

In this category the calculations have been conducted for the soil pool using the equation that was used for soils of arable land. The calculations have shown that the state of hay lands is stable and thus no emissions take place, whereas the areas of pastures are the source of emission.

Wetlands (4.D)

Wetlands, in their number marshes, in Georgia due to specific landscape and climatic conditions are mainly presented in Kolkheti and Javakheti, though it should be noted, that despite high anthropogenic impact, the fragments and habitats of watery areas are also preserved in Eastern Georgia. In total, wetlands cover 51,500 ha of Georgian territory.

Settlements (4.E)

Since the data needed for calculations (such as: areas covered by timber plants (ha) in all settlements (cities, villages and settlements), in all years, as well as the volume of annual accumulation of carbon in the mentioned crops (t C/year), and average age of woody plants in composition of cover (year), were not available in Georgia, the calculations were not conducted. Only limited data on planting provided in the sustainable energy action plans for several self-governed cities are available, which is not sufficient to represent and reflect the general situation in Georgia.

Biomass burning (4.V)

The calculations for this source category, based on currently available data, were only carried out in the forest land section. In particular, the magnitude of CO_2 and other greenhouse gas emissions from biomass combustion during forest fires was estimated by years.

2.14 Waste (CRF Sector 5)

Waste Management is still an environmental challenge for Georgia - poor waste management leads to one of the most important environmental problems.

Georgia makes efforts to improve the situation. In 2015 Solid Waste Management Code of Georgia entered into force. The Code aimed at establishing a legal framework in the field of solid waste management for implementing measures that will facilitate waste prevention and its increased re-use as well as environmentally safe treatment of waste (which includes recycling and separation of secondary raw materials, energy recovery from waste and safe disposal of waste).

Solid Waste Management Company of Georgia (SWMCG) intends to construct new regional landfills and systems of connected transfer stations to assure a fully integrated solid waste management system in Georgia in the future. The core mission of SWMCG is to replace all former municipal landfills over the period of about 10 years with a system of regional landfills and a network of connected transfer stations. A certain number of former municipal landfills will be closed, and some of them will be transformed into transfer stations.

Untreated municipal wastewater is a major cause of surface water pollution in Georgia. Water used in households and industry contains a huge amount of toxins that gravely degrade the natural environment, flora and fauna, and the quality of life of the population.

The centralized sewage system exists in 45 towns in Georgia. The systems are, however, in poor condition. The plants are typically 30-45 years old; some are still uncompleted, and most of them are not maintained. Most of the wastewater treatment plants cannot provide sewage treatment with high efficiency. None of the existing plants (excluding Adlia plant) provide actual biological treatment since the technical facilities are out of order.

In Adlia treatment plant wastewater is cleaned in several mechanical and chemical stages. At primary mechanical cleaning stage wastewater is cleaned of sand, fat, and residue. Silt is collected and stabilized. At biological cleaning stage ammonium transforms into nitrate and protein and hydrocarbons are reduced. At secondary mechanical cleaning silt is removed.

The estimated GHG emissions from waste sector are provided in **Error! Reference source not found.** and **Error! Reference source not found.**

Table 2.14.1: **Methane and Nitrous Oxide emissions (in Gg) from Waste sector in 1990-2017**

Year	CH_4				N_2O
	Solid Waste Disposal Sites (5.A)	Domestic W/W Handling (5.D.1)	Industrial W/W Handling (5.D.2)	Total	Domestic W/W Handling
1990	31.15	11.45	8.84	51.44	0.18
1991	32.78	11.5	5.83	50.11	0.18
1992	34.27	11.48	4.47	50.22	0.18
1993	35.63	11.22	3.34	50.19	0.19
1994	36.94	10.29	1.96	49.19	0.19
1995	38.18	9.99	2.52	50.69	0.19
1996	39.27	9.71	3.12	52.10	0.19
1997	40.25	9.46	3.76	53.47	0.18
1998	41.13	9.32	4.32	54.77	0.18
1999	41.97	9.23	4.99	56.19	0.19
2000	42.95	9.14	5.59	57.68	0.19
2001	43.82	9.06	5.78	58.66	0.18
2002	44.59	8.99	5.87	59.45	0.18
2003	45.28	8.87	6.05	60.20	0.18
2004	45.94	8.74	6.3	60.98	0.19
2005	46.62	8.61	6.53	61.76	0.18
2006	47.33	8.49	7.04	62.86	0.18
2007	48.14	8.36	7.5	64.00	0.18
2008	48.94	8.23	7.91	65.08	0.18
2009	49.71	8.19	8.8	66.70	0.18
2010	50.37	8.13	9.46	67.96	0.18
2011	50.68	8.08	10.45	69.21	0.18
2012	51.93	8	10.66	70.59	0.18
2013	52.29	7.96	10.51	70.76	0.18
2014	52.59	7.95	10.6	71.14	0.18
2015	52.80	7.97	10.91	71.68	0.18
2016	53.00	7.98	10.47	71.45	0.19
2017	53.17	7.97	10.42	71.56	0.19

Table 2.14.2: Methane and Nitrous Oxide emissions (in Gg CO_2-eq) from Waste sector in 1990-2017

Year	Solid Waste Disposal Sites-CH_4	Domestic W/W Handling-CH_4	Industrial W/W Handling-CH_4	Domestic W/W Handling-N_2O	Total
1990	654	240	186	55	**1,135**
1991	688	241	122	55	**1,106**
1992	720	241	94	55	**1,110**
1993	748	236	70	58	**1,112**
1994	776	216	41	58	**1,091**
1995	802	210	53	60	**1,125**
1996	825	204	66	58	**1,153**
1997	845	199	79	57	**1,180**
1998	864	196	91	57	**1,208**
1999	881	194	105	57	**1,237**
2000	902	192	117	58	**1,269**
2001	920	190	121	57	**1,288**
2002	936	189	123	57	**1,305**
2003	951	186	127	57	**1,321**
2004	965	184	132	58	**1,339**
2005	979	181	137	57	**1,354**
2006	994	178	148	56	**1,376**
2007	1,011	176	158	55	**1,400**
2008	1,028	173	166	54	**1,421**
2009	1,044	172	185	55	**1,456**
2010	1,058	171	199	55	**1,483**
2011	1,064	170	220	55	**1,509**
2012	1,090	168	224	56	**1,538**
2013	1,098	167	221	56	**1,542**
2014	1,104	167	223	57	**1,551**
2015	1,109	167	229	57	**1,562**
2016	1,113	168	220	58	**1,559**
2017	1,117	167	219	59	**1,562**

Solid Waste Disposal (5.A.)

Presently there are 57 municipal landfills in Georgia. Solid Waste Management Company of Georgia manages 54 landfills, 2 landfills are managed by Municipality of Batumi city in Adjara Autonomous Republic and Didi Lilo landfill is managed by Tbilisi municipality.

The methane emissions from landfills in Georgia are estimated based on the IPCC First order decay (FOD) method. The IPCC FOD method assumes that the degradable organic component/degradable organic carbon (DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are produced.

Wastewater Treatment and Discharge (5.D.)

The water used in households and industry contains a huge amount of toxins that significantly damage the environment. Wastewater handling systems transfer wastewater from its source to a disposal site. Wastewater treatment systems are used to biologically stabilize the wastewater prior to disposal. At the first stage of the wastewater treatment (primary treatment) larger solids from the wastewater are removed. Remaining particulates are then allowed to settle. At the next stage treatment comprises the combination of biological processes that promote biodegradation by microorganisms.

Sludge is produced at both stages of treatment. Sludge is produced during the primary treatment consists of solids that are removed from the wastewater. Sludge produced during the secondary treatment is a result of biological growth in the biomass, as well as the collection of small particles. This sludge should be further treated before it can be safely disposed of. Methods of sludge treatment include aerobic and anaerobic stabilization (digestion), conditioning, centrifugation, composting, and drying.

CH_4 is produced when wastewater or sludge is anaerobically treated. The methane emissions from aerobic systems are negligible. Wastewater treatment systems generate N_2O through the nitrification and denitrification of sewage nitrogen. Consumption of foodstuffs by humans results in the production of sewage. Main source of nitrogen from human sewage is protein, a complex, high-molecular-mass, organic compound that consists of amino acids joined by peptide bonds.

Assessment of CH_4 production potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater and the wastewater treatment system.

2.15 Recalculation of GHG emissions

During this inventory GHG emissions and removals were calculated using 2006 IPCC guidelines for the years 1991-1993, 1995-1999, 2001-2004, 2006-2009, 2016 and 2017, and figures were recalculated for all the previous years (1990, 1994, 2000, 2005, 2010-2015) in all sectors except for the IPPU sector where GHG emissions had been recalculated for all previous years during the last inventory.

Table 2.15.1: Difference in total GHG emissions in the latest and the previous national inventories

National GHG emissions	Emissions in Gg CO_2-eq									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Total (excluding LULUCF)-Latest data	45,813	15,745	10,923	11,168	13,688	16,027	16,927	15,964	16,861	18,214
Total (excluding LULUCF)-Previous data	45,607	15,415	10,479	10,684	13,208	15,563	16,549	15,487	16,278	17,589
Difference	**0%**	**2%**	**4%**	**5%**	**4%**	**3%**	**2%**	**3%**	**4%**	**4%**
Total (including LULUCF)-Latest data	39,461	9,121	5,892	7,006	9,151	11,163	12,178	11,130	12,252	13,597
Total (including LULUCF)-Previous data	38,768	8,685	5,472	5,926	9,595	10,490	12,738	10,750	13,780	13,707
Difference	**2%**	**5%**	**8%**	**18%**	**-5%**	**6%**	**-4%**	**4%**	**-11%**	**-1%**

More specific information on differences in results by sectors is provided below.

Energy

Table 2.15.2: Category-specific documentation of recalculations (Transport-1A3)

Transport Sector	Emissions in Gg CO_2-eq									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	3,822	1,419	945	1,537	2,580	2,563	2,672	3,301	3,735	4,139
Previous Data	3,822	1,420	945	1,537	2,601	2,585	2,690	3,380	3,758	4,162
Difference	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**-0.8%**	**-0.9%**	**-0.7%**	**-2.3%**	**-0.6%**	**-0.6%**
Documentation Reason for Recalculation: British Petroleum Georgia provided specified data of natural gas and diesel consumption which is used in the oil and gas transit pipeline substations. Also, The Ministry of Economy and Sustainable Development provided data on oil products consumption by international Bunkers (Navigation). Those data were previously unknown and aggregated in the transport sector and in recent inventory it was extracted.										

Agriculture

Table 2.15.3: Category-Specific Documentation of Recalculations (Enteric fermentation)

Enteric fermentation / CH_4	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	89.7	63.5	78.3	80.9	72.3	71.6	76.2	81.5	87.7	91.1
Previous Data	77.1	51.8	62.9	64.7	56.4	56.4	59.8	63.6	68.1	70.1
Difference	**16%**	**23%**	**24%**	**25%**	**28%**	**27%**	**27%**	**28%**	**29%**	**30%**
Documentation Reason for Recalculation: The specified data on cattle distribution by breeds has been provided by the highly experienced person Mr. Levan Tortladze - Head of the Department of Zootechny of the Agrarian University of Georgia. Emission factor for enteric fermentation significantly depends on cattle breed.										

Table 2.15.4: Category-Specific Documentation of Recalculations (Manure management)

Manure management / CH_4	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	5.8	3	3.5	3.6	2	2	2.4	2.5	2.5	2.6
Previous Data	9	5.2	6.2	6.4	4.4	4.4	5	5.2	5.5	5.6
Difference	**-36%**	**-42%**	**-44%**	**-44%**	**-55%**	**-55%**	**-52%**	**-52%**	**-55%**	**-54%**
Documentation Reason for Recalculation: In case of enteric fermentation, specified data on cattle distribution by breeds was used. More significantly, recalculations were performed applying Tier 2 approach.										

Table 2.15.5: Category-Specific Documentation of Recalculations (Manure management)

Manure management / N_2O	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	1.17	0.81	1	1.03	0.9	0.89	0.96	1.02	1.1	1.15
Previous Data	1.21	0.8	0.98	1	0.85	0.85	0.91	0.96	1.04	1.07
Difference	**-3%**	**1%**	**2%**	**3%**	**6%**	**5%**	**5%**	**6%**	**6%**	**7%**
Documentation Reason for Recalculation: In case of enteric fermentation, specified data on cattle distribution by breeds was used. Nitrogen excretion rate depends on amount of managed manure N available for soil application, i.e. on cattle breed.										

Table 2.15.6: Category-Specific Documentation of Recalculations (Direct emissions from managed soils)

Direct emissions from managed soils / N_2O	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	3.49	2.08	2.59	2.74	2.44	2.33	2.56	3	2.82	2.87
Previous Data	3.54	2.07	2.56	2.7	2.35	2.24	2.45	2.9	2.7	2.74
Difference	**-1%**	**0%**	**1%**	**1%**	**4%**	**4%**	**4%**	**3%**	**4%**	**5%**
Documentation Reason for Recalculation: In case of enteric fermentation, specified data on cattle distribution by breeds was used. Amount of animal manure applied to soils and amount of urine and dung deposited by grazing animals on pasture, range and paddock depends on cattle breed.										

Table 2.15.7: **Category-Specific Documentation of Recalculations (Indirect emissions from managed soils)**

Indirect emissions from managed Soils / N_2O	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	637	377	477	502	453	429	473	560	517	525
Previous Data	645	375	472	494	438	414	455	542	498	503
Difference	**-1%**	**1%**	**1%**	**2%**	**3%**	**4%**	**4%**	**3%**	**4%**	**4%**

Documentation Reason for Recalculation:
In case of enteric fermentation, specified data on cattle distribution by breeds was used. Atmospheric deposition of N volatilized from managed soils and Nitrogen leaching/runoff from managed soils depends on amount of animal manure applied to soils and amount of urine and dung deposited by grazing animals on pasture, range and paddock, i.e. on cattle breed.

Land-use, Land Use Change and Forestry

Table 2.15.8: **Category-Specific Documentation of Recalculations (Forest lands)**

Forest lands/CO2	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	(6,224)	(6,204)	(6,091)	(5,497)	(5,375)	(5,736)	(5,616)	(5,794)	(5,498)	(5,484)
Previous Data	(6,458)	(6,374)	(6,174)	(5,896)	(5,790)	(6,078)	(5,831)	(5,774)	(5,646)	(5,621)
Difference	**-3.6%**	**-2.7%**	**-1.3%**	**-6.8%**	**-7.2%**	**-5.6%**	**-3.7%**	**0.3%**	**-2.6%**	**-2.4%**

Documentation Reason for Recalculation:
Activity data and the emissions factors has been updated and specified.

Table 2.15.9: **Category-Specific Documentation of Recalculations (Perennial crops)**

Perennial crops/CO2	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	(2,746)	(2,549)	(1,358)	(924)	(862)	(839)	(839)	(847)	(847)	(847)
Previous Data	(2,695)	(2,417)	(1,586)	(1,163)	(924)	(655)	(963)	(1,001)	(693)	(847)
Difference	**1.9%**	**5.5%**	**-14.4%**	**-20.6%**	**-6.7%**	**28.1%**	**-12.9%**	**-15.4%**	**22.2%**	**0.0%**

Documentation Reason for Recalculation:
Activity data and the emissions factors has been updated and specified.

Table 2.15.10: **Category-Specific Documentation of Recalculations (Arable lands)**

Arable lands/CO2	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	(283)	(788)	(494)	(653)	(1,211)	(1,200)	(1,206)	(1,105)	(1,175)	(1,198)
Previous Data	(570)	(775)	(480)	(640)	(1,198)	(1,187)	(1,192)	(1,091)	(1,080)	(1,096)
Difference	**-50.4%**	**1.7%**	**2.9%**	**2.0%**	**1.1%**	**1.1%**	**1.2%**	**1.3%**	**8.8%**	**9.3%**

Documentation Reason for Recalculation:
Activity data and the emissions factors has been updated and specified.

Table 2.15.11: **Category-Specific Documentation of Recalculations (Grasslands)**

Grassland/CO2	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	2,901	2,915	2,912	2,912	2,912	2,912	2,912	2,912	2,912	2,912
Previous Data	2,800	2,813	2,810	2,811	2,811	2,811	2,811	2,811	2,811	2,811

Grassland/CO2	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Difference	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**	**3.6%**
Documentation Reason for Recalculation: Activity data and the emissions factors has been updated and specified.										

Waste

Table 2.15.12: Category-Specific Documentation of Recalculations (Emissions from Solid Waste Disposal Sites)

Emissions from Solid Waste Disposal Sites / CH4	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	31.2	36.9	42.9	46.6	48.5	49.3	49.7	50.1	50.5	50.7
Previous Data	26.6	31.6	36.4	39.2	42	42.4	42.5	42.6	42.6	42.6
Difference	**17%**	**17%**	**18%**	**19%**	**15%**	**16%**	**17%**	**18%**	**19%**	**19%**
Documentation Reason for Recalculation: Compared to previous inventory, time Delay - the period between deposition of the waste and full production of CH4 is considered. Specified data on amount of solid waste disposal on landfills was used.										

Table 2.15.13: Category-Specific Documentation of Recalculations (CH_4 Emissions from Domestic Wastewater Handling)

Domestic Wastewater Handling / CH_4	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	11.5	10.3	9.1	8.6	8.1	8.1	8	8	8	8
Previous Data	10.8	10.4	9.1	8.7	8.7	8.7	8.6	8.6	8.7	8.7
Difference	**6%**	**-1%**	**0%**	**-1%**	**-7%**	**-7%**	**-7%**	**-7%**	**-8%**	**-8%**
Documentation Reason for Recalculation: Data on rural and urban population was specified.										

Table 2.15.14: Category-Specific Documentation of Recalculations (N_2O Emissions from Domestic Wastewater Handling)

Domestic Wastewater Handling / N_2O	Emissions in Gg									
	1990	1994	2000	2005	2010	2011	2012	2013	2014	2015
Latest Data	11.5	10.3	9.1	8.6	8.1	8.1	8	8	8	8
Previous Data	10.8	10.4	9.1	8.7	8.7	8.7	8.6	8.6	8.7	8.7
Difference	**6%**	**-1%**	**0%**	**-1%**	**-7%**	**-7%**	**-7%**	**-7%**	**-8%**	**-8%**
Documentation Reason for Recalculation: Corrected data on per capita protein consumption was used										

3 Climate Change Mitigation Policies And Measures

3.1 Introduction

On September 25, 2015, just before the 21st Climate Change Conference in Paris, Georgia submitted the Intended Nationally Determined Contribution (INDC)[52] to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). According to the INDC, the country has voluntarily pledged

[52] https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx

to reduce greenhouse gas emissions by 15% by 2030 and additional 10% with financial and technological support from partner countries and donors, compared to the "traditional business" scenario. It should be noted that the 25% reduction would provide a 40% reduction by 2030 compared to the 1990 level.

In line with the requirements of the Paris Agreement, Georgia is obliged to submit a more ambitious, updated document of nationally defined contributions in 2020. The Ministry of Environmental Protection and Agriculture of Georgia has prepared an updated NDC and will submit it to the UNFCCC by the end of 2020. According to the updated NDC, Georgia makes an unconditional commitment that by 2030, national greenhouse gas emissions will be 35% lower than the 1990 levels. In the case of international support, Georgia is committed to reducing greenhouse gas emissions by 50% or 57% nationally by 2030 compared to 1990 levels if global greenhouse gas emissions follow the 2^0C and 1.5^0C scenarios, respectively.

The Ministry of Environment Protection and Agriculture of Georgia, with the technical assistance of GIZ, is preparing a Climate Action Plan (CAP), which should be an implementation plan of the NDC. The Climate Action Plan will cover the following sectors: electricity generation and transmission, transport, buildings, industry, agriculture, forestry and waste management.

Under the Paris Agreement, countries must develop and submit to the UNFCCC Secretariat a “Mid-Century, Long-Term Low Greenhouse Gas Emission Development Strategy” in 2020. This long-term strategy will be developed as part of the EU-funded EU4Climate project. The EU4Climate project aims to promote the goals and policies of the Paris Agreement and to ensure low-emission and climate-friendly development in the Eastern Partnership countries, including Georgia.

In 2016, the Georgia-EU Association Agreement entered into force, emphasizing the need for cooperation in the following areas: climate change mitigation, climate change adaptation, carbon trading, climate change integration into sectoral policies, and the development of clean technologies. The agreement also emphasizes the need for cooperation in the following areas: the National Adaptation Plan of Action (NAPA), the Low Emissions Development Strategy (LEDS), the Nationally Appropriate Mitigation Actions (NAMA) and technology transfer measures based on the assessment of technology needs assessment.

Georgia is involved in the preparation and implementation of Nationally Appropriate Mitigation Action (NAMA) projects. Within the framework of this initiative, one NAMA "Adaptive Sustainable Management in Borjomi-Bakuriani Forest District" was implemented. Two NAMAs are in the process of finding funding[53].

At the local level, 6 cities and 17 municipalities of Georgia have joined the EU initiative "Covenant of Mayors". This process is of national importance, as the signatories represent about 60% of the Georgian population and an even larger share of GDP. The signatories for the reduction of greenhouse gas emissions in their territory until 2030 by 40 % in respect to the 1990 levels. In 2014, the European Commission launched a new Covenant of Mayors initiative on climate change adaptation as part of an EU adaptation strategy aimed at involving cities in adapting to climate change. In 2015, the European Commission combined two initiatives to develop an integrated approach in the field of climate and energy.

3.2 International Market Mechanisms

Georgia, as a country not included in UNFCCC Annex I, can participate in only one of the three

[53] NAMA Registry - https://www4.unfccc.int/sites/PublicNAMA/SitePages/Country.aspx?CountryId=66

mechanisms set out in the Kyoto Protocol, namely the Clean Development Mechanism (CDM). 7 CDM projects have been registered in Georgia, the annual reduction of emissions is about 1.8 million tons of CO2[54]. Under Article 6 of the Paris Agreement, the parties have agreed to set up new market and non-market mechanisms, taking into account the experience of the CDM and will be focusing their cooperation on climate policy issues[55].

Table 3.2.1: CDM projects registered in Georgia

Year of Registration	Project Title	Reduction (T CO2 eq/tear)	Certificates issued
21 September 2009	Leak Reduction in Above Ground Gas Distribution Equipment in the KazTransgaz-Tbilisi Gas Distribution System- Tbilisi, Georgia	339,197	822,647 CER (2009-2014)
10 October 2012	Leak Reduction in Above Ground Gas Distribution Equipment in 'Socar Georgia Gas' gas distribution system, Georgia	173,651	–
17 October 2012	Georgia: Enguri Hydropower Plant Rehabilitation Project	581,715	420,103 CER (2013-2014)
1 November 2012	Adjaristskali HPP project	391,956	–
21 December 2012	Gudauri HPP project	22,891	33,030 CER (2013-2015)
17 May 2013	Dariali HPP project	259,229	256,082 CER (2016-2018)

Under Article 6 of the Paris Agreement, the parties agreed to establish new market and non-market mechanisms, taking into account the experience of existing CDM projects and focusing more on cooperation on climate policy issues[56].

3.3 Implemented, Ongoing And Planned Mitigation Measures

3.3.1 Energy Sector

The largest share of greenhouse gas emissions in Georgia (60%) comes from the energy sector, which includes greenhouse gases emitted into the atmosphere by the combustion of fossil fuels, as well as volatile emissions from coal, oil and gas extraction, processing and transportation. Emissions from the energy sector, among other sub-sectors, include greenhouse gases released into the atmosphere as a result of the burning of fossil fuels in the transport and building sub-sectors. According to the National Greenhouse Gas Inventory in Georgia, the following key source categories were identified in the energy sector (excluding the transport sub-sector): gas consumption in buildings, volatile emissions from gas distribution, gas consumption in electricity generation, fossil fuel energy consumption in the industrial sector.

On July 1, 2017, Georgia became a full member of the European Energy Union, which requires the harmonization of the country's national legislation with the EU energy legislation within a strictly defined timeframe. Commitments to promote and develop energy efficiency and renewable energy sources are key to mitigating climate change. By 2020-2030, the country should develop targets for the share of renewable energy in final energy consumption and the amount of energy saved by energy efficiency. The Ministry of

[54] Clean Development Mechanism
[55] Market and non-market based approaches in the Paris Agreement, UNFCCC.
[56] Market and non-market based approaches in the Paris Agreement, UNFCCC.

Economy and Sustainable Development of Georgia has started reforming the energy sector and developed new laws and action plans. In 2019-2020, Parliament passed the following laws: on energy and water supply, on energy efficiency[57], energy efficiency of buildings[58], and encouragement of production and use of energy from renewable sources[59].

According to the laws, the state policy on energy efficiency envisages the creation of a legislative framework for energy efficiency, the definition of a national energy efficiency target and the elimination of barriers that hinder energy efficiency and consumption and eliminate barriers to energy efficiency and consumption and achieve the target energy saving targets set out in the National Action Plan to save both primary energy sources and end-use energy.

On December 23, 2019, the Government of Georgia approved the “National Energy Efficiency Action Plan (2019-2020)” for the implementation of the energy efficiency policy by Decree N2680.

According to the 2020-2030 energy strategy, the country has the opportunity to increase the share of renewable energy sources (hydro, wind and solar), and thus reduce the share of imported electricity and generation of imported thermal power plants, thereby increasing the degree of energy independence and clean energy. In December 2019, the Law on Encouraging the Production and Use of Energy from Renewable Sources, adopted by the Parliament of Georgia, provides a legal basis for mechanisms to promote the production of renewable energy, the so-called “development of support schemes”. Such mechanisms in international practice are the "Premium Tariff", "Green Certificate", "Price Difference Agreement" and "Special Green Tariff". The purpose of these mechanisms is to facilitate the production of electricity from renewable energy sources (hydro, wind, solar). Also, according to this law, by the end of 2020 the government must approve the support schemes developed by the Ministry, which include incentives, schemes or mechanisms for the use of energy from renewable sources, including biomass, in Georgia, such as: investment assistance, tax exemption or reduction , Tax refund. By 2021, the rules for announcing and conducting a competitive auction to encourage the production of energy from renewable sources and the granting and revoking of the status of privileged producer of energy from renewable sources should be adopted.

The government adopted the "10-year Renewable Energy Development Plan" provided by law in December 2019. The National Renewable Energy Action Plan includes activities for the period 2019-2021 only. According to the action plan, small-scale heating and cooling support schemes from renewable energy sources in the country are not implemented at this stage and should be reflected in the bylaws, which are defined by law in 2020-2021.

The adoption of several strategic laws in the energy sector in 2019-2020 will in turn pose a significant challenge for the sector. Their effective implementation requires the creation of secondary legislation, which is planned for 2020-2021, institutional changes, capacity building and significant human resources. In addition, it is planned to update the already approved national energy efficiency and renewable energy action plans. Work on the Renewable Energy Action Plan is already underway and the Ministry plans to approve the plan by the end of 2020. The time frame of the plan is defined as 2021-2030. Work will also begin on the Energy Efficiency Action Plan from 2021, which will also run for 2021-2030. Both plans require expert resources, which are lacking in the Ministry of Economy. It is important to support donor

[57] Law on Energy Efficiency, 21 May 2020
[58] Law on Energy Efficiency of Buildings, 21 May 2020
[59] Law on Promotion of Production and Use of Energy from Renewable Sources, 20 December 2020

and international organizations in drafting similar strategic documents and secondary legislation for the Ministry.

The main challenge in terms of emissions in the electricity generation sector remains the low efficiency level of the existing old thermal power plants. Although 2 combined cycle stations have been added to the system in recent years and it was planned to replace inefficient old stations with new ones, due to growing electricity demand and delays in the development of new hydropower plants, it was not possible to disconnect the old stations from the system. It should be noted, however, that major generation takes place at new stations and old stations do not operate at high loads. It is planned to add two more combined cycle stations to the system and close the old stations completely, which will have a positive impact on the amount of emissions in the electricity generation sector.

In terms of emissions in the construction sector, the main problems remain: low level of energy efficiency of existing buildings, low awareness of modern renewable energy and energy efficient technologies, especially in the household sector, lack of preferential credit or co-financing programs for energy efficient and renewable energy. Prior to the enactment of the already approved law on the energy efficiency of buildings, it is necessary to develop many new secondary legislation documents. There is also a need to introduce new systems, such as an energy audit system that includes training for energy auditors, certification of energy auditors, conducting energy audits for buildings, certification of buildings, and so on. Along with the regulatory framework, it is important to strengthen capacity in the sector, both in the public and commercial sectors, and to strengthen strategic communication to ensure proper awareness of new changes in the sector and their potential impact.

Also a significant barrier is the lack of data and statistics in the construction sector. There is no unified database considering the buildings, their basic parameters (year of construction, materials used, technical characteristics), which is necessary for informed decision and policy planning in the construction sector.

In accordance with article 7, paragraph 3 of the Law on Energy and Water Supply, energy policy includes the National Energy and Climate Plan (NECP). The NECP is a new initiative of the European Union and the member states of the Energy Union are also recommended to develop a unified, integrated policy and measures for energy and climate issues at the national level. The NECP development process should be conducted in parallel with the CAP and NDC development, so it is extremely important to coordinate these processes. The NECP should cover the period 2021-2030 and include a vision for 2050 in order to be in line with the policy objectives of the European Union, the Energy Community or the UNFCCC. NECP includes 5 main areas:

- Energy security;
- Domestic energy market;
- Energy efficiency;
- Reducing greenhouse gas emissions and renewable energy sources;
- Research, innovation and competitiveness.

The NECP fully relies on and reflects the state measures that will form the basis of the relevant energy policy strategy. Georgia must submit an integrated plan to the Energy Union Secretariat by the end of 2020.

Table 3.3.1.1: Implemented, ongoing and planned mitigation measures in the energy sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented (2013-2016)	**Title**: Construction of the first wind power plant **Objective**: To develop generation from renewable energy sources **Implementation level**: National	**Budget**: 31.2 million. dollar **Source of financing**: (70% - loan, 30% - mobilized by "Qartli Wind Farm" partners) **Implementer:** Qartli Wind Farm Ltd	An average of 8.5 Gg of CO2 per six years.	The annual potential depends on the amount of energy generated by the station in a particular year. National Grid Emission Factor (tons of CO2 eq/MWh) by years: 2016 - 0.093 2017 - 0.094 2018 - 0.082 2019 - 0.126	The station operated in test mode in 2016. It was put into operation in 2017	Reduced emissions: 2016-0.8 Gg; 2017 -8.25 Gg, 2018-6.9 Gg., 2019- 10.7 Gg.	**Socio-economic benefits:** 35 jobs created. The availability of a new generation source has reduced dependence on imported electricity.
2	Implemented (2017-2020)	**Title:** Construction of Combined Cycle Thermal Power Plants Gardabani 1 and 2 **Objective**: To reduce gas consumption and corresponding emissions for electricity generation. **Implementation level**: National	**Budget**: $ 230 million Gardabani for 1 thermal power plant. $ 185 million Investment - Gardabani 2 **Source of funding**: Gardabani 1- Georgian Gas and Oil Corporation, Partnership Fund. **Implementer**: Chalik Energy - Gardabani 1 Gardabani 2 was implemented by the Georgian Gas and Oil Corporation.	An average of 200 bg of CO2 per six years. The annual reduction depends on the output of a particular year an the emission factor of the same year.	The resources required for the actual output of the stations are compared to the resources of the existing inefficient Tbilissi thermal power plant. The efficiency of the combined cycle power plant is 54%, the efficiency of other existing thermal power plants is 31-33%. National Grid Emission Factor (tons of CO2 eq/MWh) by years: 2016 - 0.093 2017 - 0.094 2018 - 0.082 2019 - 0.126	Gardabani 1 station has been built and has been operation since 2017 Gardabani 2- has been i operation since 2020	Reduced emissions: Gardabani 1 2016-108 Gg; 2017-110 Gg; 2018-147 Gg; 2019-255 Gg. Gardabani 2 Generation of Gardabani 1 for 2018-2019 is taken for evaluation. 2018 saved 147 Gg, in 2019 -255 Gg	**Environmental benefits:** Gas consumption is sharply reduced in the electricity generation sector and consequently the amount of emissions. **Social benefits**: Creation of additional jobs (Gardabani 1 employs 153 people) Also, the electricity generated by this station is more cost-effective and therefore the consumption of imported fuel becomes more rational.
3	Implemented (2010-2016)	**Title:** Preferential credit line "Energocredit" for investment in renewable and energy efficient technologies (household and commercial sector). **Objective**: To increase access to renewable and energy efficient technologies (reduce capital expenditures) and to promote **Implementation level**: National	**Budget:** $ 63.11 million issued by participating banks in the form of soft loans (subsidies). Program **Funding source**: European Bank for Reconstruction and Development (EBRD). **Implementer**: All major commercial banks were involved in the implementation of the program: TBC; Bank Republic; Bank of Georgia, Credo, Base Bank.	168 Gg CO2 eq.	The data is provided by Energocredit in the form of a reduced emission amount. Internal methodology was used.	The program was implemented in 2010-2016.	Since 2016, 168 Gg of CO2 eq. Decreases from projects implemented annually.	**Environmental benefits:** The introduction of renewable energy and energy efficient technologies has reduced fossil fuel consumption and harmful emissions into the atmosphere. **Social benefits**: Renewable and energy efficient technologies have not only helped beneficiaries reduce energy consumption, but also improved their living conditions and comfort levels. There was also support for local businesses, increased sales of products from companies participating in the program (energy efficient and renewable technology dealers) and their promotion.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
4	Implemented (2012-2016)	**Title:** Establishment of the Climate Change Financial and Technology Transfer Center (FINTEC). **Objective**: To support the industrial and commercial sectors in equipping themselves with energy efficient and renewable energy technologies in order to reduce emissions, energy and water consumption and also to increase the efficient use of resources. **Implementation level**: National	**Budget:** $ 88 million. This is an international program and funds are distributed according to countries and regions. The amount allocated to Georgia depends on the number of applications made by commercial and industrial facilities. **Funding source**: GEF **Implementer**: European Bank for Reconstruction and Development (EBRD)	7.5 Gg. CO2 eq. Annually.	The annual potential of greenhouse gas emissions is calculated according to the internal methodology within the program.	8 projects were implemented in Georgia with the support of the program.	As a result of the implemented projects, 7.5 g of CO2 are saved per year from 2017.	**Social benefits:** promotion of local businesses and economy, introduction of modern green technologies, energy saving, efficient use of resources.
5	Implemented (2012-2017)	**Title:** Use of efficient wood stoves and solar panels within villages under NAMA. **Objective**: Introduction of renewable and energy efficient technologies in rural settlements **Implementation level**: Regional	**Budget:** NAMA was not initially approved on a large scale and budget and therefore the project was implemented with the help of various donors on a small scale. About 10,000 euros a year **Source of funding**: Various donors **Implementer**: WECF and the Green Movement	0.874 Gg CO2 eq. annually. In case of full implementation of the NAMA project, 30 Gg of CO2 eq. Annually until 2023, 157 Gg CO2 eq. until 2039.	The introduction of energy-efficient wood stoves on an existing scale saves an average of 2 tonnes of CO2 per year, while a solar water heater reduces emissions by an average of 1 tonne per year.	Since 2012, 642 solar water heaters have been installed, 91 energy efficient stoves and 50 buildings have been heated.	According to the monitoring results, a total of 874 tons of CO2 per year was saved by all measures.	**Environmental benefits:** The introduction of efficient wood stoves helps to reduce pressure on forests and improve indoor air quality. **Social benefits:** Development of regions, efficient use of resources, energy saving, improvement of living conditions for the local population, promotion of renewable and efficient technologies
6	Implemented (2010-2019)	**Title:** Construction of hydroelectric power plants in Georgia **Objective:** To harness the local potential of renewable energy. Measures and integrates stations built in 2010-2020. **Implementation level:** National	**Budget:** Unknown **Source of funding**: All stations were mostly built with foreign and local private investment. **Implementer**: Various local and foreign development companies	200 Gg CO2 eq. on average annually.	National Grid Emission Factor (tons of CO2 eq / MWh) by years: 2019 - 0.126	A total of 44 new hydropower plants were built in 2010-2020 (29 stations in 2010-2017; 15 stations in 2018-2020).	Using the 2019 emission factor, 191 Gg of CO2 was saved. In 2019, the output of all new plants (built in 2010-2020) was 1,519 GWh;	**Socio-economic benefits:** Technological development, creation of additional jobs (especially in the regions), development of regions (construction of a hydropower plant requires appropriate infrastructure (eg roads) which will remain in the use of the municipality)
7	Implemented (2015-2016)	**Title:** Installation of solar PV panels in 'Iliauni' and Tbilisi International Airport. **Objective**: Introduction and popularization of renewable energy (demonstration project) **Implementation level**: Local	**Budget:** $ 4.8 million. **Funding Source**: Government of Japan (Grant) **Implementer**: Itochu Corporation, Fuji Furukawa Engineering & Construction Co.Ltd. Ltd. "Grusia".	0.06 Gg CO2 eq. annually.	National Grid Emission Factor (tons of CO2 eq / MWh) by years: 2016 - 0.093 2017 - 0.094 2018 - 0.082 2019 - 0.126	The system is installed i Iliauni and at the international airport. Power at the airport increased slightly from 316 kW to 325 kW.	The reduction in emissions from the generation of the panel installed at Iliauni and the airport is about 57 tons of CO2 eq. per year.	**Social benefits:** Promotion of renewable and modern technologies.
8	Ongoing (from 2018)	**Title:** Improving Energy Efficiency in Public Buildings. **Objective**: To improve the energy efficiency of public buildings (27 public buildings across the country, mainly schools) and to introduce renewable energy technologies in the selected buildings **Implementation level**: Regional	**Budget:** 5.14 million euros. **Funding source:** NEFCO, E5P and the Danish Ministry of Foreign Affairs **Implementer**: Municipal Development Fund	1.1-1.4 Gg CO2 eq. per year.	The reduction potential is assessed by the project's internal methodology.	Is in the stage of tenders and contracts. Physical work has not yet begun due to the pandemic.	NA	**Social benefits:** Rehabilitated public buildings and increased comfort levels, reduced energy consumption and the promotion of energy efficient and renewable energy technologies.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
9	Ongoing (from 2019)	**Title:** Construction of the first solar power plant in the village of Udabno. **Objective**: To develop renewable energy and reduce dependence on imported energy **Implementation level:** National	**Budget:** $ 4.5 million **Source of funding**: Foreign investment. **Implementer**: Georgian Solar Company, a company founded by the Georgian Energy Development Fund, which owns 90% of the station's shares.	0.87 Gg CO2 eq. per year.	National Grid Emission Factor 2019 - 0.126 tons of CO2 eq / MWh. Estimated annual output is 6.9 million kWh	Construction was scheduled to begin in the fall of 2019, but due to financial problems, construction could not start on time.	NA	**Social benefits:** Creating new jobs, utilizing local renewable resources and reducing imports, technological development, stimulating the local economy (eg solar PV panel manufacturers, dealers and service companies)
10	Ongoing (from 2020)	**Title:** Rehabilitation of 26 public buildings and improvement of energy efficiency in Batumi. **Objective**: To improve energy efficiency in public buildings (25 gardens and 1 historic building) **Implementation level**: Local	**Budget:** 5.7 million euros. **Funding source**: German Development Bank KfW. Co-financing 10% by Batumi Municipality **Implementer**: Consulting company Fichtner	0.063 Gg CO2 eq. per year.	The project aims to reduce energy (gas) consumption in gardens by at least 20%. The average annual gas consumption of each garden is 6,500 m3. In case of reduction of consumption by 20%, 1,300 m^3 of garden will be saved.	The consultant is being contracted at this stage.	NA	**Social benefits:** Development of local energy efficient construction market, introduction of energy saving and energy efficient technologies and popularization of construction practices.
11	Ongoing (from 2019)	**Title:** Construction of new hydropower plants **Objective**: To develop local renewable resources **Implementation level:** National	**Budget:** $ 543 million. **Source of funding:** Private investments **Implementer**: Local and foreign developer companies.	189.9 Gg CO2 eq. annually.	National Grid Emission Factor 2019 - 0.126 tons of CO2 eq/MWh. Estimated annual output is 1,507 GWh.	Of the signed memoranda, 22 stations are under construction, their total capacity is 323 MW.	NA	**Social benefits:** New jobs, infrastructure development (construction of access roads to the station, communications, etc.); Promoting the local economy, introducing modern technologies.
12	Ongoing (from 2019)	**Title:** Construction of 2 new wind power plants **Objective**: To develop local renewable energy potential **Implementation level:** National	**Budget:** $ 135 million **Source of funding**: Private investment **Implementer**: Development companies	43 Gg CO2 eq. annually	National Grid Emission Factor 2019 - 0.126 tons of CO2 eq/MWh. Estimated annual output is 342 million kWh.	The Georgian government has approved a project to build wind farms near Tbilisi and Kaspi. Construction is scheduled for completion in 2022.	NA	**Social benefits:** Creating new jobs, introducing new technologies, reducing the share of imported energy and enhancing energy security.
13	Ongoing (from 2016)	**Title:** Net Accounting Software **Objective**: To promote the development of renewable energy technologies **Implementation level**: National	**Budget:** NA **Implementer**: Initiated by GNERC.	0.374 Gg CO2 eq. annually	he average working hours for a solar anel in Georgia is 1,350 hours per ear. National Grid Emission Factor 019 - 0.126 tons of CO2 eq/MWh.	180 solar panels with a total capacity of 2.2 MW have been put into operation since the enactment of the net metering regulation (as of the beginning of 2020).	The average annual generation is 2,970 MWh. In 2019, greenhouse gas emissions were reduced by 374.2 tons of CO2 eq.	**Social benefits:** Promotion of modern renewable energy technologies and market development, utilization of local renewable resources and reduction of imported energy, stimulation of local economy (by developing solar panel market)

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
14	Planned (2020-2030)	**Title:** Construction of 5 solar power plants. **Objective**: To develop local renewable energy potential. **Implementation level**: National	**Budget:** to be specified after completion of the excavation phase **Funding source**: Private and foreign investment	16.6 Gg CO2 eq. annually.	Total capacity of 5 stations 93 MW, output 132 000 MWh. National Grid Emission Factor 2019 - 0.126 tons of CO2 eq/MWh.	The projects are in the research stage	NA	**Social benefits:** Utilization of local renewable potential, increase of the share of renewable energy in the energy balance, reduction of imported energy, creation of new jobs, development of the market of local renewable technologies
15	Planned	**Title:** Construction of hydroelectric power plants in Georgia **Objective**: To harness the local potential of renewable energy. Stations under construction licensing stage are reviewed (26 in total). **Implementation level:** National	**Budget:** $ 389 million. **Source of funding**: private and foreign investment **Implementer**: Local and foreign development companies	135.2 Gg CO2 eq. annually	The total planned output of 26 stations is 1,073 GWh. National Grid Emission Factor 2019 - 0.126 tons of CO2 eq / MWh.	These stations are in the process of licensing and obtaining a construction permit. The total capacity of the stations is 240 MW.	NA	**Social benefits:** Utilization of local renewable resources, reduction of imported energy, development of regional infrastructure (at the locations of planned stations), creation of new jobs, encouragement of the local economy, development of professional staff
16	Planned (2021-2020)	**Title:** Installation of energy efficient lighting in public buildings **Objective**: To save energy in public buildings **Implementation level:** National	**Budget:** 157,000 Euros (according to NEEAP) **Source of funding**: State budget **Implementer:** Ministry of Economy and Sustainable Development. Ministry of Regional Development and Infrastructure and Municipalities	0.176 Gg CO2 eq. annually.	Estimated savings are at 1.4 GWh by 2030. National Grid Emission Factor 2019 - 0.126 tons of CO2 eq / MWh.	This measure is implemented in stages, with the goal of -100% replacing inefficient lighting by 2022.	NA	**Environmental benefits:** Energy savings will reduce emissions of harmful substances into the air from thermal power plants. **Social benefits:** Demonstrate and popularize effective technologies; Save energy costs, encourage the production of local energy efficient lighting technologies
17	Planned (2021-2022)	**Title:** Tightening Customs Regulations on Inefficient Lighting Technologies **Purpose**: Complete replacement of Varvara lamps with efficient technologies **Implementation level:** National	**Budget:** 4.1 million euros (according to NEEAP). The budget is estimated according to the resources needed by the household and private sector to acquire new technologies. **Implementer**: Ministry of Economy Partner: Customs Department, Municipalities, Private Sector	6.1 Gg CO2 eq. by2030	Energy saving capacity 48.7 GWh per year by 2030. National Grid Emission Factor 2019 - 0.126 tons of CO2 eq / MWh.	Tightening customs regulations is being considered by the government	NA	**Environmental benefits:** Energy savings reduce emissions of harmful substances into the air from thermal power plants. **Social benefits:** Encourage the production of local energy efficient lighting technologies, introduce modern energy efficient technologies.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
18	Planned (2021-2023)	**Title:** Measures to Improve Energy Efficiency in Public Schools **Objective**: To save energy in public buildings **Implementation level:** National	**Budget:** 2.477 million euros Source of funding: International donor organizations **Implementer**: Ministry of Economy and Sustainable Development Partner: Ministry of Education, Ministry of Infrastructure	0.77 Gg CO2 eq. annually.	The methodology and assumptions were developed by the team working on the Climate Action Plan.	The implementation of the measure depends on donor funding, no amount is allocated from the state budget for this event.	NA	**Environmental benefits:** Energy savings reduce emissions of harmful substances into the air. **Social benefits:** Energy saving in public buildings (schools), promotion of energy efficient measures, improvement of learning environment (comfort).
19	Planned (2021-2023)	**Title:** Financial Support Measures and Awareness Programs to Encourage the Use of Solar Water Heaters in Buildings **Objective**: To promote the introduction of renewable energy technologies, reduce gas consumption **Implementation level:** National	**Budget:** Unknown **Source of funding:** Depends on the amount of assistance available. **Implementer**: Ministry of Environment and Agriculture	18.7 Gg CO2 eq. annually.	The methodology and assumptions were developed by the team working on the Climate Action Plan.	The implementation of the event depends on donor funding, no funds are allocated from the state budget for this event.	NA	**Environmental benefits:** Energy savings reduce emissions of harmful substances into the air. **Social benefits:** Introduce modern renewable energy technologies, develop the local market for solar water heaters and create new jobs.
20	Planned (2022-2023)	**Title:** Construction of 2 new combined cycle thermal power plants Gardabani 3 and 4 **Objective:** To close old, inefficient thermal power plants and replace them with efficient thermal power plants **Implementation level:** National	**Budget:** Confidential **Funding source:** Unknown **Implementer**: Gardabani 3- Gas and Oil Corporation Gardabani 4- will be selected on the basis of tender	On average 510 Gg CO2 eq. annually.	Generation of Gardabani 1 in 2019. National Grid Emission Factor 2019 - 0.126 tons of CO2 eq / MWh.	Technical-economic study of the stations is planned.	NA	**Environmental benefits:** Shutting down inefficient thermal power plants and reducing harmful emissions and gas losses. **Social benefits**: creation of new jobs, introduction of modern technologies in the electricity generation sector.

3.3.2 Transportation Sector

Georgia is located at the crossroads of Europe and Asia, where strategic cargo is transported. The country's economic growth and sustainable development largely depends on the effective use of its potential as a transit country. Since the 1990s, the function of Georgia as one of the sections of the Europe-Caucasus-Asia transport corridor has increased significantly. This leads to the need to create a quality transit infrastructure in Georgia.

The number of vehicles registered in Georgia is characterized by an increasing trend. The number of vehicles in 2018 has increased by 55% compared to 2007. Within the country, up to 25 million tons of cargo (approximately 59.9 percent of the total cargo transported) is transported annually by road and about 260 million passengers are transported. International shipments are large. Annual shipments in 2011-2018 were in the range of 30 million tons. In 2018, international shipments increased slightly compared to the previous year, amounting to 31.1 million tons. Due to such volumes, the load on the main roads is large.

Georgia's transport sector is growing rapidly and unsustainably. Most of the car fleet in the country is old and faulty private vehicles. In addition, the share of modern technologies and public transport in the sector is small. The fleet growth factor is important, which is directly related to the increase in emissions. The car fleet has doubled in the last 10 years, which is quite alarming, and does not indicate a focus on public transport.

In 2015-2030, passenger activity could increase by 50%, while truck activity by 120%. This difference between the growth trends is due to the fact that GDP growth has a stronger impact on trucks compared to passenger transport, as well as the geographical location of Georgia. International factors such as the demand for efficient international travel and trade between Central Asia and Europe contribute to the growth of Georgia's freight transport activity.

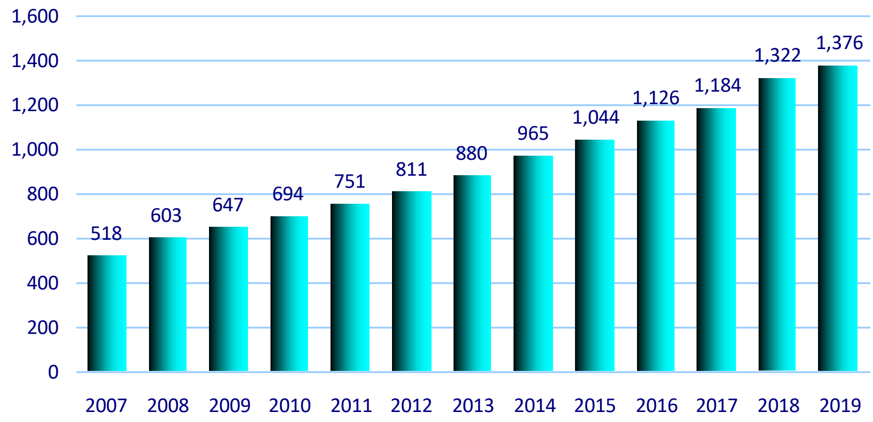

Figure 3.3.2.1: Growth dynamics of the number (in thousands) of vehicles registered in Georgia 2007-2019

Within the country, up to 25 million tons of cargo is transported annually by road (about 59.9 percent of the total cargo transported) and about 260 million passengers travel.

International shipping is large. Annual shipments in 2011-2018 were in the range of 30 million tons. In 2018, international shipments increased slightly compared to the previous year, amounting to 31.1 million tons. Due to this volume, there is a large load on the main roads.

There is no vision for the transport sector in the country as a unified system and a strategy for its development at the national level. The standards in the sector are very scarce and the standards of different countries are being used, which makes the situation in the sector more and more complicated and obscure.

Only at the level of individual municipalities are strategically correct steps taken and the principles of sustainable development introduced. The bus fleet has been renovated and policy and strategy documents have been developed to help increase public transport system and non-motorized transport consumption. These documents are:

1. Tbilisi Sustainable Urban Transport Strategy
2. Tbilisi Sustainable Urban Mobility Strategy (under development)
3. Rustavi bicycle travel strategy
4. Bakuriani Multimodal Transport Strategy (under development)
5. Regional General Scheme of Low Emission Public Transport in the Autonomous Republic of Adjara
6. Batumi Integrated Sustainable Urban Mobility Plan
7. Sustainable Transport Development Strategy and Action Plan of Khulo Municipality
8. Sustainable Transport Development Strategy and Action Plan of Keda Municipality
9. Sustainable Transport Development Strategy and Action Plan of Kobuleti Municipality
10. Sustainable Transport Development Strategy and Action Plan of Shuakhevi Municipality
11. Sustainable Transport Development Strategy and Action Plan of Khelvachauri Municipality.

Tbilisi Sustainable Urban Transport Mobility Plan will be a 15-year, time-bound document detailing all aspects of transport development: public and private transport, distribution of vehicles and bicycles, parking, and pedestrians. Based on this document, it will be possible to develop the transport infrastructure of Tbilisi in accordance with the standards and modern requirements, which will allow each citizen to use sustainable urban transport, less - private car and travel as safe and comfortable as possible.

The goal of Bakuriani Multimodal Transport Strategy is to improve mobility in the project area - especially during the winter season. By developing a flow and parking management strategy, and regulating the intermodal nodes of intersections, a rapid transit system will be developed and access and connections to ski lifts will be improved.

Also noteworthy is the current National Road Safety Strategy of Georgia, which defines the main directions of successful and sustainable road safety management in Georgia in the long run.

Projects that have significant potential for mitigation are fragmented, but in the absence of systemic visions, some of them stall in the final stages of development and its future becomes blurred. This is the Tbilisi Bypass Railway project, which started in 2010. More than half of the work (65%) has been completed, 213 million Swiss francs have been spent, but after 8 years the work was stopped, the reason being the flaws identified in the project.

Unlike the Bypass Railway Project, 175 Euro5 buses are being successfully launched in 6 large municipalities with the help of the European Bank for Reconstruction and Development. In 2020-2022, the project will organize and strengthen transport bodies / agencies and legislative regulations.

It is planned to develop a 2.7-kilometer Samgori-Vazisubani cable car, which aims to connect the densely populated Vazisubani settlement (more than 40,000 inhabitants) with the Samgori metro. The population will have direct access to the agrarian market and the transport hub through the ropeway. Changing the type of vehicle using more environmentally friendly and cleaner public transport will significantly relieve the existing transport system, leading to a reduction in air pollutants and greenhouse gas emissions.

Georgia has introduced tax breaks since 2018 to stimulate imports of electric and hybrid vehicles. In particular, in the case of the purchase of a hybrid vehicle, the excise tax was reduced by 50% (for vehicles older than 6 years) and 60% (for vehicles newer than 6 years). However, excise taxes will be completely abolished (100% reduction) in case of purchase of an electric vehicle. This has significantly increased the share of hybrid vehicles in imported vehicles (from 5.5% in 2016 to 34.8% in 2018)[60].

On December 1, 2017, the Government of Georgia adopted a Resolution on Periodic Technical Inspection of Vehicles[61]. The decree entered into force in 2018 and aims to establish a unified organizational-technical and normative basis for periodic technical inspections of vehicles, to ensure the safety of vehicles and to reduce traffic jams caused by their technical malfunction, minimize damage to the system, reduce human and environmental damage, through regular inspections and decommissioning of vehicles that are major contaminants.

According to the updated National Document of Contribution (NDC), Georgia plans to reduce greenhouse gas emissions by 15% by 2030 compared to baseline forecasts in the transport sector. According to the Climate Action Plan of Georgia, in the traditional development scenario for 2030, the forecast rate of greenhouse gas emissions from the transport sector is 7,110 Gg CO2 eq, with the introduction of mitigation policies and measures it will be possible to reduce emissions to 6,044 Gg CO2 eq. In the case of international aid, emissions will be reduced by an additional 5,569 Gg of CO2 eq. The main mitigation measures in the action plan are: renewal of the vehicle fleet by removing old and low-efficiency vehicles, introduction of tax incentives for electric and hybrid transport, increase of taxes on fossil fuels, incentives for public transport, tax exemption, bio-tax incentives.

Due to Georgia's unique location, international transit is an important commercial opportunity, and the development of relevant infrastructure is a top priority for international transit.

A detailed description of the completed, ongoing and planned mitigation measures in the transport sector is presented in the table below.

[60] Vehicle Fleet, Ministry of Internal Affairs, 2019.
[61] Resolution of the Government of Georgia N510, December 1, 2017.

Table 3.3.2.1: Implemented, ongoing and planned mitigation measures in the transport sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented 2016-2018	**title:** Biodiesel production in Georgia - "Biodiesel Georgia" Ltd **Purpose**: Reducing emissions by replacing petroleum biodiesel with biodiesel **Implementation level**: National	**Funding source:** Private investment **Implementer**: Ltd. Biodiesel Georgia Other partner organizations: Ministry of Internal Affairs; Georgian Biomass Association	32 Gg CO2 eq. annually by 2030	Using one ton of biodiesel instead of one ton of biodiesel saves 2.67 tons of carbon dioxide emissions into the atmosphere.	In July 2018, the enterprise "Biodiesel Georgia" Ltd (www.gbd.ge) was opened. After the test period, the plant reached the production of 10 tons of biodiesel per month. Products are sold in various networks of gas stations, in the form of 10% impurity in mineral diesel, under the brand name "B10 Biodiesel".	Greenhouse gas emissions have been reduced annually: 2018 - 0.48 Gg CO2 eq. 2019 - 0.63 Gg CO2 eq.	**Environmental benefits:** Emissions of harmful substances into the environment from road transport have been reduced. **Social benefits**: New jobs will be created. Worked oils from food establishments will be collected and processed.
2	Implemented 2015-2017	**title:** Urban mobility - expansion of the metro in Tbilisi. **Objective:** To expand the Tbilisi metro system with one additional station. **Implementation level** - local	**Budget:** 31.2 million euros **Funding source**: Asian Development Bank (ADB) **Implementer**: Municipal Development Fund	503 Gg CO2 eq. annually by 2030	The final energy savings were calculated based on the change in modality from individual vehicles to subway, based on the amount of energy consumption per 1000 passengers-km. A typical passenger travels 6.4 km. 28.16 million passengers per kilometer will be transported annually from personal vehicles to the subway.	The new metro station has been in operation since 2017.	The distance of the route has increased by 1.5 km and it is expected that this expansion will increase the number of passengers on the metro network by 4.4 million annually. The annual reduction in greenhouse gas emissions could not be calculated due to the lack of statistics.	**Environmental benefits:** Emissions of harmful substances into the environment from road transport have been reduced. **Social benefits**: New jobs created. A public transport system was developed. Increased economic activity in the vicinity of the metro station.
3	Implemented 2007-2019	**title:** Baku-Tbilisi-Kars railway project. **Purpose**: Replacement of freight transportation by rail. Rail transport will replace road freight. **Implementation level** - National	**Budget:** $ 1 billion **Source of funding**: Baku State Oil Fund (SOFAZ) **Implementer**: Georgian railway	23 Gg CO2 eq. annually by 2030	Monitoring of ton-km/year information in freight transport, provided by Georgian Railway Ltd. For the initial phase, the line envisages transportation of 6.5 million tons per year, which in the long run will increase the target to 17 million tons. The project also envisages the transportation of more than 1 million passengers.	The Georgian section of the railway project has been completed, it will be put into operation as soon as the construction works on the Turkish section are completed. The new railway line will handle all types of cargo.	Reduction of greenhouse gas emissions will be calculated as soon as the entire project section is put into operation.	**Environmental benefits:** Emissions of harmful substances into the environment from road-freight transport have been reduced. **Social benefits**: New jobs will be created. Increased economic activity in the vicinity of railway stations.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
4	Ongoing –2011-2020	**title:** Expansion and modernization of the Georgian Railway. **Purpose**: Increase the possible throughput of the railway line **Implementation level** - National	**Budget:** 147,384 million euros **Funding source:** Georgian railway **Implementer**: Georgian railway	46.2 Gg CO2 eq. annually by 2030	Energy savings are due to the switchover of freight transport by rail to railways. Based on the information provided by the Georgian Railway - monitoring of cargo per ton-km/year.	Currently, 86% of the total work is completed. Part of the project, which dealt with the modernization of railway infrastructure along the line and the construction of three tunnels.	Reduction of greenhouse gas emissions will be calculated as soon as the railway expansion works are completed.	**Environmental benefits:** Emissions of harmful substances into the environment from road-freight transport have been reduced. **Social benefits**: New jobs will be created.
5	Ongoing-2017-2021	**title:** Measures to improve the transport system in Tbilisi **Purpose**: Improving the current transport and environmental situation, replacing the consumption of private cars with public transport. **Implementation level** - local	**Budget:** 27.5 million euros **Funding source:** European Bank for Reconstruction and Development (EBRD) **Implementer**: Tbilisi Municipality Government and Other partner organizations: Tbilisi Transport Company; Tbilisi minibus; Tbilisi Parking	100 Gg CO2 eq. annually by 2030	The final energy savings are calculated based on the energy saved as a result of replacing diesel buses with new, efficient CNG buses. Total final energy consumption savings are calculated based on the total market potential (number of buses replaced) over time.	In 2017, 143 MAN CNG buses were brought to Tbilisi; 310 buses will be added to Tbilisi in 2019. 10 main corridors have been identified and bus lanes are being marked in stages.	Reductions in greenhouse gas emissions will be calculated as soon as the project is completed and statistics collection begins.	**Environmental benefits:** Emissions of harmful substances into the environment from road transport have been reduced. **Social benefits**: new jobs will be created. The number of road accidents will be reduced.
6	Ongoing 2019-2022	**title:** Measures to be taken to improve the transport system in Batumi **Purpose**: Improving the existing transport and environmental situation, replacing the consumption of private cars with public transport. **Implementation level:** Local	**Budget:** 2.5 million euros **Funding source:** European Bank for Reconstruction and Development (EBRD) **Implementer**: Batumi Municipality Government	7 Gg CO2 eq. annually by 2030	Reduction of greenhouse gas emissions is calculated on the basis of energy saved as a result of replacing obsolete diesel buses with new, efficient Euro-5 diesel and electric buses.	40 diesel and 10 electric buses have been purchased, and a pilot project is underway to separate the bus lane on Chavchavadze Street.	Reductions in greenhouse gas emissions will be calculated as soon as the project is completed and statistical data is collected.	**Environmental benefits:** Emissions of harmful substances into the environment from road transport have been reduced. **Social benefits**: new jobs will be created. The number of road accidents will be reduced.
7	Ongoing 2019-2021	**Title:** Improving the capacity, quality and efficiency of public transport systems and non-motorized vehicles **Purpose:** Improving the existing transport and environmental situation, replacing the consumption of private cars with public transport. **Implementation level:** Local (Zugdidi, Rustavi, Kutaisi and Gori)	**Budget:** 18.7 million euros **Funding source**: European Bank for Reconstruction and Development (EBRD) **Implementer**: Municipal government	141 Gg CO2 eq. annually by 2030	Reduction of greenhouse gas emissions is calculated on the basis of energy saved as a result of replacing obsolete diesel buses with new, efficient Euro-5 diesel and electric buses.	175 buses have already been purchased, the winner company will be identified which will determine the strategy of redistribution of these buses on different routes and also a transport authority will be formed in 6 cities which will continue to operate buses in the future.	Reductions in greenhouse gas emissions will be calculated as soon as the project is completed and statistical data is collected .	**Environmental benefits:** Emissions of harmful substances into the environment from road transport have been reduced. **Social benefits**: new jobs will be created. The number of road accidents will be reduced.

3.3.3 Industry Sector

During the chemical and physical processing of raw materials in the industry sector, technological processes are accompanied by the release of significant amounts of carbon dioxide and other greenhouse gases into the atmosphere. According to the latest report of the National Greenhouse Gas Inventory in Georgia, the following key source categories were identified in the industrial processes sector: cement production, iron and steel production, ferroalloy production, ammonia production, nitric acid production. At this stage, non-energetic emissions of greenhouse gases can be reduced in the following three sectors: cement production, ammonia production, and nitric acid production.

The industrial sector is also rich in greenhouse gases emitted into the atmosphere by the combustion of fossil fuels for energy purposes, which are registered in the energy sector according to the IPCC 2006 guidelines. Key sources in this regard are the production of non-metallic mineral products (the most energy-intensive of the various types of production in this category are: cement production, glass container production, brick and block production, lime production), iron and steel production, food industry, and construction.

HeidelbergCement is the largest company in the non-metallic construction materials production sector in Georgia, which owns three cement plants - one in Kaspi and two in Rustavi. The company can produce 2 million tons of cement and 1.4 million tons of clinker annually. Reconstruction of the Kaspi plant is currently underway. The maximum production of clinker reached 3,500 t/day. The plant produces clinker by the dry method of processing raw materials, which is the most energy efficient process in clinker production. The dry method of making clinker has given the company significant emission savings for energy purposes as it no longer needs to evaporate water from a raw suspension. The company also plans to reduce emissions for non-energy purposes by using other additives that do not emit carbon dioxide instead of limestone in the production of clinker and cement.

There are 4 enterprises in the production of ferroalloys - Georgian Manganese (same as Zestaponi Ferroalloy Plant), Chiatura Manganese[62], Russmetal[63] and GTM Group[64]. Zestaponi Ferroalloy Plant is the largest producer of silicomanganese in the region. Its annual production is 185,000 tons per year. Measures to reduce energy emissions are planned for eight mining furnaces at the Zestaponi Ferroalloy Plant at the expense of their complete reconstruction. One furnace has already undergone such a reconstruction.

As a result of the constant perfection of electrical units, the share of liquid metal obtained in electric furnaces is constantly increasing. The efficiency of using heat in electric furnaces is about 60%. 40% energy losses pose tasks to electrometallurgy that aim to further improve electrothermal melting technologically and structurally. In the field of ferrous metallurgy, the production of ferroalloys has the highest energy capacity. Electricity consumption in Georgia during electrothermal melting, when ferrosilicon manganese alloys are produced, is in the range of 3000-5000 kWh/ton (norms are less than 2500 kWh/ton). Despite the low electricity tariffs compared to the world market, the price of one ton of ferroalloys produced is quite high, which significantly reduces their competitiveness.

Expensive metallurgical coke used in the production of ferroalloys, the average cost of which is 0.4-0.45 tons per ton of ferroalloy products, at a cost of $ 150-200 per ton, exacerbates the above problem. Virtually

[62] Georgian American Alloys – www.gaalloys.com
[63] www.rusmetali.com
[64] www.gtmgroup.ge

all electrometallurgical plants in Georgia face these problems. They are forced to look for ways to reduce energy consumption in the technologies used with them.

Currently, virtually all ferroalloy plants operating in Georgia operate on electric thermal melting furnaces, the replacement of which, for example with duplex melting furnaces, is associated with significant investment costs. It will be relatively inexpensive if an agreement is made with the mining furnaces in the ferroalloy plant of the slag kiln unit. Such an arrangement, which would work in parallel with ferroalloy furnaces, would allow them to reduce energy costs by up to 15%, which is quite a high rate for currently physically and morally obsolete furnace units.

The center of chemical production in Georgia is Rustavi Chemical Combine JSC "Energy Invest". The plant currently produces mainly two types of products: ammonia and nitric acid, which are used to produce nitrogen fertilizers. The most energy-intensive is the production of ammonia, followed by the production of nitric acid. One of the most important parameters of profitability in the production of ammonia is the amount of energy consumption. Currently, ammonia is produced by the Haber-Bosch chemical process. The plant has already taken electricity from high-energy water vapor using a turbocharger as part of the planned measures to reduce energy emissions. The nitrogen plant is also planned to reduce non-energy emissions by improving technological processes (for example, by replacing gas conversion burners, reducing nitrogen oxides and trapping carbon dioxide).

Iron and steel are produced in three enterprises - Geosteele[65], Rustavi Metallurgical Plant[66], and Iberia Steele. In these factories, steel is produced by melting scrap and slag in electric furnaces, while the largest share (80-85%) is produced by melting scrap (secondary steel production). At Rustavi Metallurgical Plant it is planned to reduce energy emissions only using few measures, which are described in the table below.

During the preparation of the 3rd National Communication, certain barriers and shortcomings in the implementation of mitigation measures in the industrial sector were identified. The most important barriers and the ways to solve them are briefly described below.

- Industrial enterprises have not defined mandatory or voluntary environmental measures. If environmental regulations are tightened, there will be more demand for energy efficient technologies;
- The most serious barrier in the industrial sector is the lack of engineering staff and low qualifications. Technical staff should be trained to acquire the knowledge and skills necessary for the study of advanced technologies and maintenance.
- Due to economic instability in the country, high financial risks and, consequently, high bank interest rates on loans, a large number of industrial enterprises are refraining from introducing resource-efficient and innovative measures. They need long-term loans with low interest rates, which are accompanied by a grant component.

Some of the barriers listed are currently partially resolved. In particular, the Ministry of Economy and Sustainable Development of Georgia has prepared a draft law on energy efficiency, which was approved by the Parliament on May 21, 2020[67]. Chapter V of this law deals with energy efficiency policies in industry. The law provides for the implementation of energy audit and the introduction of an energy management

[65] www.geosteel.com.ge
[66] www.rmp.ge
[67] https://matsne.gov.ge/ka/document/view/4873938?publication=0

system in industry. In order to improve energy efficiency in industry, the Ministry is authorized to enter into a voluntary agreement with the enterprise in agreement with the Government of Georgia. The Ministry evaluates the target indicators offered by the enterprise before concluding the voluntary agreement. If the Ministry does not consider the proposed target indicators satisfactory, it has the right to set mandatory target indicators. At the same time, the law provides incentives for industrial enterprises to introduce new energy-saving measures.

According to Georgia's updated NDC and Climate Action Plan, low-carbon approaches to the industrial sector are planned through the promotion of innovative technologies and services tailored to climate change, in order to achieve a 5% emission limit with no out-of-bounds scenarios.

The strategic goal of climate change mitigation in the industrial sector is to reduce greenhouse gases by introducing low-carbon measures at the level of 5,687 Gg CO2 equivalent compared to the traditional development scenario rate (5,986 Gg CO2 equivalent).

In the industrial sector in general, three types of mitigation measures can be considered:

- Increase energy efficiency in the industrial sector, replacing outdated technologies and processes with new energy-saving technologies and processes;
- Fuel replacement, replacement of a currently used high-carbon energy signature with a low-carbon energy signature;
- Use of carbon dioxide capture and storage technologies.

Of these, the last two are usually more expensive than the first. There are those in energy efficiency measures that are profitable for the enterprise and have a relatively short payback period. Energy efficiency measures are divided into two types according to the possibility of dissemination and identification:

- A measure specific to a particular production process, the identification and assessment of economic viability of which requires a detailed production energy audit;
- Measures that are relatively general and that, even without prior energy auditing, are known to benefit a wide range of enterprises, such as energy efficient engines (electric motors with frequency regulators), efficient cooling/cooling systems, and so on.

It is important to promote both types of measures in Georgia. In the case of the first type of measures, it is necessary to identify them mainly in large enterprises, but it is also important that medium and small enterprises have the opportunity to conduct energy audits. This is reflected in access to relevant qualified staff and the ability to use financial instruments to identify enterprise-specific measures. As for the second type of measures, they can be implemented through the introduction of standards. There is also a need to train and empower industry representatives to see how they can reduce production costs and product cost through energy efficiency measures. It is important to create financial mechanisms that will make the first investment capital available to industrial enterprises.

A detailed description of the completed, ongoing and planned mitigation measures in the industrial sector is presented in the table below.

Table 3.3.3.1: Implemented, ongoing and planned mitigation measures in the industrial sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented (2016-2018)	**Title:** Transfer of clinker production from wet method to dry method at HeidelbergCement Kaspi plant; **Objective:** Save energy and reduce costs through technological improvements. **Implementation level** - local	**Budget:** $ 97 million. **Funding source:** Company investment **Implementer**: Heidelbergcement	Annually - 194.4 Gg CO2 eq. by 2030	With the introduction of new technology, energy efficiency has increased (energy consumption has been reduced from 5.82 GJ / t to 3.4 GJ / t-clinker); Emissions are 3000 * 30 * 12 * (0.66-0.48) = 194.4 Emissions: 0.66 t CO2/t clinker by wet method; 0.48 t CO2/t clinker by dry method	Technology has been introduced	The time since the modernization of the Kaspi plant is 18 months. Clinker production 3000 t / day. In 2018 - 32.4 Gg In 2019 - 194.4 Gg In 2020 - 97.2 Gg	**Environmental benefits:** No more harmful substances are released into the atmosphere **Social benefits**: Increased number of employees
2	Implemented (2016-2018)	**Title:** Recycling of energy obtained during the clinker cooling process at the HeidelbergCement Kaspi plant; **Objective**: Save energy and reduce costs through technological improvements. **Implementation level** - local	**Budget:** $ 2 million. **Funding source:** Company investment **Implementer**: Heidelbergcement	Annually 7.5 Gg CO2 eq.	The introduction of new technology has increased energy efficiency; Natural gas combustion will emit 0.202 k CO2 eq/kWh (IPCC 1996); 5000 * 0.202 * 7500/1000 = 7.5 Gg	The 5,000 kW gas burner was replaced.	In 2018, 1.25 Gg In 2019, 7.5 Gg In 2020, 3.7 Gg	**Environmental benefits:** No more harmful substances are released into the atmosphere
3	Implemented (2017-2019)	**Title:** Using the heat of the technological process in Rustavi Azoti. **Objective**: Save energy and reduce costs through technological improvements. A 9 MW turbine was installed, from which it uses 0.8 MW for its own consumption; **Implementation level** - Local	**Budget:** $ 5.6 million. **Funding source**: Company investment **Implementer**: Rustavi Azoti	Annually 6.5 Gg CO2 eq.	(9-0.8) MW. X 8000 hp/yr = 65,600 MWh/yr. Greenhouse gas emissions will be reduced by 6.5 g per year. Emission reduction coefficient for electricity savings is 0.104 kg / kWh. Network Emission Factor for Georgia, Ministry of Energy (2017)	Technology has been introduced	Reduced electricity consumption from the state power system (9-0.8) MW. X 4300 hp / yr = 35260 MWh / yr. Greenhouse gas emissions were reduced by a total of 3.5 Gg	**Environmental benefits:** Reduced emissions of harmful substances into the environment
4	Implemented (2013-2015)	**Title:** Modernization of arc furnaces at Georgian Manganese Ferroalloy Plant; **Objective**: Save energy and reduce costs through technological improvements. **Implementation level** - Local	**Budget:** $ 8 million. **Funding source**: Company investment **Implementer**: "Georgian Manganese"	Annually 1 Gg CO2 eq.	2% of the electricity consumed annually by the enterprise will be saved. 0.104 kg CO2e/kWh Network Emission Factor for Georgia, Ministry of Energy (2017)	Technology has been introduced	Greenhouse gas emissions in 2016-2020 were reduced by a total of 1 * 4 = 4 Gg	**Environmental benefits:** Reduced emissions of harmful substances into the environment **Social benefits**: The number of employees increased by 50 men

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
5	Implemented 2018	**Title:** Dairy factory "Amirani"; **Purpose**: Replacement of local water heating system with energy efficient measure (condensate return line regeneration) **Implementation level** Local	**Budget:** 1100 Euros **Funding source:** Company investment **Implementer**: Dairy factory "Amirani";	Annually 0.005 Gg CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e / kWh of greenhouse gas (IPCC 1996)	Technology has been introduced	In 2019, 0.005 Gg of CO2 eq. In 2020, 0.003 Gg CO2 eq.	**Environmental benefits:** Reduced natural gas consumption from the gas network and emissions of harmful substances into the environment.
6	Ongoing (2015 -2023)	**Title:** Modernization of arc furnaces at Georgian Manganese Ferroalloy Plant; **Objective**: Save energy and reduce costs through technological improvements. **Implementation level -** Local	**Budget:** $ 64 million **Funding source:** Company investment **Implementer**: "Georgian Manganese"	8 Gg of CO2 per year.	Emission reduction coefficient for electricity savings is 0.104 kg/kWh. Network Emission Factor for Georgia, Ministry of Energy (2017)	The event was implemented in 2015 and it cost $ 8 million. Due to financial issues, the modernization of the rest of the furnaces was postponed.	NA	**Environmental benefits:** Reduced electricity consumption, as well as reduced environmental emissions from furnace overload melt
7	Ongoing 2020 -2021	**Title:** Energy efficient measures in the production of iron and steel at the Rustavi Metallurgical Plant; **Objective**: Save energy and reduce costs through technological improvements. Conducting a continuous cycle of hot molding through a methodical furnace; **Implementation level -** Local	**Budget:** $ 0.3 million **Funding source**: Company investment **Implementer**: "Rustavi Steel"	Annually 1.01 Gg of CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e/kWh of greenhouse gas (IPCC 1996)	Technical study prepared; The event requires the stop of the methodical furnace to carry out the modernization.	NA	NA
8	Ongoing 2019 -2020	**Title:** Capital Club Ltd. Wine and Cognac Factory Regeneration of local water cooling circulating system and hot water energy **Objective**: Save energy and reduce costs through technological improvements **Implementation level -** Local	**Budget:** 37,000 euros **Funding source**: Company investment **Implementer**: "Capital Club" Ltd	Annually 0.113 Gg CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e / kWh of greenhouse gas (IPCC 1996)	The plant was inspected with UNIDO funding and the number of possible savings in specific figures was estimated.	NA	**Environmental benefits:** Water consumption for the cooling system no longer occurs from the city network. Reduced gas consumption

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
9	Ongoing 2018-2022	**Title:** Agar sugar factory Replacement of a local three steam boiler at 25 t / h and transfer to another fuel **Objective**: Save energy and reduce costs through technological improvements **Implementation level** - Local	**Budget:** $ 1.05 million **Funding source:** Company investment **Implementer:** Agar Sugar Factory	Annually 9.8 Gg CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e / kWh of greenhouse gas (IPCC 1996)	The issue has been technically studied and requires the replacement of three steam boilers. Currently only the automatic burner control scheme is implemented.	NA	**Environmental benefits:** Gas consumption was saved and safety was increased. Replacing boilers will significantly reduce gas consumption.
10	Planned After 2020	**Title:** Replacement of burners used in the production of ammonia in "Rustavi Azoti" and rehabilitation of steam distribution networks **Objective**: Save energy and reduce costs through technological improvements **Implementation level** - Local	**Budget:** $ 0.98 million **Funding source**: Company investment **Implementer**: "Rustavi Azoti"	Annually 24 Gg CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e / kWh of greenhouse gas (IPCC 1996)	A technical study has been prepared	NA	**Environmental benefits:** Gas consumption will be saved and emissions of harmful substances into the environment will be reduced
11	Planned After 2020	**Title:** Modernization of compressors used in the production of ammonia in "Rustavi Azoti" **Objective**: Save energy and reduce costs through technological improvements **Implementation level** - Local	**Budget:** $ 9-10 million **Funding source**: Company investment **Implementer**: "Rustavi Azoti"	Annually 17.6 Gg CO2 eq.	Emission reduction coefficient for electricity savings is 0.104 kg CO2e / kWh. Network Emission Factor for Georgia, Ministry of Energy (2017)	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced
12	Planned After 2020	**Title:** Adjusting the frequency of electric motors of pumps in the technical water supply system and spray refrigerators in "Rustavi Azoti"; **Objective**: Save energy and reduce costs through technological improvements **Implementation level** - Local	**Budget:** $ 0.275 million **Funding source**: Company investment **Implementer**: "Rustavi Azoti"	Annually 0.7 Gg CO2 eq.	Emission reduction coefficient for electricity savings is 0.104 kg CO2e / kWh. Network Emission Factor for Georgia, Ministry of Energy (2017)	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
13	Planned After 2020	**Title:** Replacement of clinker with limestone or zeolite (volcanic shale) up to 5% in cement production at the Heidelberg Cement Plant in Heidelberg. **Objective**: Save energy by reducing technological improvements and reducing emissions **Implementation level -** Local	**Budget:** Production costs will be supplemented by increased costs of limestone / zeolite by 5%. Instead, the production costs of the same number of clinkers will be reduced. **Implementer**: "Heidelbergcement"	Annually 23 Gg CO_2 eq.	0.05 x 0.48 t CO_2/t clinker by dry method; The average annual production is 3000 t/day * 330 days	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced
14	Planned After 2020	**Title:** At the Heidelberg plant in Kaspi Cement, in the production of clinker, limestone is replaced by pre-treated ash or metal-containing slag. **Objective**: Save energy by reducing technological improvements and reducing emissions. Abducted ash has the ability to replace 30-50% of clinker in Portland cement **Implementation level -** Local	**Budget:** Increased costs of materials used will be added to production costs. Instead, the production costs of the same number of clinkers will be reduced **Implementer**: Heidelbergcement	Annually 142 Gg CO_2 eq.	The introduction of technology will reduce CO_2 emissions by 30% compared to the existing ones; By dry method on 0.3 x 0.48 t CO_2 / t clinker; The average annual production is 3000 t / day * 330 days	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced
15	Planned After 2020	**Title:** Removal of CO_2 in the production of ammonia in "Rustavi Azoti" by chemical absorption. **Objective**: Energy saving through technological improvements and Emission reduction. Solvent regeneration by plants requires vacuuming and much less energy than chemical absorption. **Implementation level -** Local	**Budget:** $ 10.2 million **Funding source**: Company investment **Implementer**: "Rustavi Azoti"	50 Gg of CO_2 eq per year.	By 2030 it will be reduced by 517 Gg. The introduction of the technology will reduce CO_2 emissions by 55% compared to the existing ones, since about 55% of the total amount of gas consumed in the production of ammonia is used in chemical processes for non-energy purposes. 1.5 tonnes of CO_2/t of ammonia (IPCC 1996)	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
16	Planned After 2020	**Title:** Selective non-catalytic recovery at Rustavi Azoti conversion plant to reduce nitrogen oxides already present in flue gases **Objective**: Energy saving through technological improvements and Emission reduction. **Implementation level -** Local	**Budget:** 1.5-2 million dollars **Funding source**: Company investment **Implementer**: "Rustavi Azoti"	Annually 4.9 Gg CO2 eq.	NOx emissions in the gases will be reduced and consequently equivalent greenhouse gas emissions will be reduced to 6.75 kg N2O/ton HNO3. The coefficient 310 is taken to convert N2O to CO2 equivalents of nitrogen suboxide.	A technical study has been prepared	NA	**Environmental benefits:** NOx emissions will be reduced.
17	Planned After 2020	**Title:** Energy recovery from electric furnaces at the Zestaponi Ferroalloy Plant. **Objective**: Save energy and reduce costs through technological improvements. **Implementation level -** Local	**Budget:** $ 16 million **Funding source**: Company investment **Implementer**: "Georgian Manganese"	Annually 7.2 Gg of CO2 eq.	The introduction of technology will reduce energy consumption by 13.5% compared to the existing one. With the introduction of technology it is possible to generate 70 GWh of electricity per year. Emission reduction coefficient for electricity savings is 0.104 kg / kWh. Network Emission Factor for Georgia, Ministry of Energy (2017)	A technical study has been prepared	NA	**Environmental benefits:** Electricity consumption will be saved. Emissions of harmful substances into the environment will be reduced
18	Planned After 2020	**Title:** Use of internal regeneration in the production of reinforced steel at the Rustavi Metallurgical Plant. Heating the air supplied to the gas burners during combustion at the expense of the heat released from the flue gases. **Objective**: Save energy and reduce costs through technological improvements. **Implementation level -** Local	**Budget:** $ 0.6 million **Funding source**: Company investment **Implementer**: "Rustavi Steel"	Annually 0.94 Gg CO2 eq.	Natural gas combustion will emit 0.202 kg CO2e / kWh Greenhouse gas (IPCC 1996) The introduction of technology will reduce energy consumption by 10% compared to existing. 800 m3 / h gas * 0.01 = 80 m3 / h 80 * 6000 h / y = 480000 m3 480000 * 9.7 = 5646 000 kWh 5646000 * 0.202 = 0.94 Gg	A technical study has been prepared	NA	**Environmental benefits:** Will save gas consumption and Emissions of harmful substances into the environment will be reduced

3.3.4 Agricultural Sector

According to 2018 data, about 19.6% of the population is employed in agriculture, which accounts for about 7.8% of GDP[68]. According to the National Statistics Office of Georgia, the production of agricultural products has been growing over the years. In 2018, the production of agricultural products, livestock, plants and agricultural services occupy 48.3%, 45.4% and 6.3%, respectively.

In Georgia, agricultural lands occupy about 43% of Georgia's territory, of which more than 377,400 ha are arable land, more than 109,600 ha are perennials and more than 300,000 ha are pastures. According to the 2014 GEOSTAT census, 77.1% of landowners own up to 1 hectare, 21.4% from 1 hectare to 5 hectares, and 1.5% own more than 5 hectares. Most landowners are smallscale farms.

Since 2012, the Government of Georgia has made agriculture a priority and launched such important programs/projects as Preferential Agro Credit, Introduce the Future, Young Entrepreneur, Agricultural Support Program, Agricultural Insurance and more[69]. The main goal of these programs/projects is to increase the production of agricultural products, however, the implementation of more programs/projects in agriculture may lead to an increase in emissions. Also, among the important projects are the industrial livestock development incentive programs planned for 2020-2021

According to the latest National Greenhouse Gas Inventory in Georgia, the following source categories are considered in the agricultural sector: intestinal (enteric) fermentation, manure management, direct and indirect emissions from agricultural soil, and incineration of agricultural waste in field conditions. Manure management includes all emissions resulting from the operation of such management systems, such as anaerobic pond, liquid system, solid storage of manure and livestock feeding stalls. Animal waste emissions from excrement excreted by cattle grazing on pastures fall into such categories as direct and indirect emissions from agricultural soils.

According to the Georgian Climate Action Plan 2020-2030 by 2030, according to the Business as usual (BAU) scenario, compared to 2015, emissions in the Georgian agricultural sector are expected to increase by about 40% to 4,624 Gg CO2 eq, of which 36.8% to intestinal fermentation, 47% from agricultural soils (direct and indirect emissions), 14.7% comes from manure management. The main sources of emissions from agricultural soils are pastures, synthetic fertilizers (direct emissions from agricultural soils) and nitrogen leakage and runoff (indirect emissions from agricultural soils).

According to the Updated NDC of Georgia, by 2030, the target rate of emissions from the agricultural sector has not been determined. However, through the measures presented in the Georgian Climate Action Plan (CAP), compared to the BAU scenario, it is planned to reduce emissions from the agricultural sector and in 2030, taking into account the planned activities, the amount of emissions in the agricultural sector is expected to reach 4,617 Gg CO2 eq.

It should also be noted that according to the Climate Action Plan of Georgia 2020-2030, in 2021-2022, the Ministry of Environment Protection and Agriculture of Georgia plans to implement the following measures / activities:

– Conduct cost-benefit analysis and feasibility studies to identify best ways to increase feed-in changes in domestic cattle;

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[68] Georgian National Statistics Office (GEOSTAT);
[69] Rural and Agricultural Development Agency-http://www.arda.gov.ge/

- Conduct cost-benefit analysis and feasibility study to identify the best ways to implement NAC management systems;
- Research and analysis of successful and widespread examples of the formation of agricultural cooperatives;
- Conduct research and consultations to identify economically and socially feasible climate-reasonable agriculture (CSA) measures in the Georgian context;
- Develop an education and awareness-raising strategy (including on the use of synthetic fertilizers).

The vision of the state policy in the agricultural sector is to create an environment based on the principles of sustainable development, which will contribute to increasing competitiveness in the agro-food sector, sustainable growth of high quality products, food security, food safety and rural poverty. The main strategic goal of agricultural policy is to increase the competitiveness of farmers and also to promote the development of commercial agriculture in the country. The agricultural strategy presents areas that will have a positive impact on both the environment and climate mitigation: raising farmers' knowledge, improving irrigation and drainage systems, rational management of the agricultural land fund, restoration/improvement of windbreaks, agriculture, and other.[70]

Georgia's Agricultural Development Strategy 2015-2020 presents seven main strategic directions, including the seventh strategic direction, climate change, environment and biodiversity conservation. One of the measures of this strategic direction is to promote the introduction of climate-friendly agricultural practices, which in turn combines three cross-cutting challenges: ensuring food security through increased production and income, adapting to climate change, and promoting climate change mitigation.

The Strategy of Agriculture and Rural Development of Georgia for 2021-2027 has three strategic goals, including the second strategic goal, sustainable use of natural resources, conservation of ecosystems, adaptation to climate change. The presented strategic goal combines five objectives, one of which is to promote environmentally adapted, climate-friendly agricultural practices and to promote the development of bio/organic production[71]. The given task in the 2021-2023 Agriculture and Rural Development Action Plan envisages identifying and promoting opportunities for adaptation to climate change[72].

Major Challenges in the Sector

Problems identified in Georgia's Low Emission Development Strategy (2017) in the agricultural sector - lack of capital, land fragmentation, lack of modern technology, and rural poverty are still significant challenges, making agricultural production inefficient and contributing to increased environmental emissions. Also, a significant challenge in the sector is low productivity. In response to the challenges presented, the Government of Georgia has developed various projects, including: preferential agro-credit, processing enterprise support project, incentive program for young entrepreneurs. Also, in response to the challenge of land fragmentation, the Government of Georgia has developed a land registration reform, the main objectives

[70] Georgia Agricultural Development Strategy 2015-2020. Strategic document available: https://mepa.gov.ge/Ge/PublicInformation/30

[71] Agriculture and Rural Development of Georgia 2021-2027 strategy. Strategic document available: https://mepa.gov.ge/Ge/PublicInformation/20395

[72] 2021-2023 Action Plan for Agriculture and Rural Development of Georgia for 2021-2027. An action plan is available at: https://mepa.gov.ge/Ge/PublicInformation/20395

of which are to develop the land market and the efficient use of land. In order to increase the productivity of agriculture, the Government of Georgia annually implements various projects in the field of irrigation and drainage. It should also be noted that in 2019, compared to 2012, the number of water supply and drainage areas in the country has almost tripled.

Also, one of the major challenges in the sector is raising awareness about climate-friendly agriculture and climate change. In February 2020, the Ministry of Environment Protection and Agriculture of Georgia established a working group on climate-friendly agriculture. The aim of the working group is to promote the introduction/popularization of climate-friendly agricultural practices in Georgia and to reflect the issues mentioned in the strategic directions/documents of agricultural policy. Also, one of the tasks of the established group is to promote awareness of climate-friendly agriculture for the various parties working in the agricultural sector.

LEPL "Agricultural Research Center" of the Ministry of Environment Protection and Agriculture of Georgia is carrying out the measure - a study of the Land Fund of Georgia to restore and improve soil fertility. The main goal of the measure is to improve the structure of degraded soils and increase fertility in all regions of Georgia. The presented activity includes a study of the land fund and the issuance of relevant recommendations. In 2018-2019, the condition of the soils on an area of approximately 100,200 ha has been studied and also, recommendations for improving soil fertility have been prepared.[73]

According to the Georgian Biennial Update Report (BUR), in 2017, it was planned to build a biogas plant that would use manure and agricultural waste. However, due to lack of financial resources the project could not be implemented.

A detailed description of the completed, ongoing and planned mitigation measures in the agricultural sector is presented in the table below.

[73] Monitoring reports on the implementation of the 2018-2020 Action Plan for the Agricultural Development Strategy of Georgia for 2015-2020 and for implementation in 2018 and 2019. Monitoring reports available at:https://mepa.gov.ge/Ge/Reports

Table 3.3.4.1: Implemented, ongoing and planned mitigation measures in the agricultural sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented 2017 - 2019	**Title:** Rational use of state-owned pastures in mountainous regions. **Purpose:** Rational use of state-owned pastures and pastures; Promoting livestock development; Selection and testing of highly productive breeds of cattle. **Implementation Level**: Highland regions.	**Budget:** The budget for 2018-2019 was - 3.7 million GEL. **Source of funding**: State budget. **Implementer**: Ministry of Environment Protection and Agriculture of Georgia / LEPL Agricultural Cooperatives Development Agency.	Annually 36.9 Gg of CO2 eq. By 2030, reduce emissions of 517.6 Gg of CO2 eq.	Emissions were calculated using EX-ACT developed by FAO.	23 cooperatives registered in highland settlements were given 7,649 ha of state-owned pastures on a 25-year lease. To the mentioned 23 agricultural cooperatives Tractors and trailers were handed over with 90% co-financing	By 2020, emissions of approximately 147.9 Gg CO2 have been reduced since the start of the project.	**Environmental benefits:** Protecting the soil from degradation (water and wind erosion); Conservation of biodiversity (genetic resources). **Social benefits**: Rehabilitation of pastures for the local population and increase of produced products.
2	Implemented 2014 - 2017	**Title:** Pasture rehabilitation and sustainable management of Vashlovani protected area. **Purpose:** Sustainable pasture management. Rehabilitation of 4,064 ha of degraded pastures, including rehabilitation of 300 ha of paved paths. **Implementation level**: Local: Vashlovani Protected Area.	**Budget:** 1.5 million dollar **Funding source**: Donors: European Union - 1 million euros; UNDP - $ 26,900. **Implementer**: Ministry of Environment Protection and Agriculture of Georgia / LEPL Agency of Protected Areas.	Annually: 14.4 Gg CO2 eq. By 2030, 244.9 Gg of CO2 eq.	Emissions were calculated using EX-ACT developed by FAO. CO2 eq. Emission reduction as a result of sustainable management of summer pastures, avoiding soil degradation and vegetation losses.	Two pilot farms were organized within the project. To demonstrate modern pasture management methods, two automatic meteorological stations were purchased and installed. Meteorological stations are included in the unified national meteorological network.	By 2020, emissions of approximately 100.8 Gg CO2 have been reduced since the start of the project.	**Environmental benefits:** Protecting the soil from degradation (water and wind erosion); Conservation of biodiversity (genetic resources). **Social benefits**: Rehabilitation of pastures for the local population A unified veterinary system has been set up for Tushi shepherds, which in the first phase will serve approximately 5,000 sheep each year and will be able to increase that number to 30,000 in the future.
3	Ongoing from 2015	**Title:** Avoid field burning of crop residues. **Purpose**: The aim of the measure is to prevent the burning of wheat waste (sludge) in the field and to reduce CO2 emissions. **Implementation level**: Dedoplistskaro Municipality.	**Budget:** The activity does not require a budget. **Source of funding:** The activity does not require a budget. **Implementer**: Ministry of Environment Protection and Agriculture of Georgia.	Average annual reduction in emissions of approximately 3.5 Gg CO2 eq. By 2030, emissions will be reduced by approximately 56.5 Gg CO2 eq.	Emissions were calculated using the EX-ACT model developed by the Food and Agriculture Organization of the United Nations (FAO) According to the methodology, Only methane and nitrous oxide emissions are taken into account.	Not prohibited by law, farmers do not burn manure in the field on the recommendation. In Dedoplistskaro district, 29,000 hectares of wheat crop waste (namja) are no longer burned in the field.	By 2020, emissions of approximately 21.2 Gg CO2 have been reduced since the start of the project.	**Environmental benefits:** Protecting the soil from degradation (water and wind erosion); More water retention in the soil. **Social benefits**: Reducing air pollution has a positive impact on the health of the population.
4	Ongoing 2015	**Title:** Introduce the future. **Purpose**:	**Budget:** The budget for 2015-2020 is about 58.5 million GEL.	Approximately 46.6 Gg of CO2 eq. Average annual	Emissions were calculated using the EX-ACT instrument developed by the Food and Agriculture Organization (FAO).	Approximately 8,101 ha of perennial gardens were planted in 2015-2019.	By 2020, emissions of approximately 233.2 Gg CO2 have been	**Environmental benefits:** Preservation and promotion of biodiversity (genetic resources).

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
	- 2030	Effective use of agricultural lands in Georgia through the cultivation of perennial crops. **Implementation level:** National	**Funding source**: state budget. **Implementer**: Ministry of Environment Protection and Agriculture of Georgia / A (A) IP Rural and Agricultural Development Agency.	reduction in emissions. By 2030, approximately 746.1 Gg of CO_2 eq. Emission reduction.	Annual crops will be replaced by perennials.		reduced since the start of the project.	**Social benefits**: In the period 2015-2019, the total number of beneficiaries under the "Implement the Future" was 1,350. The socio-economic situation of the rural population has improved.
5	Ongoing 2020 - 2024	**Title:** Dairy sector modernization and markets Access project (DiMMA). **Purpose**: Promoting rural economic development, overcoming poverty through the development of a competitive, sustainable and diversified dairy industry; The project will help dairy farmers. It will also facilitate the creation / development of an effective pasture management system. **Implementation level:** National	**Budget:** 19.7 million. euro. **Source of funding**: State Budget / IFAD International Fund for Agricultural Development./Adaptation Fund **Implementer**: Ministry of Environment Protection and Agriculture of Georgia / A (A) IP Rural and Agricultural Development Agency.	Average annual reduction in emissions of approximately 30.3 Gg CO_2 eq. By 2030, emissions will be reduced by approximately 303.1 Gg CO_2 eq.	Emissions were calculated using the EX-ACT model developed by the Food and Agriculture Organization of the United Nations (FAO) In the beginning - poorly degraded pastures, and as a result of improvement will be non-degraded.	A project implementation guide document has been developed As a result of the project, better managed pastures per 10,000 ha will be obtained in the following regions: Imereti, Samegrelo-Zemo Svaneti and Samtskhe-Javakheti, Racha-Lechkhumi and Kvemo Svaneti, Kakheti and Kvemo Kartli.	**NA**	**Environmental benefits:** Conservation and promotion of biodiversity (genetic resources); Protecting the soil from degradation. **Social benefits**: 5,000 grants; 400 new jobs; 6,000 individuals will undergo training; 300 km required infrastructure (road), 10,000 ha of better managed pasture.
6	Ongoing 2021 - 2030	**Title:** Reduction of emissions from enteric fermentation in cattle. Optimize food quality and improve nutrition. **Purpose**: Improving feed quality and reducing emissions for cattle. **Implementation level:** Local	**Budget:** - **Funding source:** Climate Fund (GCF); International Donor Development Agencies. **Implementer**: Ministry of Environment Protection and Agriculture of Georgia.	Average annual reduction in emissions of 6.83 Gg CO_2 eq.	Emissions were calculated using the EX-ACT model developed by the Food and Agriculture Organization of the United Nations (FAO). There are a variety of food resources in the country. The content of condensed tannins and other mixtures in Georgian grape varieties is sufficient to reduce intestinal fermentation. Also, it is assumed that the system will include 20% of smoked goods in 2021, and by 2030 this figure will reach 80%.	A research document was prepared	NA	**Environmental benefits:** Conservation and promotion of biodiversity (genetic resources). **Social benefits:** Increase farmers' incomes and increase welfare

3.3.5 Land Use and Forestry Sector

Land use, land use change, and forestry (LULUCF) is one of the most important sectors of greenhouse gas emissions and absorption in Georgia. The key categories of the sector are forest lands and meadows, as well as arable lands, especially perennials.

Georgia's forests, which cover about 40% of the country's total area, play a crucial role in Georgia's greenhouse gas balance. The socio-economic situation in the country after gaining independence has had an extremely negative impact on the forestry sector and has had a direct impact on forests, leading to a significant reduction in their carbon dioxide absorption potential. Nevertheless, the National Greenhouse Gas Inventory Report in Georgia (1990-2017) shows that forests are a significant absorber of greenhouse gases and can make a significant contribution to climate change mitigation under consistent measures.

The same can be said for the other categories of the sector, the situation of the 1990s, like the forest sector, had a negative impact on the areas occupied by perennials, as well as on meadows and pastures. According to statistics, there is a decrease in the area occupied by both annual crops and perennials[74], for example, in 1990, perennials occupied 334 thousand hectares in the country, while in 2015, they decreased to 109.6 thousand hectares. Unfortunately, the current statistics do not show any land use categories or changes in them in terms of category change, however, a high rate of pasture and meadow degradation is evident. Due to the degradation of pastures and forests, the carbon sequestration potential of the LULUCF sector is significantly reduced.[75].

The main challenge for the sector is forest degradation, which is mainly caused by unsustainable and inefficient use of forest resources. Timber still remains the main source of energy in rural areas, with 90% of the rural population partially or completely dependent on timber for space heating, water heating and food preparation. In addition, access to both energy efficient technologies and alternative energy resources is limited. In the wake of this and the socio-economic background of the country, the ongoing processes in the forestry sector over the years have been characterized by frequent institutional and legislative changes due to the instability of political and strategic priorities. Due to the lack of a clearly defined strategy and action plan, the processes failed to develop consistently, violating the necessary preconditions for the sustainable management of the sector, which implies a sound legal framework and adequate financial and human resources. Incomplete and outdated information on quantitative and qualitative indicators of forests did not allow for long-term planning of forest management and sustainable forest use in accordance with the functional purpose of forests.

To eliminate unsustainable forest management, the Georgian government launched a large-scale forest sector reform in 2013 and should complete it by 2020-21. The objectives of the forest sector reform are (a) to change current approaches to forest use and management, (b) to develop a unified forest management system, and (c) to improve the institutional and technical skills of forest management bodies.

The process was based on the "National Forest Concept"[76] approved by the Parliament of Georgia, which is the main framework document defining the policy in the sector and which aims to introduce a sustainable forest management system in the country. Actions related to the development of the sector to ensure the

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[74] Source: National Statistics Office of Georgia
[75] According to the BAU scenario of the Low Emission Development Strategy (2017), by 2030 the LULUCF sector will still remain a carbon absorber, although its absorption potential will decrease by 6.5 times and therefore it will be closer to the emission category.
[76] N1742-Iს, 11/12/2013

implementation of the National Forest Concept are reflected in the documents of the Third National Environmental Action Program 2017-2021 (NEAP III)[77], the Georgian Biodiversity Strategy and Action Plan (2014-2020) [78], the Georgian Rural Development Strategy and Action Plan (2017-2020) [79].

In particular, the Third National Environmental Action Program of Georgia (NEAP III) identifies 5 main objectives (Objective (1): to improve the legislative framework and introduce a sustainable forest management system; (2) to reduce forest pressure by encouraging the use of alternative fuel sources (3) Strengthening the capacity of forest policy, management and control agencies, (4) promoting the use of forest ecosystem services, (5) promoting forestry education development and raising public awareness), which should be facilitated by the 26 joint actions under these objectives .

The Biodiversity Strategy and Action Plan (2014-2020) has two national objectives (B.1 and C.3) related to the forestry sector, and 25 related actions should ensure the establishment of a legislative and institutional framework to ensure the sustainable forest use of the country, effective law enforcement mechanisms and regular monitoring. Introduction, prevention and/or mitigation of forest degradation. As for the rural development strategy and action plan, the priority measure is to improve the management of water, forest and other resources in the targeted rural areas, which is reflected in the activities of sustainable use of forest resources, forest maintenance and restoration, as well as forest registration and inventory activities.

The importance of forest resources and their sustainable management is mentioned in the country's top-level climate policy: Georgia's National Defined Contribution (NDC) identifies forests as the main sector of national climate action, which has a quantitative commitment to make sustainable forest management broader. To mitigate climate change in the forestry sector, the Government of Georgia considers the following three measures as priorities: (a) establishing sustainable forest management practices; (b) Implement reforestation/forest restoration and promote natural restoration; and (c) increase protected areas.

Progress in the sector is noticeable as a result of the actions taken in 2013-2019. The Parliament of Georgia has adopted[80] a new Forest Code, which has been under development since 2016. With the development of the new Forest Code, it can be said that the fulfillment of the obligations defined by international as well as the above-mentioned national strategies, has started[81].

The new draft Forest Code is built on the principles set out in the National Forest Concept and changes approaches to problematic issues such as:

- Fragmentation and reduction of forest fund
- Incomplete data on quantitative and qualitative indicators of forests
- Neglecting the multifunctional use and economic potential of forests
- High population dependence on firewood and forest degradation
- Weak institutional model of forest management body
- Lack of qualified staff

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[77] Resolution of the Government of Georgia №1124 22.05.2018
[78] Resolution of the Government of Georgia N343 8.05.2014
[79] Resolution of the Government of Georgia №631 30.12.2016

[80] May 22, 2020

[81] Item N299 of the National Action Plan (2015) for the Implementation of the Association Agreement between Georgia and the EU and the Association Agenda - “Preparation of a new Forest Code; Review and bring into compliance the relevant legislative and sub-legislative normative acts "

At the same time, the new bill meets the country's commitments to EU integration and international standards in the sector.

Significant progress has also been made in forest inventory, with periodic forest inventory being one of the main and statistically reliable data sources, not only in terms of sustainable forest management, but also in terms of the full involvement of the forest sector in the climate change process. Forest inventory will improve the quality of national greenhouse gas inventory, as well as increase the reliability of forest vulnerability assessment and adaptation measures.

In 2019, with the support of the German government, the country launched the first national forest inventory[82], the final results of which will be in 2021. However, since 2013, significant progress has been made in terms of detailed forest inventories[83].

At present, as a result of the inventory, data on 20% of the forest fund have been updated, including fully at the level of Adjara, Guria and Samtskhe-Javakheti regions (except Adigeni forest district), as well as specific forest districts (Kharagauli, Lagodekhi) in Imereti and Kakheti regions. It is noteworthy that outdated data on forests have been a constant impediment to the sector being fully represented in the country's national communications on climate change. However, within the third and fourth national reports, the forest massifs of Adjara, Zemo Svaneti, Borjomi-Bakuriani, Guria, Kakheti and Mtskheta-Mtianeti were assessed, and the vulnerability of local forest ecosystems to current climate change was analyzed. Based on the results obtained, adaptation measures to climate change were drawn up and project proposals were prepared.

Progress has been made in the country since the preparation of the Third National Communication, including the implementation of recommendations. In addition to improving the institutional and legislative framework, the scale of reforestation and the fight against forest pests and diseases has increased since 2015, responding to the Intended Nationally Determined Contribution (INDC) commitment (Implementation of reforestation measures by 2030 of predetermined 1500 ha and production of natural renewal promotion measures at 7500 ha). For example, 250 hectares of forest destroyed by fire in the Borjomi gorge were fully restored.

Progress has also been made in implementing the mitigation measures outlined in Georgia's second updated biennial report. In addition to the activities carried out in the forest sector (category of forest lands), in 2011-2015 Tbilisi City Hall planted perennial plants and developed green spaces in Tbilisi Municipality, planted 820,000 trees, rehabilitated Turtle Lake (29.2 ha) and Khudadov (66.5 ha) forests. "Ecological Islands" were created in different parts of the city and the green cover of the city increased by 8.1 ha[84].

In order to implement sustainable pasture management and modern systems, a number of projects were implemented in 2014-2018 aimed at reducing grazing pressure in the forests surrounding the pilot areas. The project "Improving Biodiversity in Priority Transboundary Protected Areas of the Ior-Mingechauri Region" was implemented by the WWF Caucasus Program Office and funded by the German Ministry for Cooperation and Economic Development (BMZ). The German National Office of the World Wide Fund for Nature (WWF) has taken action to improve grazing practices on winter pastures near the Chachuna Reserve.

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[82]The National Forest Invetory (NFI) is conducted every 10 years and covers the entire country. The National Forest Inventory focuses on obtaining general information for use in forestry policy and strategic decision-making.

[83]Detailed forest inventory / forest management (FMI) is carried out at the level of the forest district (often coinciding with the boundaries of the municipality) and a management plan is prepared based on it.

[84] According to expert estimates, one tree absorbs 0.007 tons of CO_2 per year and as a result of the implemented measures will capture an average of 4.5 g of CO_2 per year.

Also one of the most important components was the protection of the floodplain forests of the Chachuna reserve and the natural renewal of the forest.

Another project was implemented in Tusheti protected areas. The aim of the project "Integrated Erosion Management in the South Caucasus" was to assess the ecological condition of pastures in Tusheti protected areas and their use, and to implement pilot projects aimed at reducing erosion. Although the project did not directly envisage forest rehabilitation, it was significantly aimed at regulating the grazing process, which helps to improve the grazing process in Tusheti protected areas. Within the framework of the project, a so-called "Tusheti Erosion Prone Pasture Model" was prepared, which should facilitate the detection of eroded sections in protected areas and their rehabilitation. Based on the model, pilot sections were selected where agro-technical activities were carried out (Shenako village and Jvarboseli village). Pasture fencing and restoration measures were carried out on selected sections. Actions were also taken to rehabilitate the forest, including fencing off sensitive sections through an electric fence and afforestation. During the same period, with the assistance of the German Society for International Cooperation (GIZ), a pasture monitoring methodology was developed for Georgia, Azerbaijan and Armenia, "Monitoring Guide for Winter Pastures in Azerbaijan and the Caucasus." In addition to assessing pasture condition, the guide also includes approaches and recommendations based on which basic recommendations for pasture management are prepared. These include load norms, calendars, restrictions, methods for detecting and managing eroded sections, improving pasture condition and designing sustainable use measures, monitoring and more. Based on this approach, Nakresi Scientific-Research Center for Species Conservation conducted studies and prepared or is preparing management plans for the following protected areas: Lagodekhi Protected Areas (protected area); Vashlovani Protected Areas (Traditional Use Zone); Tusheti Protected Areas (Traditional Use Zone, Protected Landscape); Borjomi-Kharagauli National Park (traditional use zone).

As for the increase of protected areas, in addition to the expansion of traditional[85] protected areas and/or the creation of new protected areas, Georgia is also developing an emerald network[86]. Currently, 18.45% of the total territory of Georgia (approximately 1.2 million hectares) is part of this network, of which 46 units of territory have already been approved, 12 - submitted.

Along with the implemented projects, important actions are planned, which should respond to the challenges in the sector and the international commitments made by the country. According to the Climate Action Plan of Georgia (2021-2030), fundamental directions have been identified for the forestry sector: (1) restoration of degraded forests, (2) management of forests in accordance with the principles of sustainable management, (3) expansion of protected areas, (4) Facilitate changes in unsustainable and inefficient forest resources usage practices. If joint action is taken under these guidelines, greenhouse gas consumption by the forestry sector will increase by 12% by 2030 compared to without them (calculations were made using the EX-ACT model).

Despite the above and some progress made, the sector still faces many challenges, including gaps in regulations and normative documents. Accordingly, the new sub-normative documents to be developed under the new Forest Code should fully reflect the reservations, which in the future will further strengthen the effective implementation of measures that directly affect the adaptation of forests to climate change and mitigation of climate change impacts. Incomplete, unreliable and outdated forest inventory data are also

[85] IUCN categories
[86] https://www.coe.int/en/web/bern-convention/emerald-network

considered to be one of the major challenges. The ability to quickly update information across the country depends on the relevant financial and human resources. The limited knowledge, practical skills and experience of governing bodies have a significant impact on the quality of effective law enforcement and the fulfillment of obligations under strategic documents. The small scale of actions related to the development of the alternative fuel market and energy efficiency does not allow for sustainable use of timber. At the same time, the level of public awareness in the country is still low, which affects the establishment and proper functioning of a sustainable forest management system.

In addition, guidelines for climate change mitigation measures and climate change impact adaptation for Georgia's forests have not yet been developed, which should form the basis for a climate change mitigation and adaptation plan for vulnerable forest groves; there has been no categorization and zoning of forests, which would also make it easier to assess their vulnerability to climate change. A state program for the provision of fuel resources to the population has not yet been developed, which will assess the feasibility of using possible alternative fuel resources to eliminate energy shortages.

Like forests, there are a multitude of challenges for other categories in the LULUCF sector (arable land, especially perennials, meadows and pastures). The scarcity of data on agricultural land degradation hinders full-fledged assessment and forecasting. There is little data on the changes in categories and the reasons for the change. With the lack of data, there is a lack of knowledge and experience in the production of climate-friendly agriculture and new technologies. In response to the challenges, the country is working to improve the legislative framework[87], as well as to prepare a number of strategic documents and action plans[88], the consistent implementation of which will reduce emissions from land use change and forestry activities.

A detailed description of completed, ongoing and planned mitigation measures in the LULUCF sector is presented in the table below.

[87] In accordance with the third, fourth and tenth chapters of the Association Agreement signed between Georgia and the European Union on June 27, 2014.
[88] Detailed information is given in the Agricultural Sector section.

Table 3.3.5.1: Implemented, ongoing and planned mitigation measures in the LULUCF sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented (2013-2015)	**Title:** Adapted Sustainable Forest Management (NAMA) in Borjomi-Bakuriani Forest District. **Objective:** Biodiversity conservation, forest restoration-planting, forest protection, by creating the capacity of staff working in forestry. **Implementation level** - regional	**Budget:** 2 million euros. **Source of funding**: Austrian Ministry of Agriculture and Forestry 1.5 million Euros, 0.5 million Euros Co-financed by the Government of Georgia **Implementer**: LEPL National Forest Agency, BFW	Annually - 8.7 Gg CO2 eq. By 2030	Inventory difference method used (on IPCC 2006 AFOLU); Biomass conversion and expansion emission factor on stock growth is used to calculate the current stock of biomass.	Sustainable forest management practices were implemented on 45,000 ha of forest, 60 ha on firefighting activities, 4.3 ha on forest restoration - with the support of natural renewal.	Total emissions of approximately 43.5 g CO2 have been reduced in the period 2016-2020.	**Environmental benefits:** Planned forest use, forest maintenance and other forestry activities based on a 10-year forest management plan. **Social benefits**: Indigenous people employed in the planned forestry work (at least 100 people seasonally), unimpeded access to resources as a result of planned forest use
2	Implemented (2011-2015)	**Title:** 2008 Restoration of Forest Burnt as a Result of Russia-Georgia Armed Conflict (Borjomi Gorge) **Purpose:** forest restoration-planting, forest protection, biodiversity conservation. **Implementation level** - regional	**Budget:** 1.5 million euros **Source of funding**: Government of Finland **Implementer:** UNDP, LEPL National Forest Agency	Annually - 11 Gg of CO2 eq. By 2020	To calculate the potential for reducing greenhouse gas emissions, the following assumptions are made: Western Georgia will accumulate 1 hectare of forest in 2011-6.6 tons of CO2; 2012-15.3 tons of CO2; 2013-25.8 tons of CO2; 2014-36.6 tons of CO2; 2015-47.4 tons of CO2; 2016-58.4 tons of CO2; 2017-69.6 tons of CO2; 2018-81.2 tons of CO2; 2019-93.4 tons of CO2; 2020-106.4 tons of CO2;	2015-2019 - An additional 144 ha area was restored at the expense of the Forest Agency	By 2020, 15.3 Gg of CO2 has been reduced.	**Environmental benefits:** Restored forest ecosystem, conserved biodiversity **Social benefits**: Capacity building for forestry workers and locals. The project also promoted agriculture, tourism and environmental education, which helped grow the economy and improve living conditions.
3	Implemented (2010-2011)	**Title:** Establishment of Javakheti Protected Area in Georgia. The area mainly includes highland and swampy areas **Objective:** Biodiversity conservation and CO2 absorption. **Implementation level** - regional	**Budget:** 2.25 million euros **Funding source**: KFW **Implementer**: WWF, LEPL Agency of Protected Areas	Annually -12.8 Gg CO2 eq.	Addition of the 2006 IPCC Guideline 2013 on National Greenhouse Gas Inventory: Wetland Soil (Methodological Guide for Wetlands for Wetlands and Dry Soils and Wastewater) If 1 hectare area does not dry out, 23.5 tons of CO2 per year will be saved. The total area of peat soils in the Javakheti Protected Area is 547 hectares.	The Javakheti Protected Area (19,286 ha) was established, with appropriate infrastructure and a legislative base. Javakheti Protected Areas have been expanded since 2020, the law will enter into force in 2021 and officially 3 dams will be added: 629 ha in the evening, 4031 ha in the Paravani Lake, 211 ha in the Abuli Lake. Total: 4871 ha will be added.	By 2020, 114.5 Gg of CO2 has been reduced	**Environmental benefits:** High level of protection and conservation of biodiversity components **Social benefits**: Creating additional income and opportunities for local people in the field of tourism and agriculture

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
4	Implemented (2013-2016)	**Title:** Demonstrate benefits of sustainable pasture management in Georgia for climate change mitigation and adaptation and benefits for local communities **Objective**: To demonstrate the benefits of climate change mitigation and adaptation measures to local communities **Implementation level** - regional	**Budget:** - 1.39 million. euro **Source of funding:** EU / UNDP **Implementer**: LEPL Agency of Protected Areas	On average per year - 10.2 Gg of CO2	To calculate the potential for reducing greenhouse gas emissions, the following assumptions are made: The average annual emissions from 4,300 hectares of degraded pastures are 10,248 Gg of CO2.	In the central part of Vashlovani National Park, on the identified section along the Lekistskali River, 4000 ha of degraded pastures and 300 ha of sheep migration routes have been completely rehabilitated.	By 2020, the total has been reduced to 71.73 Gg CO2	**Environmental Benefits:** Mitigation of environmental degradation **Social benefits**: Empowering the local population, promoting livestock and sheep breeding
5	Implemented (2014-2018)	**Title:** Expansion of protected areas in Adjara region and improvement of management efficiency. **Objective**: To improve the management of protected areas and reduce CO2 emissions **Implementation level** - regional	**Budget:** $ 1.3 million **Funding source**: GEF **Implementer**: LEPL Agency of Protected Areas	Average per year - 22.9 Gg CO2	To calculate the potential for reducing greenhouse gas emissions, the following assumptions are made: 1 hectare of agricultural forest area is collected (according to 2015 data) - 0.73 t C, in case of change of its status it will accumulate -0.87 t C (3.2 t CO2). Machakhela forest area - 7,174 ha.	Sustainable Management Area Increased: Machakhela National Park (8,733 ha area) was established, an appropriate governance structure (or National Park Governing Board) was established, a deep ecological and resource use inventory was completed, and detailed management zoning was defined.	By 2020, 27.9 Gg of CO2 has been reduced	**Environmental benefits:** High level of protection and conservation of biodiversity components **Social benefits**: Creating additional income and opportunities for local people in the field of tourism and agriculture
6	Ongoing (2020-2023)	**Title**: Restoration of 625 ha of degraded forest area (including fire forests) through forest cultivation **Implementation Level** - National (in different regions)	**Budget:** Not estimated **Source of funding**: State budget **Implementer**: LEPL National Forest Agency	Annually -11.5 Gg CO2 eq.	The EX-ACT41 model is used in accordance with the Greenhouse Gas Inventory Manual (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent/ha per unit year.	Forest restoration projects have been prepared for the activities to be implemented in 2020. In 2020, forest planting will be carried out on an area of 40 hectares. Recovery areas are being identified	Reduced by 2020 (40 ha cultivation) to 0.8 Gg CO2	**Environmental benefits:** Restored forest ecosystem, conserved biodiversity **Social benefits**: locals employed on jobs
7	Ongoing (2020-2024)	**Title:** Rehabilitation of 2,411 ha of degraded forest area by facilitating natural renewal **Objective:** Rehabilitation of 800 ha of degraded forest area by the National Forest Agency in 2020-2023 (200 ha annually). Restoration of 600 ha of degraded (subalpine) forest area by Adjara Forest Agency in 2019-2024. Rehabilitation of 991 ha of forest area by Akhmeta Municipality in	**Budget:** Not estimated **Source of funding**: state budget; GIZ **Implementer**: LEPL National Forest Agency, LEPL Adjara Forest Agency, Tbilisi Municipality City Hall, Akhmeta Municipality	Per year - 6.9 Gg of CO2 eq.	The EX-ACT model is used in accordance with the Greenhouse Gas Inventory Guidelines (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent/ha per unit year.	Forest restoration project for 267.1 ha area has been prepared. Restoration of degraded forest area will be carried out by LEPL National Forest Agency in 2020. Restoration of 20 ha of degraded forest area by Tbilisi	Reduced (20 ha recovery) by 2020 to 0.4 Gg CO2	**Environmental benefits:** Restored forest ecosystem, conserved biodiversity **Social benefits**: locals employed on jobs

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
		2020-2024. Increase greenhouse gas absorption potential. **Implementation Level** - National (in different regions)				Municipality - in 2019.		
8	Ongoin g (2020-2027)	**Title:** Establish sustainable forest management practices through the implementation of sustainable management plans **Objective**: To establish sustainable forest management practices in the area of 402,109 ha according to the forest management plan prepared for 11 municipalities as a result of the inventory, which also includes forestry measures (forest restoration, forest maintenance, sanitary felling, timber production, etc.) Arranging forest infrastructure **Implementation Level** - National (in different regions)	**Budget:** Not estimated **Source of funding**: state budget; GEF; Government of Slovenia; Government of Germany, Government of Austria **Implementer**: LEPL National Forest Agency; SSD Department of Environmental Supervision Department of Biodiversity and Forestry Akhmeta Municipality A (A) IP "Tusheti Protected Landscape Administration"	Per year - 560 Gg of CO2 eq.	The EX-ACT model is used in accordance with the Greenhouse Gas Inventory Guidelines (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent/ha per unit year.	Forest management plans for 63,763 ha (Chokhatauri, Lanchkhuti) have been prepared and approved Field works completed 21,116 ha (Lagodekhi) Field works are underway on 131,842 ha (Akhmeta, Lentekhi)	NA	**Environmental Benefits:** Long-Term Forestry Measures, Sustainable Resource Extraction **Social benefits**: Increased access to forest resources as a result of organized forest use
9	Planned (2020-2027)	**Title:** Establishing sustainable forest management practices by strengthening oversight and capacity **Objective**: To establish and implement sustainable forest management practices in 270,807 ha of forest area by strengthening the supervision, sustainable logging and production of firewood, legal framework, knowledge management and capacity, measurement, reporting and verification (MRV) system. **Implementation Level** - National (in different regions)	**Budget:** Not estimated **Source of funding**: state budget; GEF; **Implementer**: GIZ, LEPL National Forest Agency; SSD Department of Environmental Supervision	Annually - 393 Gg of CO2 equivalent.	The EX-ACT model is used in accordance with the Greenhouse Gas Inventory Guidelines (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent/ha per unit year.	A project application has been prepared and submitted to the Green Climate Fund	NA	**Environmental benefits:** reduced degradation caused by illegal activities **Social benefits**: Increased access to forest resources as a result of organized forest use
10	Planned (2020-2030)	**Title:** Protection and sustainable management of the approved and candidate Emerald Forest Area within the Territory **Objective**: To protect and sustain 643,100 ha (590,103 ha approved, 52,997 ha candidate) within the approved and candidate Emerald Network area. **Implementation Level** - National (in different regions)	**Budget:** Not estimated **Funding source**: Not identified **Implementer**: LEPL National Forest Agency; LEPL Agency of Protected Areas; Department of Biodiversity and Forestry (MEPA)	Annually -51 Gg of CO2 equivalent.	The EX-ACT model is used in accordance with the Greenhouse Gas Inventory Guidelines (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent/ha per unit year.	Research is underway to prepare appropriate management plans for 337,730 ha (9 places) in Samegrelo-Zemo Svaneti and Racha-Lechkhumi-Kvemo Svaneti regions.	NA	**Environmental benefits:** Conservation and protection of biodiversity **Social and Economic Benefits**: Development of additional jobs and incomes through the development of multi-purpose forest use, both for the local population and for forest management bodies

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
11	Planned (2020-2030)	**Title:** Protection and/or sustainable management of the forest area within the extended and newly protected areas **Objective**: To protect and / or sustainably manage the forest area of 38 hectares (29 hectares of Javakheti protected area, 9 hectares of Kolkheti protected area) within the extended protected areas. Protection and/or sustainable management of 162,895 ha of forest area within the new protected areas. **Implementation level**: Regional	**Budget:** Not estimated **Funding source**: Not identified **Implementer**: LEPL Agency of Protected Areas;	Within the Extended Protected Areas: 4330 ECG of CO2 by 2030. Within the New Protected Areas: By 2030 - 212.9 g of CO2 equivalent. from where: Established Erusheti National Park - 7.0 Gg. CO2 eq. Established Racha National Park - 28.7 Gg. CO2 eq. Established Racha-Lechkhumi protected areas - 48.1 Gg. CO2 eq. Established Aragvi Protected Landscape - 39.8 Gg. CO2 eq. Established Svaneti Protected Areas - 37.2 Gg. CO2 eq. Established Samegrelo Protected Areas - 20.6 Gg. CO2 eq.) Established Trialeti Protected Areas - 7.8 Gg. CO2 eq. Established Brotherhood Protected Areas - 15.8 GHz CO2 Eq. Established Athenian Protected Areas - 7.8 GHz CO2 eq.	The EX-ACT model is used in accordance with the Greenhouse Gas Inventory Guidelines (IPCC 2006). EX-ACT is a metering system that determines the carbon stock as well as the scale of change (including emissions and absorption) by land area and is measured in tonnes of CO2 equivalent / ha per unit year.	No specific activities have been initiated	NA	**Environmental benefits:** Conservation and protection of biodiversity **Social and Economic Benefits**: Developing Multipurpose Forest Use Additional Jobs and Income for Both Local and Forest Management Bodies

3.3.6 Waste Sector

In Georgia, like other developing countries, waste management is associated with a number of financial and environmental problems of national, regional and local importance. The waste sector in the country (solid waste and wastewater) is an important source of greenhouse gas emissions. The waste sector in Georgia is represented by sub-sectors of solid waste disposal sites (landfills), solid waste biological treatment, solid waste incineration and wastewater treatment.

The country strives to develop a solid waste management system based on best international practices; Introduce an integrated waste management system to ensure that (a) all residents have access to a clean-up/waste disposal service with modern regional landfills and transfer stations that will gradually replace existing, non-standard landfills with modern methane systems; (b) a gradual reduction in the disposal of biodegradable waste at landfills; (c) an increase in the amount of recycled waste; and (d) production of high quality compost.

In order to improve the solid waste management system, a number of important steps have been taken by the responsible agencies in recent years, which have completely changed the current situation. Landfills in the regions were improved (infrastructure was built, fenced, weighbridges were installed, operators were appointed, an accounting system was developed and introduced, etc.).

The infrastructure of the wastewater collection and especially the treatment system in the country needs to be significantly improved. Regulating the water supply and sewage system remains a significant challenge in Georgia.

Although fundamental changes have taken place in the waste management sector, the current data on mitigation of greenhouse gas emissions are almost unchanged. In the future, the implementation of current and planned activities in the sector is expected to yield significant practical results.

At present, the waste management sector is regulated by legislation, strategic documents and international commitments made by the country in the field of waste management in accordance to Euro directives.

In Georgia, like other developing countries, solid waste management is associated with challenges of national, regional and local importance and a number of financial and environmental problems. According to the results of the National Greenhouse Gas Inventory in Georgia, the disposal of solid waste and wastewater in the waste sector is an important source of greenhouse gas emissions.

Significant changes have taken place in the waste management sector since the presentation of Georgia's Third National Communication to the UN Framework Convention on Climate Change. A waste management policy (legislation and strategic documents) has been developed in accordance with European directives and taking into account the experience of developed countries. At present, almost all (except Adjara landfills) existing non-hazardous waste landfills are operating according to the compliance plan; In accordance with the requirements of the legislation, landfills were closed and transfer stations were constructed, and construction of new, international standard, regional non-hazardous waste landfills was planned. Rehabilitation/arrangement of wastewater network and construction of wastewater treatment facilities have been implemented, are underway and are planned throughout Georgia.

Nevertheless, emissions from the waste sector are characterized by an upward trend over the years; In particular, methane emissions from existing household waste landfills are increasing due to the increase in the amount of biodegradable waste disposed of in landfills. Methane emissions from existing landfills are managed only at the landfill in Rustavi under the auspices of the Georgian Waste Management Company

Ltd., where a torch in accordance with modern standards for landfill gas combustion was installed in 2020 and methane emissions management is underway. The problem is the lack of accurate data on both the amount of household waste generated and its fractional composition. Also, the information on the condition of wastewater treatment systems in industrial facilities is inaccurate.

The waste sector in Georgia is represented by sub-sectors of solid waste disposal sites (landfills), solid waste biological treatment, solid waste incineration and wastewater treatment. In recent years, a number of important steps have been taken by the responsible agencies to improve the solid waste management system, which has completely changed the current situation. Improvement of existing landfills was carried out: all landfills were fenced, infrastructure was arranged, weighbridges were installed, operators were appointed, an accounting system was developed and introduced, etc.

Landfills

At present, there are 57 official municipal landfills in the country: one landfill in Tbilisi, two in the Autonomous Republic of Adjara, and 54 landfills in the regions of the country. Only two landfills (Tbilisi and Rustavi) have the right to continue operating on the basis of a permit issued in accordance with the Law of Georgia on Environmental Impact Permits. Of the remaining 54 landfills, 23 have already been closed and 31 landfills are still operational.

In the future, by 2025, it is planned to arrange 7 new regional landfills throughout Georgia, in accordance with international standards, the construction of the eighth landfill has already started in Adjara. In the end, all landfills together must fully ensure the safe disposal of household waste generated in the country for the environment and human health.

Household waste is mainly collected in cities and district centers. Part of the rural population does not use the cleaning service. This part of the rural population dumps household as well as hazardous waste in the surrounding rural areas, in ravines, riverbeds, thus creating hundreds of uncontrolled, natural landfills.[89].

In most municipalities, there is no accurate information on the size of the illegal landfill areas, the exact fractional composition and quantities of waste dumped there. Their closure/remediation is included in the National Strategy for 2020.

Information on the composition of municipal waste in Georgia is based only on studies or expert assessments conducted within the framework of various international projects (in Tbilisi, Kvemo Kartli, Kutaisi, Kakheti and Adjara Autonomous Republic). According to this assessment, the waste generated by the population living in cities and districts varies from each other in quantity and composition.

Separation of municipal waste is fragmented in municipalities. A large amount of biodegradable fraction is found in municipal waste to be disposed of in landfills, the decomposition products of which are a source of methane emissions.

Composting

The country lacks the technical and technological capabilities for biodegradable waste recycling, human resources with relevant skills. Composting of organic waste is carried out in fragments. Only individual farmers and small-capacity composting plants in Marneuli produce compost from biodegradable waste. At

[89] Generally, a natural landfill is an uncontrolled dump of construction and household waste.

the same time, currently only a newly established company in Kutaisi (within the framework of an international project) has received an official permit for composting in the country.

Incineration

Insufficient awareness from stakeholders and the public involved in waste management issues leads to the practice of open burning of green waste, used oils and plastic waste by the population. The latter causes air pollution and poses a threat to both human health and the environment.

Incinerators operating in the country operate only on medical waste, without further use of energy.

Wastewater

One of the most important sources of greenhouse gas emissions from the waste sector is wastewater, which includes domestic, commercial and industrial wastewater. Lack of wastewater treatment facilities and sewage network in cities and regional centers, out of order treatment plants have a negative impact on the environment, polluting rivers and other waters, which in turn poses a great risk to human health.

Today, 80% of the country is connected to the sewage network. Although the sewage network has been significantly improved, it is provided only to the population living in the centers and cities of the regions. As for the rural population, most of them are without sewage system. There are 45 treatment systems in Georgia, however, most of the wastewater treatment facilities do not provide quality treatment. Only 4 wastewater treatment plants (Gardabani (serving Tbilisi-Rustavi and Mtskheta), Batumi (Adlia), Kobuleti and Sachkhere) more or less meet modern standards.

Sewage treatment plants in accordance with international standards are in test mode in Ureki, Anaklia, Zugdidi and Poti. A total of 48 sewage projects are underway and planned (27 projects include sewage network construction and 21 projects - construction of treatment facilities, of which 7 treatment facilities are under construction and 14 are planned). Modern, biological treatment technology has been selected for wastewater treatment in treatment facilities. Clearly, after the treatment plant is put into operation, the pollution of surface water bodies will be significantly reduced, which will dramatically improve the living conditions of the population and reduce the risk of adverse health effects.

Although fundamental changes have taken place in the waste management sector, the current data on mitigation of greenhouse gas emissions are almost unchanged.

Challenges remain the arrangement of wastewater collection and treatment system infrastructure, the construction of new, regional landfills and wastewater treatment plants, and scarce and inaccurate information on the composition and amount of waste. To date, no existing and closed landfills, as well as existing wastewater treatment plants, have a methane emission management system. The problem is the scarcity of qualified local engineering staff in the waste sector.

Georgian Policy in the Waste Sector

At present, the waste management sector is regulated by legislation, strategic documents and international commitments made by the country in the field of waste management.

According to the 2016-2030 National Waste Management Strategy goals and objectives, Georgia aspires to become a country focused on waste prevention and recycling, which aspires to introduce an integrated waste management system with the best international experience; a system that provides access to cleaning/waste disposal services for all residents, and a modern methane removal system will be introduced at all new and closed (where cost-effective) landfills; a system that provides a gradual reduction of biodegradable waste disposal and the production of high quality compost from biowaste, as well as increasing the amount of recycled waste.

The Waste Management Code, which came into force in January 2015, establishes the legal framework for waste collection, transportation, processing, storage and disposal, and defines the rights and obligations of the competent authorities. The Code introduced the European Hierarchy of Waste Management, clarified the categories of landfills (hazardous waste, non-hazardous waste and inert waste landfills), tightened sanctions/penalties for waste pollution, etc.

Under the Waste Management Code, from 2019, municipalities will be required to introduce a separate household waste collection/transportation system, which is likely to significantly reduce the amount of recyclable waste to landfill as well as the amount of waste to be disposed of.

The document "Regional Development Program of Georgia 2018-2021" approved in 2018, as well as the document "Strategy for Development of Mountainous Settlements of Georgia 2019-2023" (2019) emphasize the balanced development of the country's regions. Which, among other activities, includes the maintenance of water supply and sewerage systems and solid waste management systems, ensuring access to services.

The Government of Georgia has implemented a number of measures to improve wastewater management, which are being implemented by the United Water Supply Company of Georgia, managed by the Ministry of Regional Development and Infrastructure of Georgia, for example with the financial support of the European Investment Bank (EIB), the feasibility study of Gori, Samtredia, Ninotsminda, Zestaponi was completed. In addition, Telavi and Tskaltubo sewage treatment plants have already been built with the funding of the World Bank, the project was implemented by the LEPL Municipal Development Fund of Georgia under the control of the Ministry of Regional Development and Infrastructure, the final beneficiary is the United Water Supply Company of Georgia. In addition, the project, funded by the German Bank for Reconstruction and Development (KfW), is conducting feasibility studies for the improvement of water supply and sewerage systems in Samtredia, Vani and Baghdati, followed by detailed design and future construction works. With the financial support of the French Development Agency (AFD), the construction of Khashuri sewage systems and treatment plant will be carried out. The design works of sewage systems and wastewater treatment plants of Dusheti, Zhinvali, Pasanauri, Martvili, Kvareli, Abastumani and Bakhmaro resorts have been completed.

The construction of wastewater treatment plants in Ureki and Anaklia has already been completed, which will provide both mechanical and biological treatment.

In 2020, the Code enters into the Principle of "Extended Producer Responsibility" (EPR), which means that the manufacturer and importer are required to ensure that their products (e.g. batteries, recycled vehicles, oils, packaging materials and electrical and electronic equipment) are collected for separation and recycling for further recovery.

In the context of an "Extended Producer Responsibility", it is important for economic operators and, in particular, producers of products containing biodegradable products or products with biodegradable components to participate in the entire life cycle of the substances, components and products themselves - from production to waste.

Providing adequate sewerage and sanitation systems to the population of the country, which includes the regulation of sewerage system infrastructure, is one of the medium-term goals of the Second National Environment and Health Action Plan of Georgia 2018-2022 (NEHAP-2).

In 2019, a draft "Biodegradable Waste Management Strategy" was developed, which is expected to enter into force in 2020. The strategy aims to reduce the amount of biodegradable waste in landfills, promote environmental mitigation and mitigate the effects of climate change.

In addition to the environmental, social and economic effects, the implementation of the legislative requirements and the objectives set out in the strategic documents in the waste sector have the potential to reduce greenhouse gas emissions. This last one will help Georgia to fulfill its obligations under the Paris Agreement.

The updated NDC does not set a target for mitigation in the waste management sector by 2030, but the Climate Action Plan outlines measures that could reduce greenhouse gas emissions by up to 41% by 2030 compared to the traditional business development scenario. Georgia supports the development of low-carbon approaches through the promotion of innovative technologies and services tailored to climate change.

A detailed description of completed, ongoing and planned mitigation measures in the waste sector is presented in the table below.

Table 3.3.6.1: Implemented, ongoing and planned mitigation measures in the waste sector

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
1	Implemented 2015-2017	**Title:** Compost production in Marneuli municipality **Objective**: Production of compost from biodegradable municipal waste. **Implementation level** - local	**Budget:** 90,000 GEL per year **Source of funding**: local budget **Implementer**: Marneuli Organic Waste Processing Plant	0.075 Gg CO2 eq. annually by 2030	Emissions were calculated taking into account the amount of reduced biodegradable waste and composting emissions (IPCC 2006). Average annual production of 450 tons of compost. N20 emissions of methane and nitrous oxide correspond to (94.7 kg CO2 eq/t compost (IPCC 2006, chapter 4, BIOLOGICAL TREATMENT OF SOLID WASTE; Hellenbrand, 1998). Hellenbrand, HJ (1998). Source: Emission of nitrous oxide and other trace gases during composting of grass and green waste. Journal of Agricultural Engineering Res. 69 pp. 365-375.)	The enterprise has been operating since 2017 and supplies hypermarkets with compost.	In 2017, 90 tons of green and biodegradable household waste were recycled, in 2018 - 410 tons, and in 2019 - 450 tons. Approximately 90.8 tonnes of compost was produced during 2017-2019, which corresponds to a reduction in 8.6 tonnes of CO2 emissions.	**Environmental benefits:** Reduced amount of waste in the environment. Ecologically clean fertilizer is produced. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced.
2	Ongoing 2020-2023	**Title:** Closure of municipal waste landfills **Purpose**: Closure of existing official, municipal waste landfills **Implementation level** - regional	**Budget:** The budget will be adjusted after a preliminary study **Funding source**: Central and local budget. Donor organizations **Implementer**: Ministry of Regional Development and Infrastructure Partner organization: Ministry of Environment and Agriculture; Relevant municipalities.	72.5 Gg CO2 eq. annually by 2030. Cumulative: Total 2024-2030: 434.49 Gg CO2 eq. (= 20.69 g CH4 :).	<u>Methodology:</u> IPCC Waste Model (updated) <u>Assumptions</u>: Closing will end in 2024. Emission reduction methodology "Calculation of pollutant emissions from solid household landfills". Source: "Kutaisi Integrated Solid Waste Management - EIA Report, 2017	Tender proposals are being studied for the project of closing the existing landfill in Kutaisi, donor KfW. A plan to close the Dmanisi landfill was prepared and agreed with MEPA	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced.
3	Ongoing 2020-2038	**Title:** Construction of a landfill in Adjara **Objective**: Construction of a new landfill in Adjara, collection and disposal of landfill gas (methane) Implementation level - regional	**Budget:** 7 million euros and 4.5 million GEL **Source of funding**: EBRD (funding in Euro), Government of Adjara (GEL). Implementer: "Hygiene" Ltd	14 Gg CO2 eq. Annually by 2030. 2022-2030 Total 6,048 g CH4 = 127 g CO2 eq.	<u>Methodology</u> "Calculation of pollutant emissions from solid household landfills". <u>Assumptions</u>: A total of 840,681 tons of methane are produced per year. Its 80% 'extraction' will start after 2 years and amount to 672,545 t / year, while the remaining 20%, which is 168,136 t, will be released into the atmosphere. Source: "Environmental Impact Assessment Report for Construction and Exploitation	A preliminary socio-economic justification project and a document on social and natural environment were prepared. A construction permit has been obtained. It is expected to be commissioned in 2021 for a period of 33 years -2054. Based on the tender, a construction company has been identified,	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. 27 new jobs will be created.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
					of Adjara Solid Household Waste" 2014	preparatory works for the construction of a landfill have started		
4	Ongoing 2019-2021	**Title:** Methane collection and incineration at Rustavi landfills **Purpose**: Collection and incineration of methane in existing landfills under the Georgian “Solid Waste Management Company” **Implementation level** - Municipal	**Budget:** 605,000 GEL **Source of funding**: State budget and EBRD - technical assistance - international expert services **Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure.	14.5 Gg CO2 eq. annually by 2030.	**Methodology:** GasSim2-atmospheric dispersion model was used. With the installation of the torch, 4.308 million m3 of gas is expected to be emitted from the landfill by 2020 over a period of 15 years (2019-2034). Of this, 2.15 million m^3 is methane. Emitted without torch - 38 g CO2 eq. Methane emissions from landfills will be reduced by 59%. Which is equal to 4.13 g CH4 (86.73 Gg CO2 eq) 2024-2030 **Source**: Preliminary Survey Report on Gas Storage and Disposal at Rustavi Landfill, 2018	Conceptual design has been developed for gas assembly and torch installation, the torch will be installed by the end of 2020.	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced.
5	Ongoing 2020-2021	**Title:** Gas (methane) collection and disposal at the Tbilisi Municipal Landfill **Implementation level** - Municipal	**Budget:** to be specified after preliminary study within the project of 57 million GEL landfill design **Source of funding**: Tbilisi Municipality **Implementer**: Tbilisi City Hall, Tbilservice Group,	114 Gg CO2 eq. Annually by 2030. It is expected to reduce emissions of 32.4 Gg methane (680.4 Gg CO2e) by 2025-2030.	<u>Assumptions:</u> The total biogas release potential is 581 million m3. For 75 years. 80% or 474.8 million m^3 will be extracted. 206 Gg of methane; Source: "Environmental and Social Impact Assessment Report". Tbilisi Solid Household Waste Landfill Construction and Operation Project 2009.	A tender has been announced for the development of a landfill design, which includes the development of a conceptual design for gas collection and torch installation. An implementing company is being selected.	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
6	Impleme nted and conclude de	**Title:** Introduction of an integrated household waste management system in Kvemo Kartli. **Objective**: Construction of a regional non-hazardous waste landfill and reloading stations; Closure of existing landfills. **Implementation level** - regional	**Budget:** 7 million Euros - loan, 3 million Euros - capital grant and 1.1 million Euros - technical assistance grant. **Source of funding**: EBRD and state budget **Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure.	36 Gg CO2 eq. annually by 2030.	<u>Assumptions:</u> 35,000 - 65,000 tons of waste disposed per year, 2019-2039, total 1,390,000 m3; Typical municipal waste composition (17.5% paper/textile, 1% garden waste, 30% food waste, 1% wood/straw, 50.5% inorganic); Typical standard approximate factors - methane enrichment factor = 1, organic waste fraction = 0.77.	The site selected for the landfill was relocated, a preliminary survey was conducted to select a new site, a scoping report was prepared and sent to the Ministry of Environment and Agriculture for consideration.	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
					Reduction of methane emissions during 3 years of torch combustion 0.0392 g CH4/s (= 823 t CO2 eq/yr), then - 1.735 g CH4/s (= 36,442 t CO2 eq/yr) Source: Kvemo Kartli Solid Waste Management Project Environmental Impact Assessment Report, 2016			
7	Planned 2020-2023	**Title:** Construction of a new regional landfill in Imereti. **Purpose**: Collection and disposal of landfill gas (methane). Aside from Imereti, the landfill will serve Racha-Lechkhumi and Kvemo Svaneti **Implementation level** - regional	**Budget:** € 26 million: € 20 million loan KfW, € 2 million grant KfW, € 4 million Contribution to Georgia **Source of funding**: KfW Georgia Contribution **Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure	93 Gg CO2 eq. annually by 2030. 2023-2030 -742 Gg CO2 eq.	Assumptions: Landfill life cycle 50 years; Presumably 50% efficiency of gas collection; Burning using a torch for the first 2 years; 240 million m^3 of landfill gas (methane and CO2) is expected in -50 years. However, 120 million m^3 of methane is equivalent to 2.13 million tons of CO2. The amount of methane supplied to the torch is: 4205.245 t/year or 5865055.788 m^3/year. Methane gas density at 20 ° C and 101.3 kPa pressure: 0.668 kg/m^3 or 1 mW mass of methane = 0.71 kg; Source: Kutaisi Integrated Solid Waste Management - Environmental Impact Assessment Report, 2017	The area selected for the construction of the landfill was relocated. A scoping report and a social and environmental impact document will be developed. Construction work is scheduled to start in 2021.	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. 47 new jobs will be created.
8	Planned 2020-2023	**Title:** Introduction of an integrated household waste management system in Samtskhe-Javakheti, Mtskheta Mtianeti and Shida Kartli regions. **Objective**: Construction of a regional non-hazardous waste landfill and transfer stations; Closure of existing landfills. Methane collection and incineration/incineration at new landfills. **Implementation level** - regional	**Budget**: loan 35 ml euro, grant 2 ml euro, local contribution 3 ml euro **Source of funding**: KfW, EBRD Georgia Contribution **Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure,	Will be assessed after the preparation of the Environmental Impact Assessment (EIA)	Methodology: Rattenberg Formula ("Gas Generation Management Manual", Trier, 1995) Reduction of greenhouse gases in 2030 compared to the BAU scenario. Assumptions: Existence of appropriate utility for disposal; Commissioning 2023; Landfill life cycle: 50 years; Presumably 50% efficiency of gas assembly. Source: "Central Georgia - Solid Waste Project Feasibility Study" 2020	The scoping document will be prepared first, then the social and natural environmental impact document - EIA, the submission of documents for environmental decision and construction permit is scheduled for 2021, the start of operation - 2023.	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
9	Planned 2020-2023	**Title:** Introduction of integrated household waste management system in Kakheti and Samegrelo Zemo Svaneti regions. **Objective**: Introduce an integrated household waste management system.	**Budget**: 38 million Euros Out of this: 30 million Euros - loan, 2 million Euros - technical assistance grant, the rest - Georgian contribution **Funding source**: KfW, Georgia Contribution	19 Gg CO2 eq. annually by 2030.	Methodology: Rattenberg Formula ("Gas Generation Management Manual", Trier, 1995) Assumptions: Total amount of waste: 1 million tonnes of	Studies were conducted, a preliminary socio-economic substantiation project was prepared; A document on the impact of social and natural	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
		Construction of a regional non-hazardous waste landfill and transfer stations, closure of existing landfills. **Implementation level** - regional	**Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure,		organic carbon over the entire life cycle of the landfill. C = 250 kg / t, T = 30 ° C, decomposition parameter k = 0.04. The entire operating period (45 years) generates 290 million m3 of gas. Source: KfW - Integrated Solid Waste Management Program II Georgia: Kakheti and Samegrelo-Zemo Svaneti Regions' Preliminary Technical-Economic Research Report 2017	environment was developed.		harmful substances from landfills are reduced. 47 new jobs will be created.
10	Planned 2020-2022	**Title:** Composting of organic and garden waste in Kutaisi municipality **Implementation level** - Municipal	**Budget:** to be specified after preliminary study **Source of funding**: International project "Black Sea Basin Program 2014-2020 (JOP Black Sea Basin 2014-2020) **Implementer**: Kutaisi Municipality, Partner Organization: Imereti Region Scientists Union "Spectrum" (Georgia)	1 Gg CO2 eq. annually by 2030.	Biodegradable waste composting emissions are calculated based on the calculation of reduced biodegradable waste potential emissions using the IPCC Waste Model. Source: JOP Black Sea Basin 2014-2020 project document	An environmental decision has been made to carry out the activity. Implementation begins in 2020	NA	**Environmental benefits:** Reducing the amount of biodegradable waste in landfills, reducing methane emissions. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
11	Planned 2019-2020	**Title:** Management of greenhouse gas emissions collected by methane tanks at Poti and Zugdidi municipal wastewater treatment plants **Implementation level** - Municipal	**Budget:** 87 million GEL **Funding source**: Asian Development Bank, ADB, local contribution **Implementer**: United Water Supply Company of Georgia, Ministry of Regional Development and Infrastructure	118 Gg CO2 eq. annually by 2030. 2021-2030 is 56.2 Gg of methane (= 1180.2 Gg CO2 eq)	The treatment plant will capture 80% of the generated methane and burn about 50% of it. Emissions reduction is 5.62 Gg of methane per year; Source: Poti Wastewater Treatment Plant 11 663 m^3/day Construction and operation project, Environmental Impact Assessment Report 2016	At present 80% of the construction is completed, the treatment plant will start operating in the second half of 2021	NA	**Environmental and social benefits:** Reduce soil, surface and groundwater pollution Will be reduced, negative impacts on ichthyofauna and human health risks
12	Planned 2022-2026	**Title:** Methane collection and incineration/utilization at existing landfills in Kutaisi **Implementation level** - Municipal	**Budget:** not set - to be implemented within the framework of the 26 million euro "Integrated Waste Management Project" in Kutaisi **Source of funding**: KfW State Contribution **Implementer**: Georgian Solid Waste Management Company, Ministry of Regional Development and Infrastructure,	According to preliminary calculations, 29 Gg of CO2 eq. annually by 2030.	In case of landfill closure: 59% reduction in methane emissions = 9.49 Gg Methane (= 199.3 Gg CO2 eq) 2024-2030 Source: Kutaisi Integrated Solid Waste Management - Environmental Impact Assessment Report, 2017	Closing works will be carried out after the construction of the regional landfill, according to the plan agreed with the Ministry of Environment and Agriculture	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
13	Planned 2022-2024	**Title:** Arranging a system for collecting and recycling gases generated at the existing landfill in Batumi. **Implementation level** - Municipal	**Budget:** not set - will be implemented within the project of Adjara new landfill worth 7 million Euros	25 Gg CO2 eq. annually by 2030. Reduction of methane emissions: 8.31 Gg	Assumption: In case of landfill closure in 2022-2030, a 59% reduction in methane emissions from the remaining mass is expected.	A preliminary study was prepared.	NA	**Environmental benefits:** Reduced amount of waste in the environment.

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
			Source of funding: EBRD and State Contribution **Implementer**: Batumi City Hall	CH_4 (= 174.3 Gg CO_2 eq) 2024-2030.	Source: "Environmental Impact Assessment Report for Construction and Exploitation of Adjara Solid Household Waste" 2014.			**Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
14	Planned 2022-2024	**Title:** Arrangement of gas collection and treatment system at the existing landfill in Kobuleti after its closure. **Implementation level** - Municipal	**Budget:** not set - will be implemented within the project of Adjara new landfill worth 7 million Euros **Source of funding:** EBRD and State Contribution **Implementer**: Local municipality	The amount of landfill gas and its energy potential have not been studied.	Methodology: Torch combustion and energy generation Source: "Environmental Impact Assessment Report for Construction and Exploitation of Adjara Solid Household Waste" 2014	The landfills are equipped with gas collection and recycling systems	NA	**Environmental benefits:** Reduced amount of waste in the environment. **Social benefits**: Emissions and odors of harmful substances from landfills are reduced. New jobs will be created.
15	Planned 2020-2025	**Title:** Paper waste recycling **Implementation level** - regional	**Budget:** to be specified after preliminary study **Source of funding**: private investment, donor organizations, municipalities. **Implementer**: Private companies Partner organization: Ministry of Environment and Agriculture;	48 Gg CO_2 eq. annually by 2030. Methane emission reduction: 483 Gg CO_2 ec (= 23 Gg methane) 2021-2030.	Assumptions: Separate collection of waste paper Methodology: IPCC Waste Model for Methane Emission Calculation Source: Composite waste surveys (in Kvemo Kartli, Kakheti, Adjara, Shida Kartli, Guria, Lechkhumi) and municipalities "Municipal Waste Management Plans 2018-2022"	There are small paper processing enterprises operating in the country	NA	**Environmental and social benefits:** reduction of biodegradable waste in landfills, reduction of methane emissions, creation of new jobs,
16	Planned 2021-2023	**Title:** Arrangement of greenhouse gas collection and treatment systems on the Batumi wastewater treatment plant **Implementation level** - local	**Budget:** 800,000 Euros, **Source of funding**: Donor organizations, international financial institutions **Implementer**: Batumi Water Ltd	23 Gg CO_2 eq. annually by 2030. 2022-2030: 9.6-10.4 Gg of methane (201.6 - 218.4 Gg CO_2 ac)	Methodology and the treatment plant will capture 80% of the generated methane and burn about 50% of it. Part of the methane will be used to supply the building with electricity. In the case of 80% methane 'removal', it is expected that the annual emissions of 1.12-1.32 g of methane (= 23.52 - 27.72 g CO_2eq) will be reduced annually. Source: Batumi (Adlia) Wastewater Treatment Plant Environmental Impact Assessment Report, 2009	A preliminary study was prepared.	NA	**Environmental and Social Benefits:** Reduces greenhouse gas emissions from treatment plants. The collected gases will be used as an additional energy source.
17	Planned 2022-2024	**Title:** Arrangement of greenhouse gas collection and recycling systems on the Tbilisi wastewater treatment plant **Implementation level** - local	**Budget:** to be specified after preliminary study	83 Gg CO_2 eq. Annually by 2030. 2022-2030 is 647 - 696 Gg CO_2 eq.	The treatment plant will capture 80% of the generated methane	Preparatory work was carried out, the potential for greenhouse gas emissions was assessed.	NA	**Environmental and Social Benefits:** Reduces greenhouse gas emissions from

#	Status	Title and Objective Level (national, regional, local)	Budget, sources of funding, implementing agency	Emission reduction potential	Methodology and basic assumptions	Progress in implementing the measure	Achieved result. Emission reduction	Environmental and social benefits
			Source of funding: N/A, presumably International Financial Institutions **Implementer**: Georgian Water and Power Ltd.		and burn about 50% of it, which is 80.934 - 86.94 Gg of CO2 eq. Source: Gardabani Wastewater Treatment Plant EIA Report 2014	At present, observation, monitoring, inspection of the old, existing methane tank system is underway		treatment plants. The collected gases will be used as an additional energy source
18	Planned 2020-2025	**Title:** Reduce the disposal of biodegradable waste in landfills **Objective**: Composting of biodegradable waste at the new regional landfill in Kakheti **Implementation level** - regional	**Budget:** 400,000 euros **Source of funding**: N/A, presumably donors to international financial institutions **Implementer**: Ministry of Environment and Agriculture, Solid Waste Management Company	0.85 g CH4, (17.86 Gg CO2 eq. per year by 2030	Assumption: Organic fraction (food and garden waste) should be removed (separated) for further composting. Food waste and garden waste - 50% (2025), 80% (2030). Source: KfW - Integrated Solid Waste Management Program II Georgia: Kakheti and Samegrelo-Zemo Svaneti Regions' Preliminary Feasibility Study Report 2017	Preliminary research is prepared for the development of project proposals (pilot projects).	NA	**Environmental and social benefits:** reduction of biodegradable waste in landfills, reduction of methane emissions, creation of new jobs,
19	Planned 2022-2025	**Title:** Collection and treatment of greenhouse gases on wastewater treatment plants in Kobuleti **Implementation level** - local	**Budget:** N/A will be specified after preliminary study **Funding source**: Donors, International Financial Institutions **Implementer**: Kobuleti Water Ltd	9 Gg CO2 eq. annually by 2030. 2022-2030: 64.26 - 71.82 Gg CO2 eq	The treatment plant will capture 80% of the generated methane and burn about 50% of it. Potential for reduction of 0.34-0.38 Gg of methane (= 7.14-7.98 Gg CO2 eq) per year, in case of 80% 'removal' of methane. Source: Kobuleti Municipal Wastewater Treatment Plant Construction and Operation Project, Environmental Impact Assessment Report 2013	A preliminary study is being prepared.	NA	**Environmental and Social Benefits:** Reduce greenhouse gas emissions from the treatment plant, collected gases will be used as an additional energy source.
20	Planned 2021-2026	**Title:** Collection and processing of greenhouse gases on Kutaisi wastewater treatment plants **Implementation level** - local	100 million euros, European Investment Bank	9 Gg CO2 eq. annually by 2030. Total, probably 70 Gg CO2 eq. 2022-2030	The treatment plant will capture 80% of the generated methane and burn about 50% of it. Reduction of 0.42 Gg of methane (8.8 Gg CO2 eq) per year Source: Kutaisi Wastewater Treatment Plant 30 059 m^3/day Construction Construction and Operation Project, EIA Report 2016	The final stage of procurement of consulting services is underway	NA	**Environmental and Social Benefits:** Reduce greenhouse gas emissions from the treatment plant, collected gases will be used as an additional energy source.

4 Vulnerability and adaptation

The climate change and its adverse impacts on ecosystems and economy pose severe threats to Georgia's sustainable development. Unique geographical location, complex dissected relief, land cover diversity and specific climate, containing almost every type of climatic zones, set conditions for wide variety of negative consequences of climate change in Georgia: (a) due to sea level rise Black Sea has affected certain areas of land, destroyed and/or damaged houses and infrastructure along the coast; (b) in highlands, growing frequency and intensity of floods, flashfloods, landslides and mudflows have caused huge damage to the economy; (c) due to decreased rainfall and enhanced evaporation semi-arid regions in Eastern Georgia are under the threat of desertification; (d) more frequent and intensive heat waves have affected human health; (e) rising temperatures, changes in precipitation patterns, reduced water availability, forest fires, pests and diseases have slowed down the growth and lowered the productivity of forests. (f) Rising temperatures, increased winds and reduced water availability have significantly declined agricultural productivity.

Effects will become more severe in the future. This will create an extra burden on the development of society. Correspondingly, adaptation to the adverse impacts of the climate change is one of the main priorities for the Government of Georgia. The main objective of the Government of Georgia is to improve country's preparedness and adaptive capacity by developing climate resilient practices that reduce vulnerability of highly exposed communities. In this regard, Georgia takes steps to integrate the climate related risks and resilience into core development planning and implementation.

4.1 Current Climate Change

In order to assess the current climate change, the pattern of changes in intensity and recurrence of average and extreme values of meteorological elements was studied based on data for a 60-year observation period (1956-2015), provided by 39 weather stations of the Georgian Meteorological Network. The stations were selected in a manner that enabled the optimal consideration of climatic features of the territory of Georgia and in accordance with the administrative and territorial division of the country.

Annual, seasonal, and monthly trends in temperature, precipitation, relative humidity and wind speed in the two 30-year periods of 1956–1985 and 1986–2015 have been compared (see details in Tables A1-A4 in the Annex). As it is often impossible to estimate socio-economic impacts of the climate change on different sectors using average values, 35 climatic indices have been calculated alongside with average values of the climatic parameters.

Air Temperature

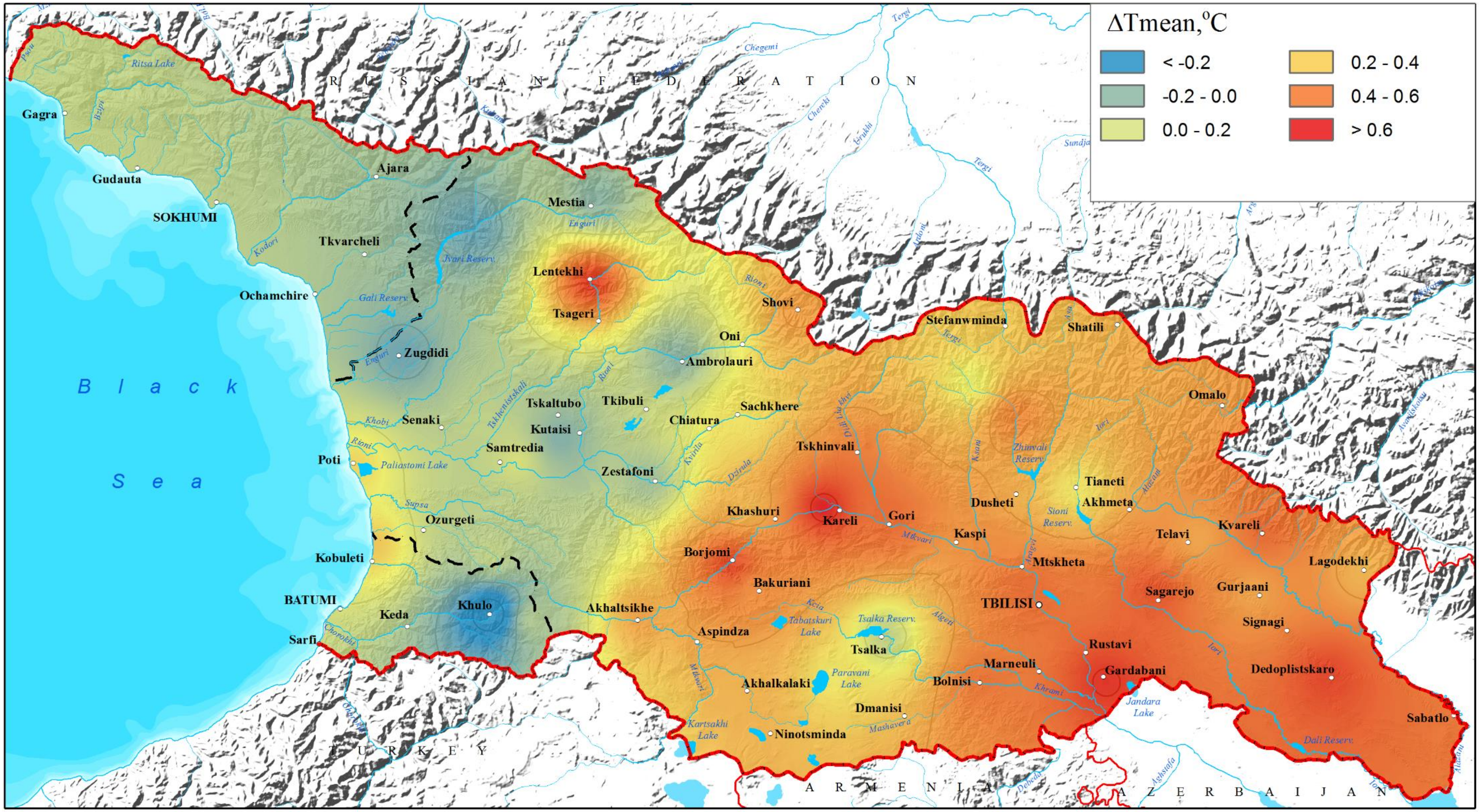
Mean air temperature. Comparing the two 30-year periods (1956-1985 and 1986-2015), we see that the average annual surface air temperature increased throughout the country by 0.25–0.58^{0}C by regions with the average increase of 0.47^{0}C. The warming is relatively intense in Samegrelo (0.63^{0}C in Zugdidi and Poti). The trend of the changes in temperature observed in the mountainous district of Adjara and Guria lacked reliability. The most significant warming was recorded in Dedoplistskaro district, where the annual increase between the two periods reached 0.73^{0}C.

Air temperature analysis by months shows that the warming was mainly caused by the increase in temperature during June-October. The maximum warming was observed in August and ranged within 1.15^{0}C – 1.57^{0}C by regions. The upward trend was persistent and consistent with the patterns observed across much of the country during the same months (June-October), as well as with average annual values. The mountainous districts of Adjara and Guria were the only exception. Quite significant warming was observed in March, especially in eastern regions of Georgia (between 0.51^{0}C and 1.03^{0}C), but the average temperature in Guria and Adjara remained almost unchanged (there was just a slight increase of 0.04^{0}C-0.05^{0}C). In the eastern regions there was an increase in air temperature during January-February (0.27^{0}C-0.69^{0}C), while in November-December, the decrease of temperature was observed throughout the country, with the most significant decrease in Guria (0.46^{0}C) and Adjara (0.45^{0}C). In April-May the change in average temperature is insignificant and relatively unstable.

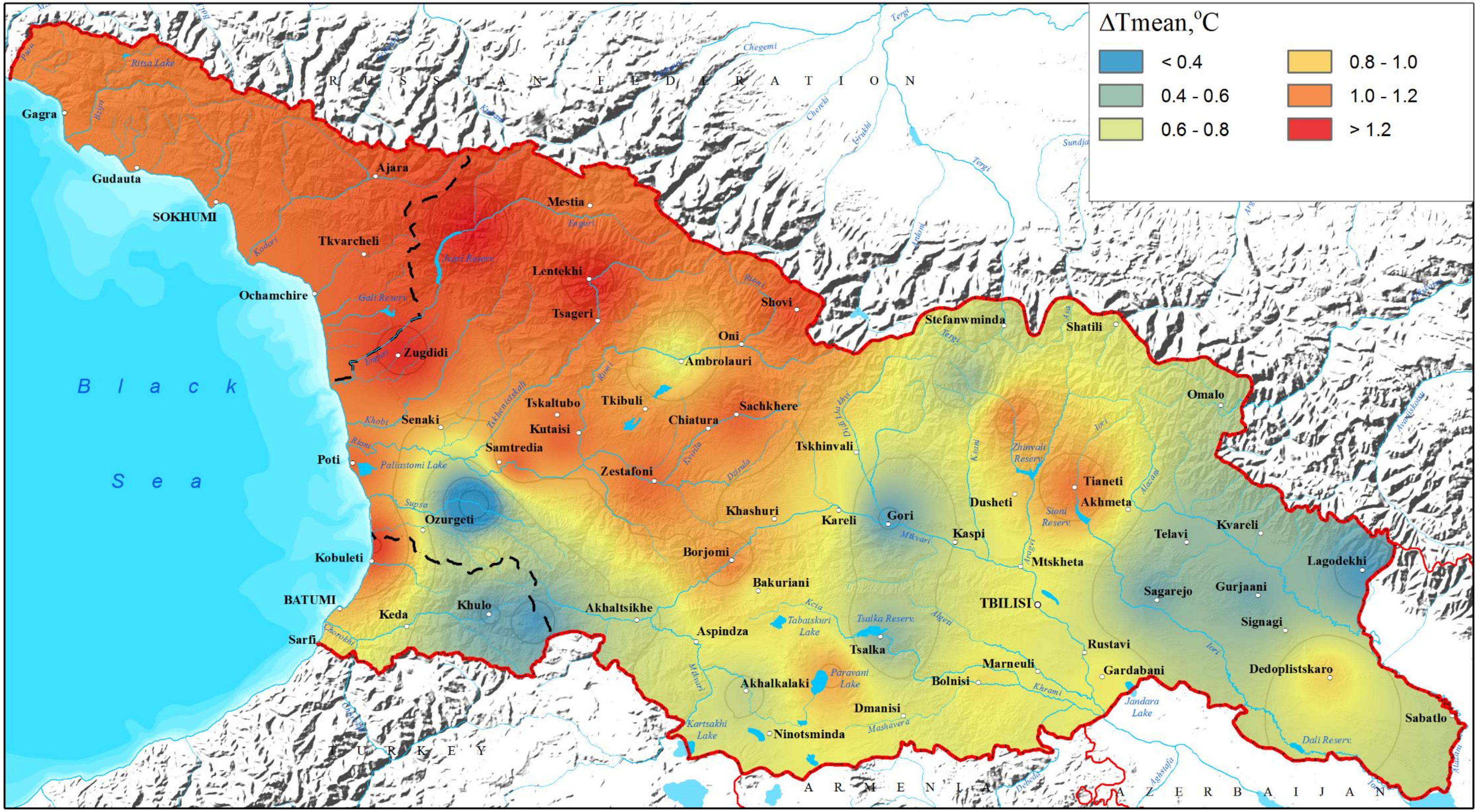
Average maximum temperature. The average maximum temperature has increased tangibly across much of Georgia with the exception of the mountainous regions of Adjara-Guria and Racha-Lechkhumi, as well as Eastern Georgia with its dry subtropical (steppe) climate.

The highest rates of change in the average maximum temperatures were observed at the Black Sea coastal zone and Kolkheti lowland adjacent areas, as well as in the South Georgia Highlands. Judging by daytime temperature, the warming was relatively intense in Eastern Georgia, especially in the southern mountainous areas. Just like with the average temperature, the increase in the average maximum temperatures was mainly conditioned by the increase in the maxima observed during the summer-autumn.

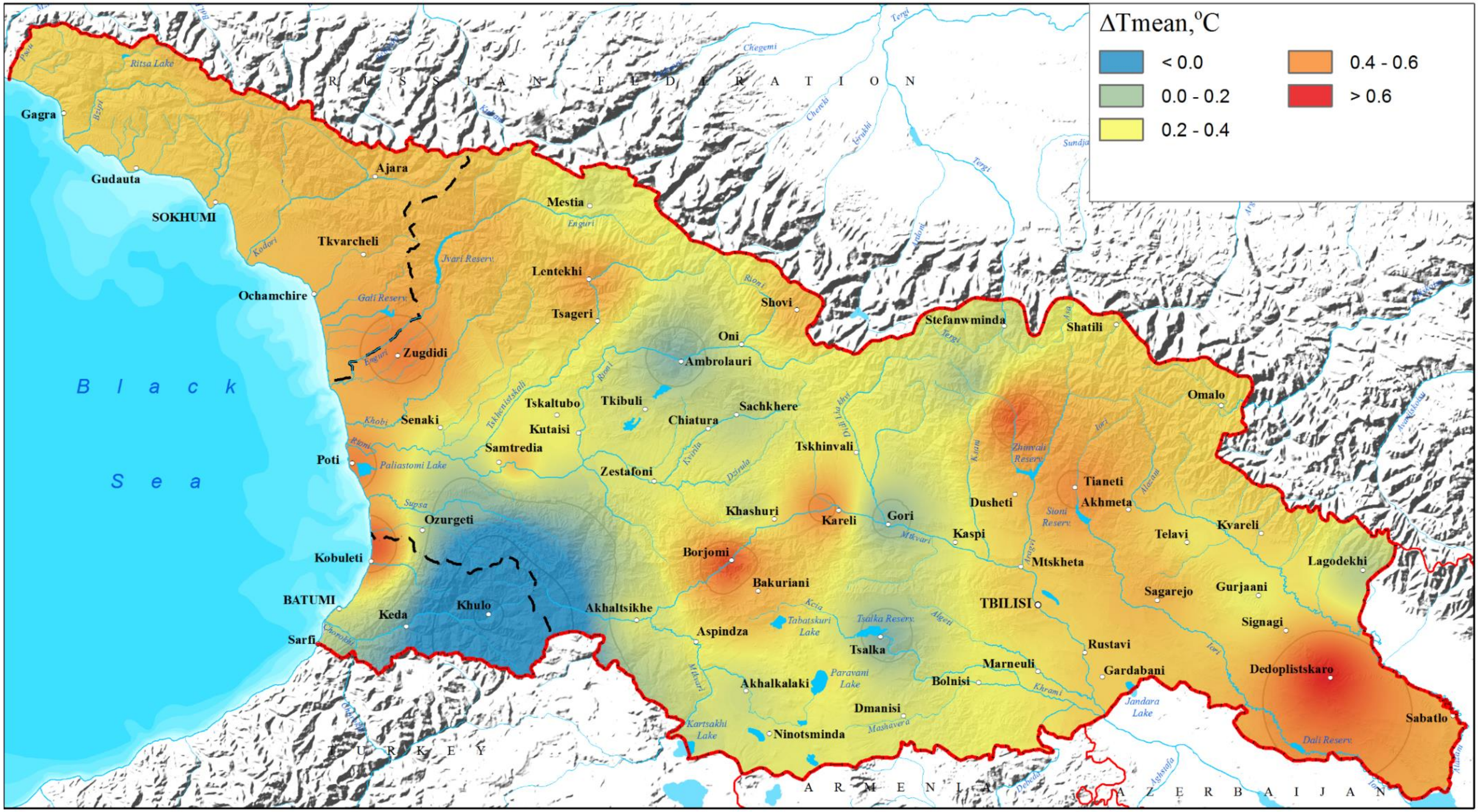
Average minimum temperature. The average minimum temperatures increased across much of Georgia, although, judging by this parameter, the warming trends concerned only one part of the country. The increase in night temperature was within 1^{0}C in 1986-2015 against 1956-1985. The maximum warming was observed in Kakheti. The upward trends were observed at the Black Sea coastal zone, in the Kolkheti lowland and Likhi Range adjacent areas. In Eastern Georgia, the weather stations recorded persistent increase in average minimum temperature in the plains and in the mid-altitude. Just like with the average and average maximum temperatures, the increase in average minimum temperature was mainly conditioned by the increase in minimum temperature recorded the summer and the autumn (June-October).



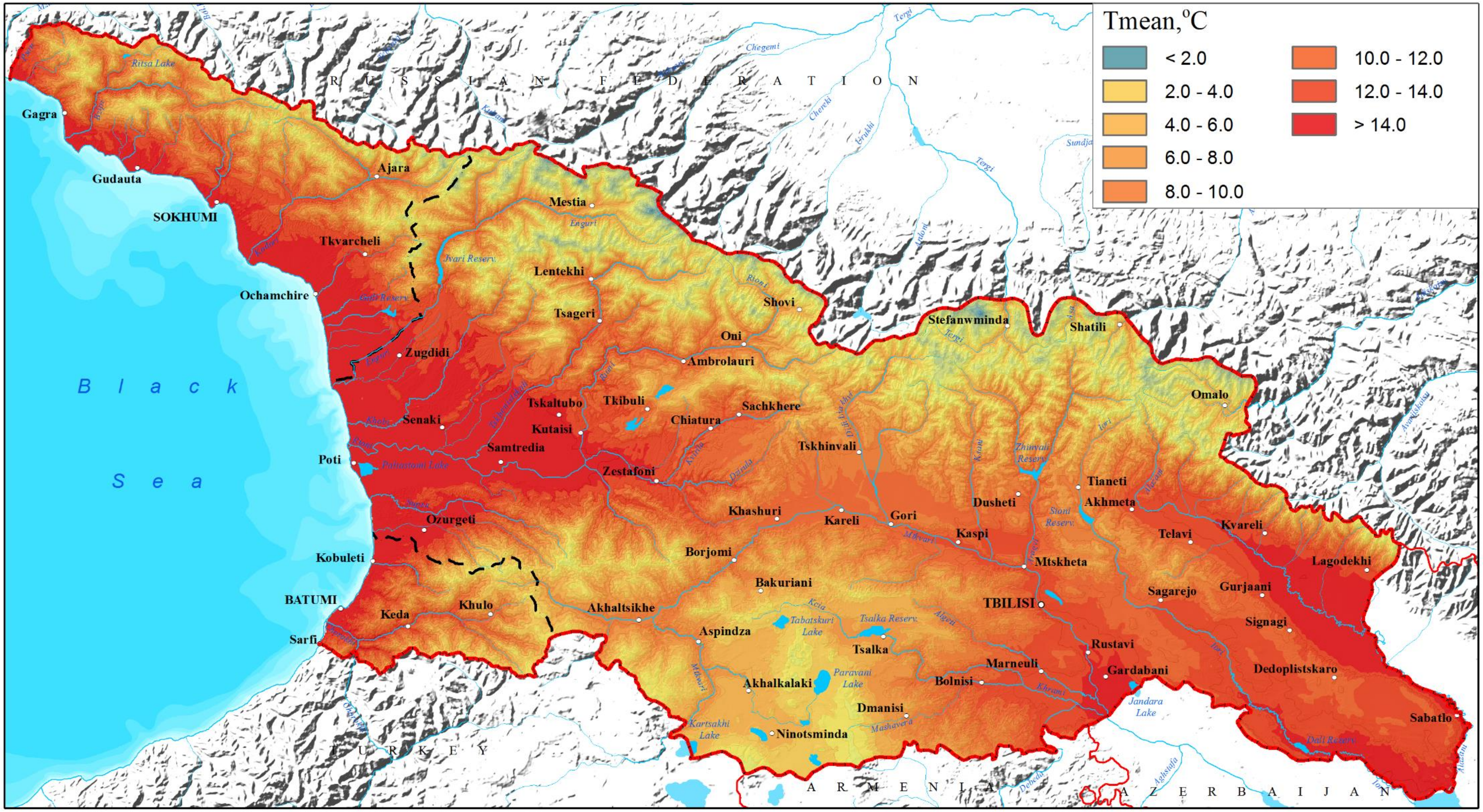
Map 4.1.1: Change in mean air temperature in January between two 30-year periods (1956–1985 და 1986–2015)



Map 4.1.2: Change in mean air temperature in July between two 30-year periods (1956–1985 და 1986–2015)



Map 4.1.3: Change in mean annual air temperature between two 30-year periods (1956–1985 and 1986–2015)



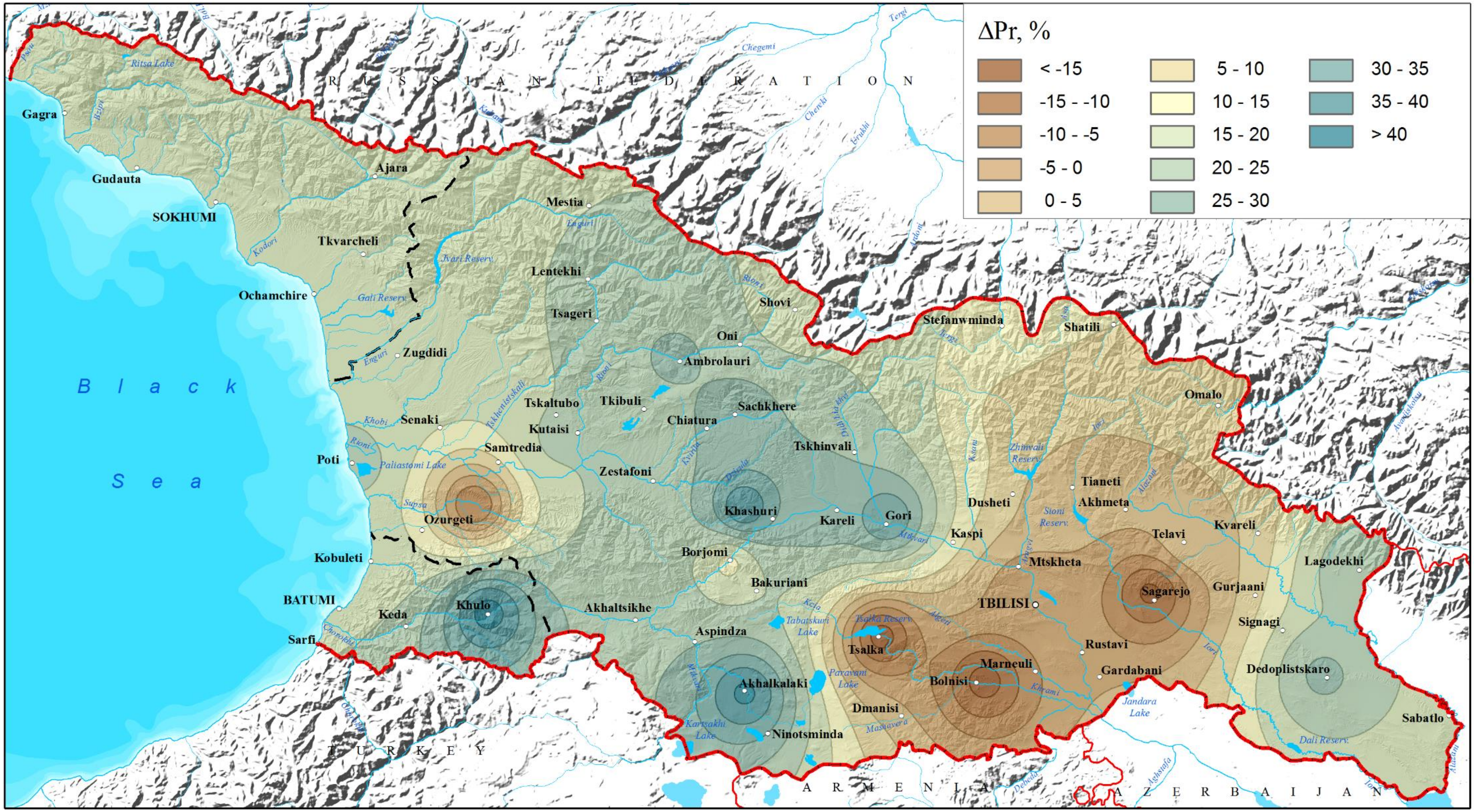
Map 4.1.4: Mean air temperature in 1986–2015

Precipitation

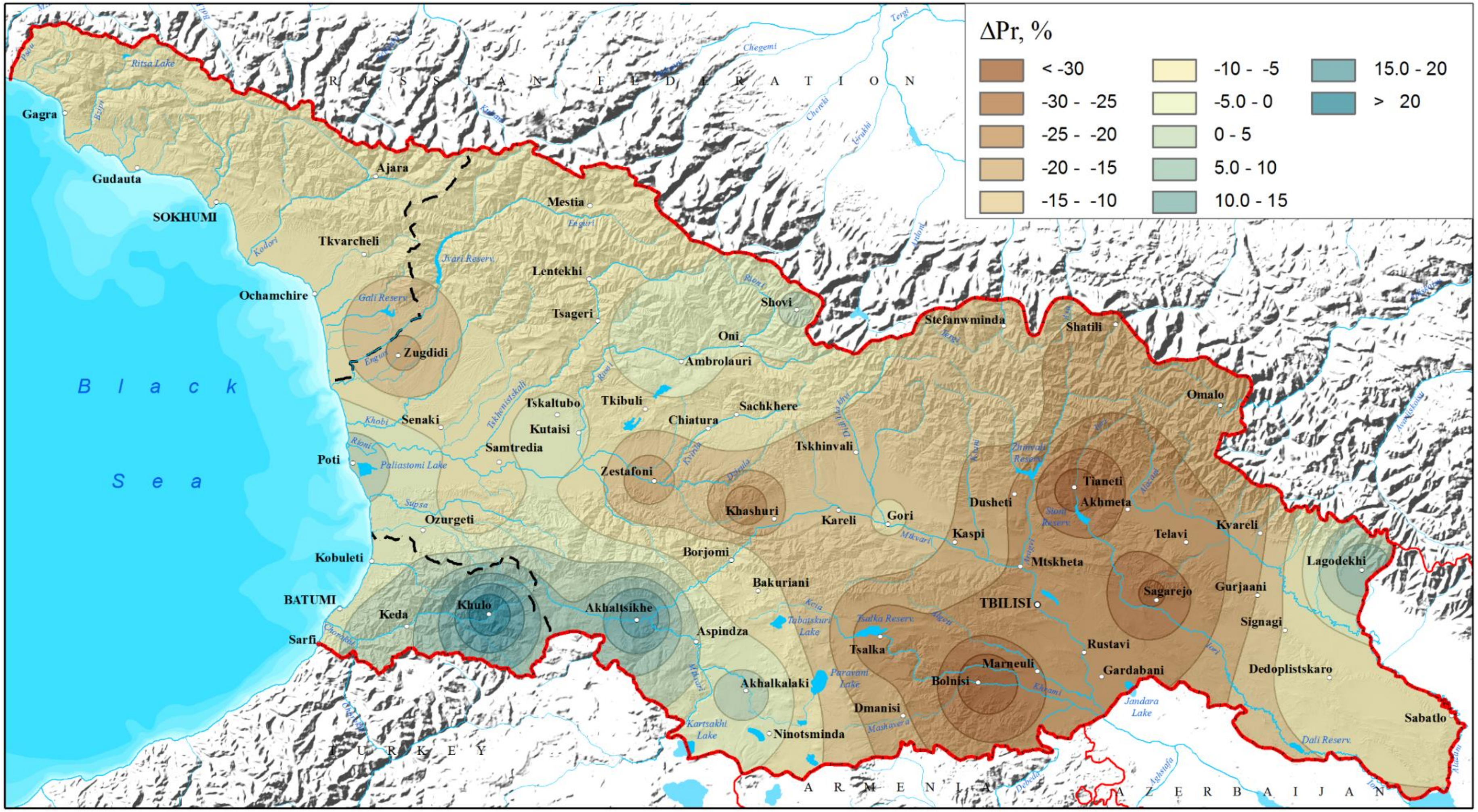
Precipitation. The annual precipitation has increased in the western part of the country and decreased in some eastern regions, although the changes in annual precipitation were mainly unstable with no clear trends observed. The upward trends in the average annual precipitation were observed almost in all locations in Western Georgia, with the most dramatic increase of 60-75 mm/10-yr and the largest difference of up to 15% between the two 30-year periods recorded in Poti and Khulo. Guria and the high mountains of Adjara (Goderdzi Pass) were the only regions demonstrated the deviation from the trend, recording significant decreases in precipitation. The highest increase in annual precipitation was observed in the eastern regions, most significantly in Lagodekhi (17%, 75 mm/10-yr), while most dramatic decrease in precipitation was in Tianeti (-18%, 39 mm/10-yr).

In the annual cycle, precipitation monthly maximums have shifted from the summer to the spring in most locations of Eastern Georgia. Thus, in the first 30-year period May and June have been the most rainy months, while presently May appears the most rainy month, with January and partially December remaining the least rainy months. In the first period, May was the driest month in most locations of Western Georgia, while in the second period, the least precipitation is observed in early spring (March-April), while the highest precipitation is recorded in October-November or in January instead of December.

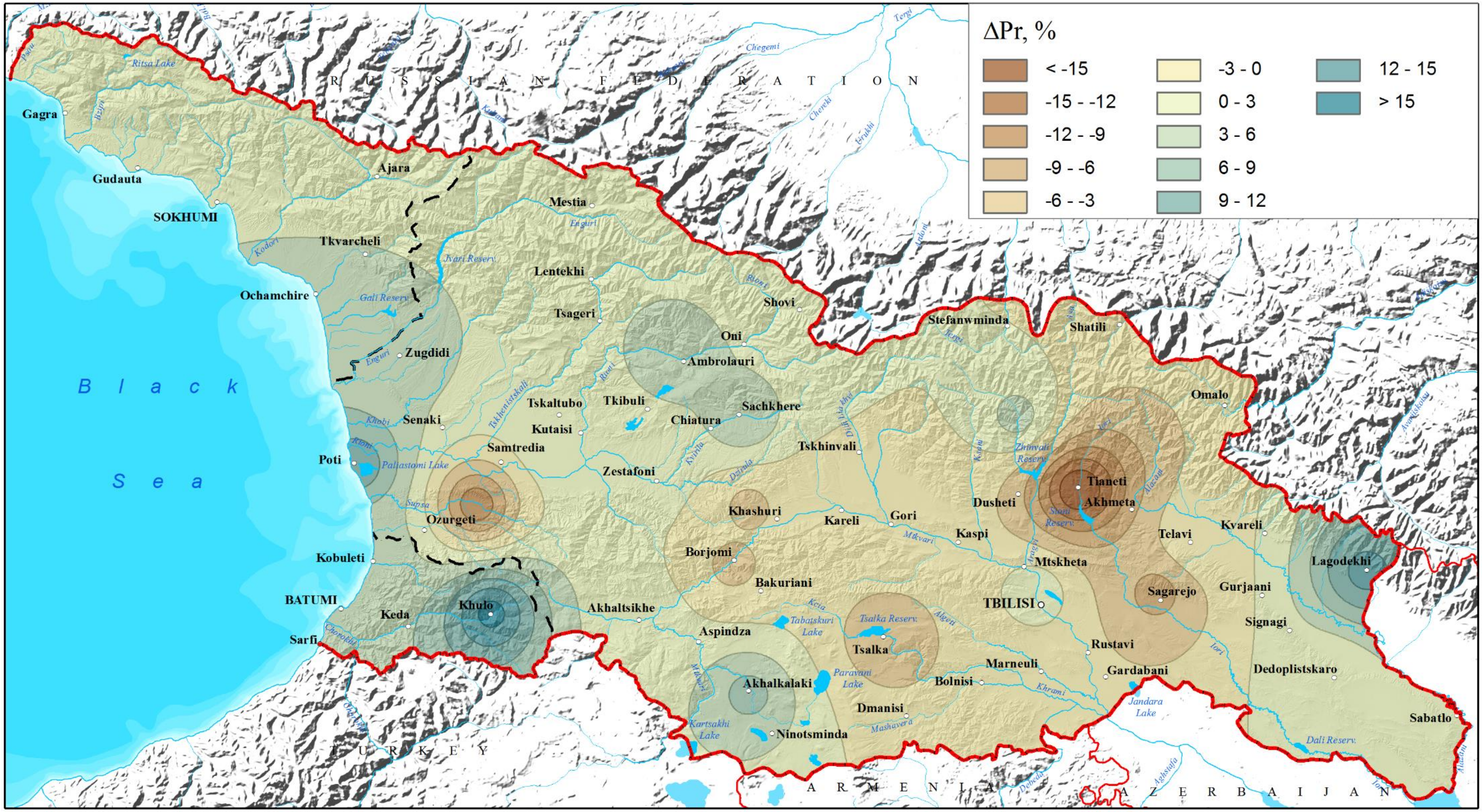
Maximum daily precipitation. An increase in maximum one-day and five-day precipitation has been observed in most regions of Georgia with some central regions (Imereti, Samtskhe-Javakheti, Shida Kartli) making an exception. However, the changes were unstable and only several reliable trends have been identified. Over the two 30-year periods, one-day maximum was exceeded in most areas in January and May, and five-day maximum was exceeded in November as well. Maximum annual precipitation was exceeded by 70-80 mm (Kobuleti, Lagodekhi), while five-day maximum was exceeded by 150-160 mm (Ambrolauri).



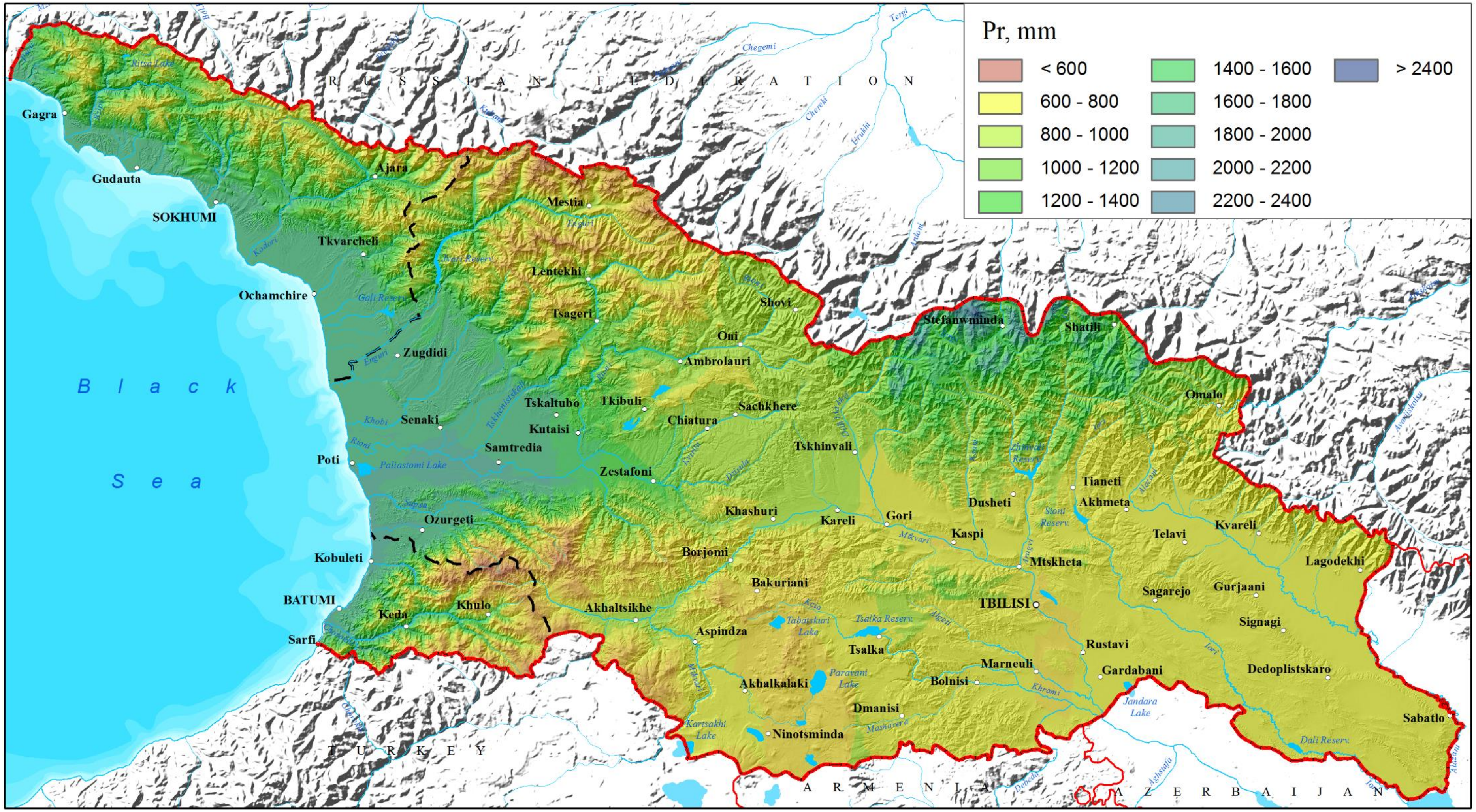
Map 4.1.5: Precipitation change in January between two 30-year periods (1956–1985 and 1986–2015)



Map 4.1.6: Precipitation change in July between two 30-year periods (1956–1985 and 1986–2015)



Map 4.1.7: Change in annual Precipitation between two 30-year periods (1956–1985 and 1986–2015)



Map 4.1.8: Average annual Precipitation in 1986–2015

Atmospheric Air Humidity

Average relative humidity. In 1986–2015, the lowest average annual relative humidity was observed in Kvemo Kartli (69%) and Sagarejo (66%), while the highest was observed in Mta-Sabueti (89%). The change in relative humidity observed in this period against 1956–1985 was insignificant, with maximum increase (7%) recorded in Telavi and maximum decrease (4%) - in Sagarejo.

Extremes of relative humidity (humid and dry days). The number of humid days (noon relative humidity exceeding 80%) has increased in the most parts of Georgia. No significant changes have been observed in the annual cycle. During both 30-year periods, the maximum number of humid days in a year was observed in early winter (December) and partly in January.

A decrease in extremely dry days (minimum relative humidity less than 30%) has been observed across much of Georgia due to a significant decrease in dry days in April-May. The annual average decrease between the two periods was 6-8 days across the country with the most significant decrease in Imereti (up to 11 days on average), and in Kutaisi, where it is reduced by 27 days. In some regions, mostly in Kakheti in spring and in the entire Eastern Georgia in early autumn, the number of dry days has increased. The most notable upward trends were observed in Kakheti, where the annual increase was 6-9 days and spring increase was 4-5 days.

The analysis of extreme values of the relative humidity confirms and explains the identified changes in the average relative humidity. In particular, the increase in humidity during the spring season is conditioned by the decrease in the number of dry days especially in Eastern Georgia, and the increase in humidity in December-January is explained by the increase in the number of humid days in these months, which is more pronounced in Western Georgia.

Wind

The average wind speed tends to decrease at almost all the mentioned stations. It decreased by 1-2 m/sec in the second period as compared to the first period.

Extreme wind values (high wind days). The number of high wind days (≥ 15 m/s) has decreased in western and increased in eastern regions of Georgia. The number of such days has decreased in Kutaisi and most significantly on the western slopes of the Likhi Range (Mta-Sabueti). The downward trends have been identified in summer and autumn. Meanwhile, in the Mtkvari/Kura Gorge, in the east, the number of high wind days has increased significantly. An increase in frequency of high wind days has been observed in Gori during all seasons. The frequency of extremely high wind days (≥ 25 m / s) has changed according to the same pattern, i.e. significantly decreased in Kutaisi and Mta-Sabueti, and steadily increased in Gori and Poti.

Seasonal Characteristics

Winter has become milder throughout Georgia for the past 30 years as compared to the previous 30 years, though the change in the **temperature regime** is less pronounced in winter than during other seasons, as the upward trends recorded in most regions in January-February are balanced by the downward trends in December. The warming is most notable in the lowlands and plains: Qartli-Kakheti in the east and Samegrelo in the west. Winters have become more severe in the mountainous areas of Adjara and Guria, where the drop of temperature is observed in January-February. The deviation from the average seasonal temperature was within ± 1^0C in the second period as compared to the first one.

Analysis of other temperature parameters shows that winters have become milder mainly because of the increase in minimum temperature. Absolute minimums in some areas (Kolkheti lowland, Dedoplistskaro) have increased by 4-5 degrees. An increase in maximum temperature was mainly observed in Eastern Georgia and in Samegrelo lowlands, while an increase in minimum temperature was recorded in the rest of the country. However, in the high mountain areas of Southern Georgia (Akhalkalaki), winters have become more severe because of the drop of the night temperature (average minimums have decreased during all winter months).

Winter warming is also confirmed by extreme temperature indices (TX10p, TN10p, TX90p, TN90p, FD0, ID0). Milder winter is mainly conditioned by the decrease of the percentage of cold nights, which is most notable in Kakheti. However, in some locations the number of warm days has also decreased in January. The frequency of cold days in Western Georgia has increased in December on average by 3-4% per month. Winter warming is also evidenced by a decrease in the number and duration of cold spells in the country. However, in the second period, in certain areas, especially in Western Georgia, the maximum duration of cold spells was exceeded on several occasions.

A significant decrease in **precipitation** has been observed in winter in Guria and Shida Qartli. In most locations, precipitation declines in February and increases in January in western and southern regions of Georgia and in December - in Eastern Georgia.

These changes in precipitation are mainly conditioned by the increase in the number of heavy precipitation days (**R30, R50**) in Western Georgia in January: on the Black Sea coast, in Kakheti lowlands and in the surrounding mountainous regions. The number of consecutive wet days has increased in the western regions (maximum by 5-6 days). One of the most noticeable trends in winter is the increase in dry spell duration (maximum by 10-11 days) in Eastern Georgia, especially in Kakheti and Mtskheta-Mtianeti (maximum by 14-16 days). An increase in the number of consecutive dry days is observed in Imereti in January and especially in December. The changes in precipitation are persistent and marked by the downward trend in winter season.

In winter, especially in January, **relative humidity** is higher than in other seasons in almost all regions of Georgia. This change is largely conditioned by the increase in the number of humid days (RH80) across much of Georgia and the decrease in the frequency of dry days (**RH30**) in Kakheti.

The average wind speed is steadily decreasing throughout the country (except Tbilisi). The frequency of high wind days has been increasing since the 2000s, especially in December and February, in the intermountain belt (Poti – Kutaisi – Mta-Sabueti – Gori – Tbilisi). The number of high wind days has noticeably increased in Gori during the 60-year period in all winter months, and the frequency of extremely high wind days - in February.

In Georgia, winters have become more humid and less severe (mainly due to a reduction in numbers of cold and frosty days and nights), with more frequent heavy precipitation days in the western regions and longer dry periods in the east, accompanied by the increase in numbers of high wind days in some locations.

Spring has become warmer almost throughout the country. Warming in spring is more significant than in winter. The average **temperature** increase in the second 30-year period against the first one is within 0.2^0C-0.3^0C, although in Mtskheta-Mtianeti and Samtskhe-Javakheti it reaches 0.4^0C-0.6^0C. Just like in winter, a downward trend (0.3^0C-0.4^0C) has been observed in spring temperature in Adjara-Guria mountains.

Unlike winter, the spring warming is mostly conditioned by the increase in the maximum temperature that has increased by 0.5^0C, with minimum temperature increasing by 0.3^0C across the country. The changes in the temperature regime are evidenced by extreme temperature indices. Based on the above, the warming in spring, unlike winter, is mainly caused by the increase in the percentage of warm days and nights and the decrease in cold and frosty nights, which reduces the probability of spring light-frosts.

The changes in **precipitation** patterns, observed in spring, are largely conditioned by seasonal factors, although only some upward trends appear to be persistent, mostly in the eastern regions of Georgia. The most significant one is the increase in precipitation in Kakheti, caused by the growth of the number of heavy precipitation days (**R30, R50**) in April-May. Besides, in spring, one-day and five-day precipitation maxima (**Rx1day, Rx5**day) have been exceeded on several occasions across much of Kakheti. In Western Georgia an increase in precipitation is observed in March and especially in May, and the decrease takes place in April.

The analysis of extreme precipitation indices shows that the increase in precipitation in the western regions is conditioned by the increased number of consecutive wet days in March and the increased number of heavy precipitation days in May. These changes will increase the risk of flashfloods and mudflows in certain locations (mountainous regions of Adjara and Samegrelo) in spring.

The 2-3% increase in **relative humidity** is observed in spring in most regions of Georgia. Downward trends in humidity have been identified in Racha-Lechkhumi and Kakheti (1-1.5%). Humidity increases mainly in April-May, when the difference between the two 30-year periods is within 3-4% and in certain locations within 5-6%.

In most areas the increase in humidity is conditioned by the decrease in the number of dry days (RH30), while in Poti and Tbilisi it is caused by the increase of the number of humid days (RH80). The increase in frequency of such days has been observed throughout the country in May.

The **average wind speed** decreases steadily in spring across Georgia except Tbilisi. The deviations with respect to the first period are within 1-2 m/sec. Yet, wind speed reduction rate is the highest in spring.

The frequency of high wind days has increased, especially in March-April in the Mtkvari Gorge (Gori-Tbilisi), and since the 2000s, on the Likhi Range (Mta-Sabueti). Similarly to winter, there has been a noticeable increase in the number of high wind days in Gori over the entire 60-year period during all spring months. This trend is an important risk factor for the agricultural sector, as it causes drying and sweeping of topsoil, thus significantly damaging spring crops. However, this factor is highly beneficial for wind power engineering.

Spring has become more humid and warm (mostly because of the higher number of warm days and nights in April), with more frequent heavy precipitation and humid days in May, accompanied by the increased number of high wind days in certain locations (Mtkvari Gorge).

Summer has become significantly warmer according to all **temperature** parameters. Warming is evidenced by the upward trends in average and extreme temperature indices throughout the county. Summer warming, like spring one, is largely conditioned by the increase in the maxima. Minimum and maximum temperature has increased on average by 1^0C and 1.5^0C respectively.

Analysis of extreme temperature indices shows that both in summer and spring the warming is largely conditioned by the increase in the percentage of warm days and nights (on average, by 8-9%) and the significant reduction in the percentage of cold days and nights (on average, by 4-5%).

In the setting of the warming, total seasonal **precipitation** has decreased in most parts of the country, though significant changes are observed only in several locations. Across much of Georgia, the decrease in precipitation is observed in August. In the eastern regions it is more intensive in July. The increase in precipitation can be observed in June only in Adjara, Kolkheti lowland, and Tbilisi.

The rise in summer temperatures increases the risk of drought.

Although the average **relative humidity** is higher in summer, the number of upward trends is the lowest during this season. A downward trend has only been observed in Imereti. On the whole, changes in summer humidity patterns are the same as in spring, but the increase in humidity is less pronounced in summer.

Similarly to the rest of the seasons, the **average wind speed** in summer decreases steadily throughout Georgia except Tbilisi. The deviations with respect to the first period are within 1-2 m/sec.

The frequency of high wind days (≥ 15 m/sec) has increased in the intermountain belt (Poti to Tbilisi) since the 2000s (by 11 days in Gori). The frequency of extremely high wind days (≥ 25 m/sec) recently has only increased in Gori. Like other seasons, the increase in the number of high wind days has been observed in Gori throughout the 60-year period during all summer months.

Summers have become significantly hot and relatively dry, with more frequent rainy and humid days in certain **locations.**

Autumn is warm and, just like summer, has all indicators of warming, though, less intensive. Analysis of temperature parameters shows that autumn warming is caused by almost equal increase in day and night temperature. Maximum and minimum temperature has increased across the country on average by 0.7^0C and 0.6^0C respectively. Analysis of extreme temperature indices shows the increase in the percentage of warm days and nights in autumn (by 4-5%, on average) and the decrease in the percentage of cold days and nights (by 2-3%, on average). Just like spring, the number of frosty nights has decreased in autumn and so did the risk of autumn light-frost.

In most parts of the country, the increase in seasonal **precipitation** is higher in autumn than during other seasons, although there are just a few reliable upward trends, mostly observed in the western regions and in Kakheti. Almost all extreme precipitation indices confirm that the increase in precipitation in autumn and particularly in October is conditioned by increases in the frequency of heavy rainfalls and in one-day and five-day precipitation maxima (so-called flood indices). The changes are significant and evidenced by trends observed along the Black Sea coast, in Samegrelo, Racha-Lechkhumi and Kakheti, according to all precipitation indices. Changes in precipitation patterns indicate increased risks of flashfloods and landslide-mudflows in these areas.

A 2-3% increase in average **relative humidity** can be observed in autumn across much of Georgia. A persistent upward trend is observed along the Black Sea coast and in the Mtkvari Gorge, where humidity increase is the highest (3-4%).

Like other seasons of the year, in autumn the **average wind speed** is steadily decreasing throughout the country except Tbilisi and Zugdidi. The deviations with respect to the first period are within 1-2 m/sec. The frequency of high wind days has increased since the 2000s in the central regions of the country - from Likhi Ridge to Gori (by 10 days per season, Gori).

Autumn has become more humid, rainy **and noticeably warmer with longer dry periods and more frequent warm days and nights in early autumn and more frequent heavy rainy and humid days in late autumn.**

The following trends have been identified in the temperature characteristics within the annual cycle:

– The number of hot days **(TX90p)** and warm nights **(TN9**0p) has increased significantly;

– The frequency of cold days **(TX10p)** and nights **(TN10p)** has decreased noticeably and the number of frost nights **(FD0)** has slightly decreased;

- The number of hot days and warm nights in the annual cycle has increased significantly in summer and autumn across the entire study area, confirming the summer warming trend, evidenced by the average climatic parameters;
- Analysis of climate characteristics shows that the increase in average temperature during the warm season (May-September) is also caused by the increased occurrence of heatwaves (**HW**) and a significant increase in heat wave duration (**HWD**);
- A decrease in the number of cold waves (**CW**) and cold wave duration (**CWD**) is obvious, but insignificant, which is evidenced by unstable warming of the cold period of the year (November-April);
- Stable positive changes are also observed in the warm spell duration index (**WSDI**) throughout the year;
- Changes in the cold spell duration index (**CSDI**) are insignificant and not evidenced by trends;
- As compared to the first 30-year period, changes in the growing season length (**GSL**) are unstable in most areas, as the warming observed in early autumn is partially compensated by cooling in late spring;
- Accumulated temperature totals - the so-called degree-day indices (**GddGrow, HddHeat, CddCold**) have demonstrated the most significant increase during the warm period;
- Almost at all the sites the above trends indicate the increase of active temperature totals above 10^0C (**GddGrow10**). The changes are most pronounced in Dedoplistskaro, at the Black Sea coast and around Kolkheti lowland.

As regards precipitation extremes, such as the percentage and contribution from extremely wet days to the annual totals (**R95pTOT, R99pTOT, R99p, R99p**), the following trends have been identified in the annual cycle:

- Changes in extreme characteristics are unstable and uneven, with only a few persistent trends identified;
- Most of them are observed in Samegrelo and Adjara mountains, where precipitation trends are conditioned by the increased frequency of heavy precipitation days. In the mountainous Adjara and Racha-Lechkhumi, the contribution from days with very high and extremely high precipitation to the annul totals has increased by 5-7% and 2-4% respectively, which corresponds to 30-40% increase in heavy precipitation and 50-75% increase in extreme precipitation. All other extreme indices, such as the number of heavy precipitation days (**R30mm, R50mm**) and maximum 1-day and 5-day precipitation (**Rx1D, Rx5D**), have increased rather significantly in these regions;
- The extreme precipitation indices in the southern and eastern regions of the country show that despite the change in annual precipitation, the number of consecutive dry days (**CDD**) is increasing almost in all locations and especially in Kakheti and Mtskheta-Mtianeti. At the same time, extreme precipitation events have been showing upward trends in Tbilisi, Telavi and Lagodekhi.

Analysis of the current trends in the climate change confirms the existence of warming processes in the country, revealing almost all climate change indicators, including:

- An increase in surface air temperature;
- An increase in humidity;
- An increase in the frequency of hot days and warm nights, and a decrease in the number of cold days and nights;
- An increase in frequency and duration of warm spells/heat waves;
- A decrease in the number of frost days;
- Changes in precipitation patterns;

– An increase in the frequency of heavy precipitation days, intensity and amount of precipitation;
– An increase in intensity and duration of droughts.

On the whole, the described changes in climatic parameters can have negative impacts on different sectors by increasing most of the existing risks.

At the same time, certain risk mitigating factors have been identified for the following sectors: agriculture – a lower risk of spring and autumn light-frosts and an increase in growing degree-days required for the growth and development of agricultural crops; tourism – extension of the tourist season at the Black Sea coast and an increased duration of the dry season (including September); energy – a downward trend in demand for energy during the heating period; health – a reduction in the frequency and duration of cold waves, etc. It should be noted, however, that almost all the above risk reduction trends are statistically not reliable, while frequency of risk contributing factors (increasing duration of droughts, extreme precipitation, heat waves and humid days, increased electricity demand during air conditioning period, increased frequency of high wind days in certain locations, etc.) is increasing steadily almost in all regions.

4.2 Climate Change Scenario

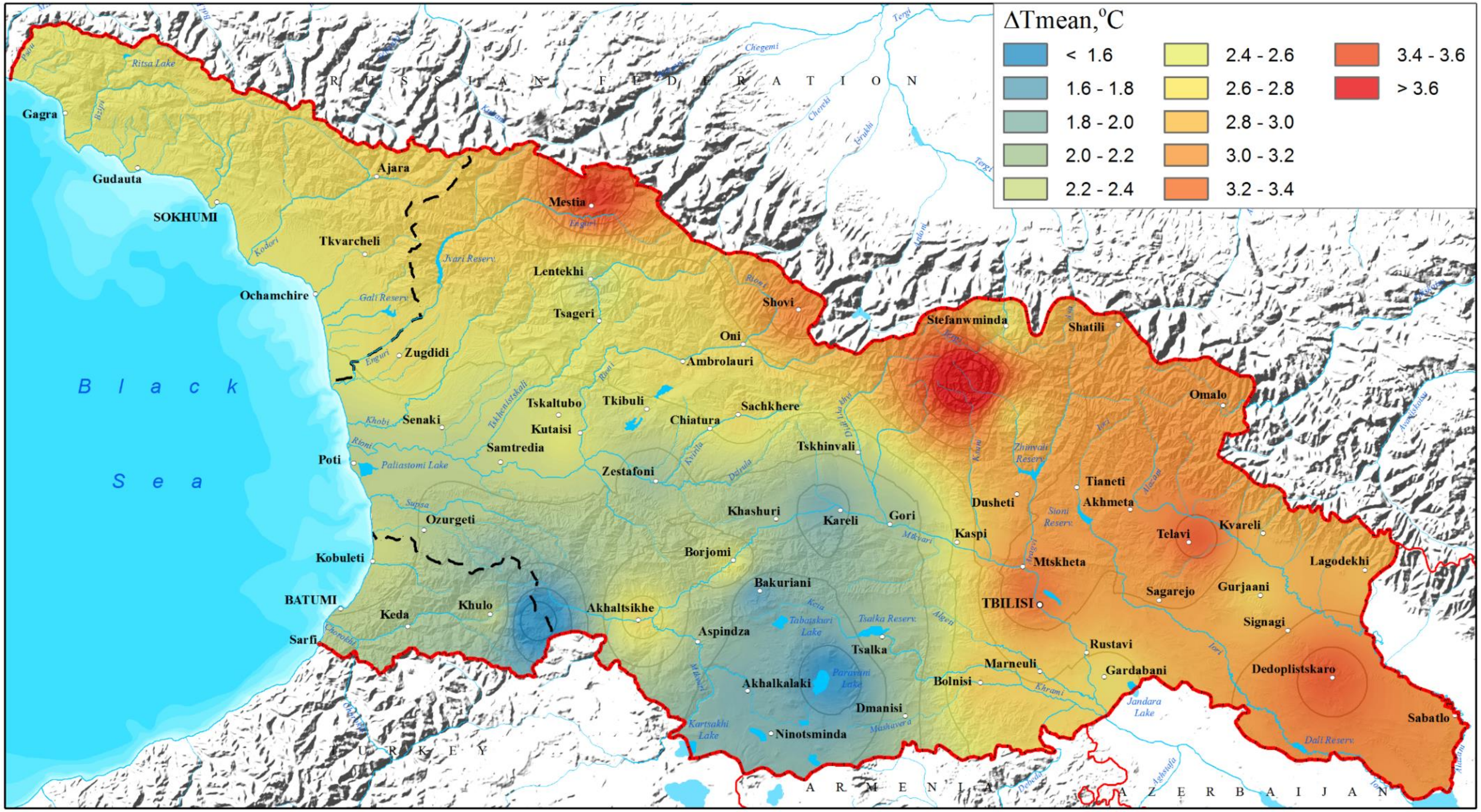
The expected climate change has been forecast using Representative Concentration Pathway (RCP) 4.5 scenario that stabilizes radiative forcing at 4.5 W/m^2 in the year 2100 without ever exceeding that value. Compared to the A1B scenario used in the Third National Communication, the RCP4.5 scenario is less severe.

Version 4.6.0 of the RegCM Regional Climate Model has been used to improve the global forecast scale. This version has refined mechanisms for describing and parameterizing a number of physical and chemical processes. In this model, we considered the impact of dust and aerosols based on results of the study titled "EFFECT OF DUST AEROSOLS IN FORMING THE REGIONAL CLIMATE OF GEORGIA". In addition, the RegCM 4.6.0 version allows for horizontal resolution refinement with the one-way nesting method. All the simulations of the regional climate model first were conducted on a coarse resolution (30 km) and over a relatively large area, and then were calculated on a 10 km grid.

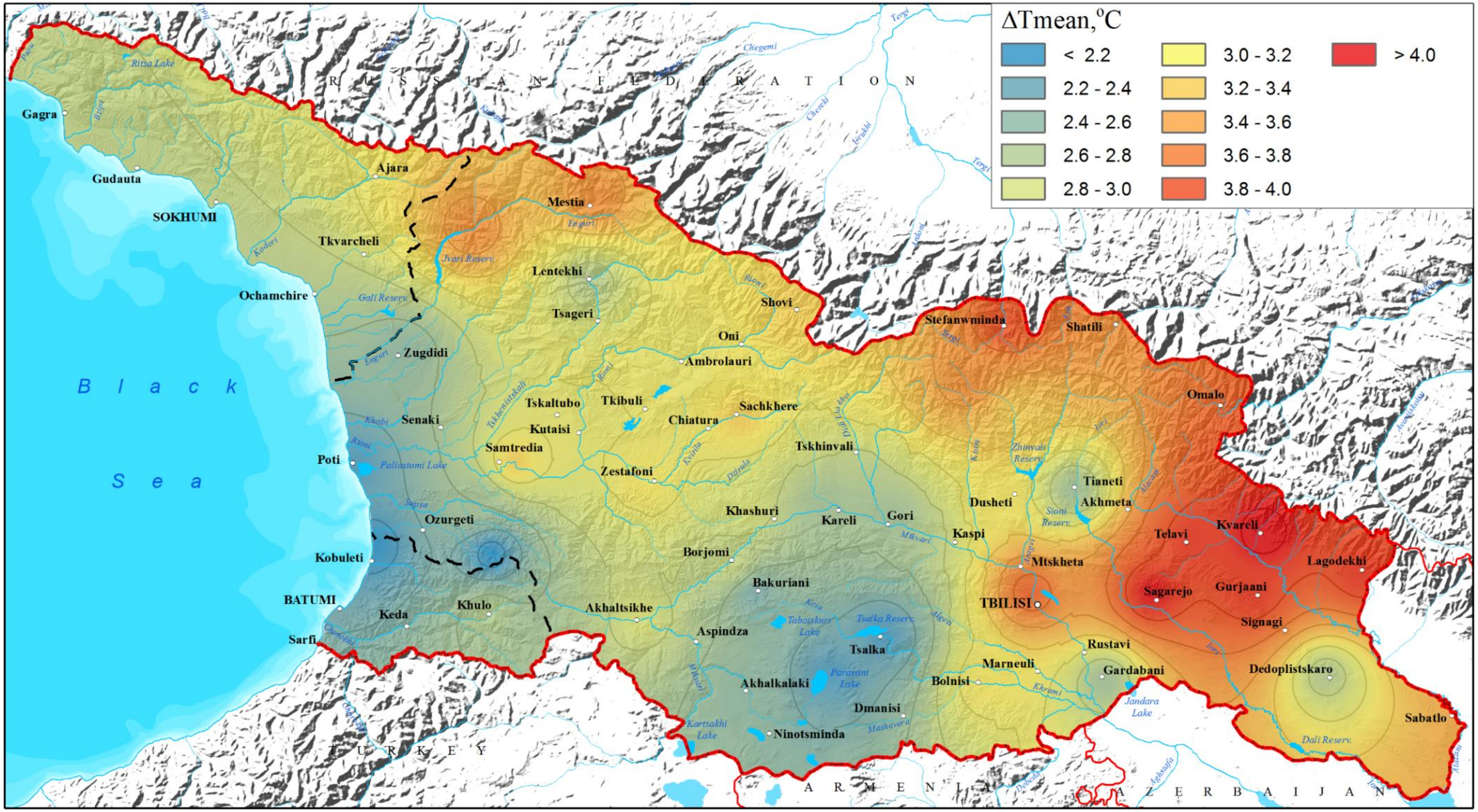
Based on the above simulation, the future trends of the climate change have been estimated by comparing the two 30-year periods (2041-2070 and 2071-2100) with the 30-year period of 1971-2000 using data from 39 weather stations of the Georgian Meteorological Network. The scenarios have been developed for monthly and annual average values of the key climate parameters such as air temperature, total precipitation, relative humidity and wind. In addition, we have calculated specialized climate parameters - indices that allow assessing the climate change impacts on individual sectors.

In 2041-2070, an increase in the **average annual temperature** throughout the country is likely to range between 1.6^0C and 3.0^0C as compared to 1971-2000. In Eastern Georgia the temperature increase will range between 1.8^0C and 3.0^0C, while in Western Georgia between 1.6^0C and 2.9^0C.

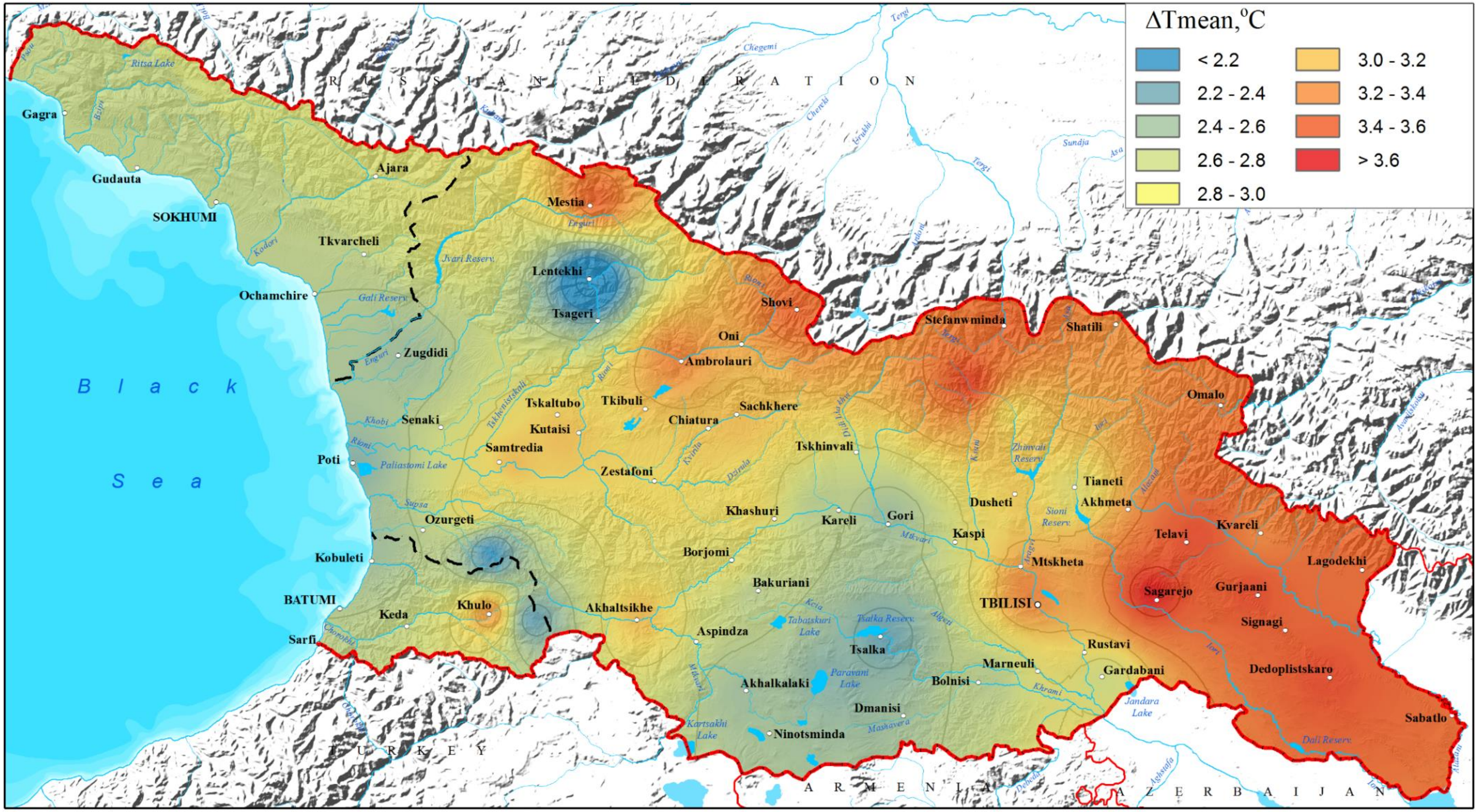
In 2071-2100, the rise in the average annual temperature will continue, reaching 0.4^0C-1.7^0C. Consequently, the temperature increase in this period will be within 2.1^0C-3.7^0C compared to the average index of 1971-2000. The temperature increase will be the lowest in Lentekhi and the highest in Sagarejo. In Eastern Georgia, the increase will be slightly higher than in the western regions. Detailed information by stations is given in Table B1 in the Annex.



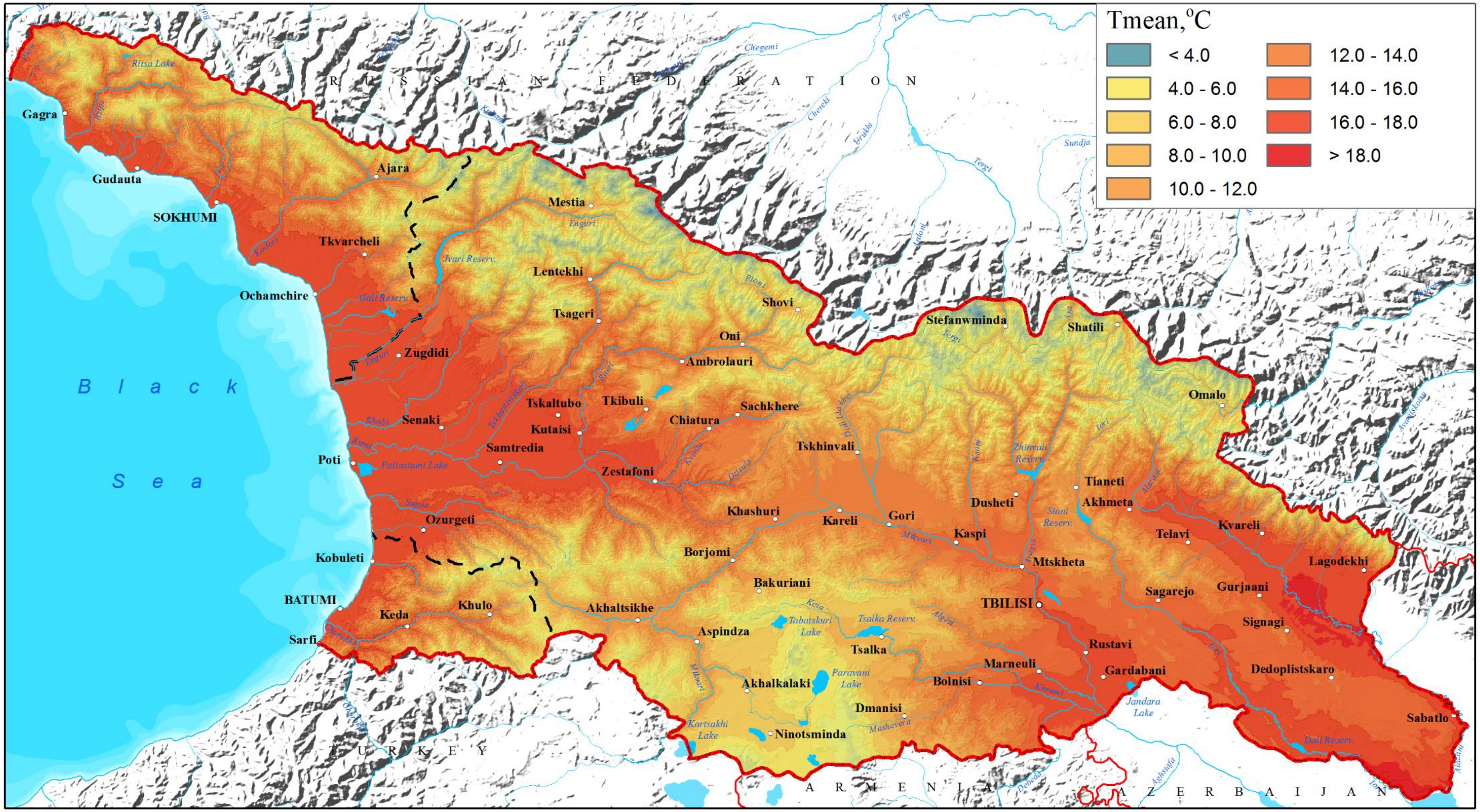
Map 4.2.1: Change in mean air temperature in January between two 30-yaer periods (1971-2000 and 2071–2100)



Map 4.2.2: Change in mean air temperature in July between two 30-yaer periods (1971-2000 and 2071–2100)



Map 4.2.3: Change in mean annual air temperature between two 30-yaer periods (1971–2000 and 2071–2100)



Map 4.2.4: Mean air temperature in 2071–2100

The annual increase in the maximum average temperature will be within 1.9^{0}C-3.0^{0}C in 2041-2070, while the average increase in the minimum average temperature will range between 1.1^{0}C and 2.3^{0}C. The average of minimum temperature will rise less significantly than that of maximum temperature. This pattern will persist in 2071-2100, when the maximum is likely to increase by 2.6^{0}C-4.3^{0}C, and the minimum – by 1.7^{0}C-3.7^{0}C.

For the years 2041-2070, the number of days with the maximum daily temperature exceeding 25^{0}C, 30^{0}C and 35^{0}C and the number of nights with the minimum temperature not going below 2^{0}C will increase at all the stations throughout the year. At the same time, the number of frost days and nights will go down significantly. During this period, the number of frost days in the highlands will decrease more significantly than the number of frost nights, while in lowland areas both indices are likely to decrease almost equally. By the end of the century, no frost days should be expected.

During the first forecast period (2041–2070), the number of nights with daily minimum temperature below 0^{0}C (FD0) will decrease on average by 19 days across the country and from 8 (in Batumi) to 47 days (in Ambrolauri) by stations, while in the second period (2071–2100) it will decrease on average by 28 days across the country and from 9 (in Batumi) to 60 days (in Ambrolauri) by stations. The decrease will be the most pronounced in winter and less pronounced and almost equal in transitional seasons. At the high-altitude stations the decrease will be intense in transitional seasons and even exceed the winter indices at certain stations. .

Percentage threshold indices have been analyzed in addition to the fixed threshold temperature indices. .

Tx90p – percentage of hot days when daily maximum temperature exceeds its 90th percentile will increase monthly during the first forecast period throughout the country except Kakheti, where it will decrease by 1%. The highest increase (maximum 30%) will be observed during the warm period (May-September), while during the rest of the year the increase will be within 10-15%. By the end of the century this figure will grow more intensively during all seasons and at all stations, with the particularly noticeable increase in the percentage of hot days in Kakheti and Kvemo Kartli, where it will reach 50% in certain months.

Tn90p - percentage of warm nights when daily minimum temperature exceeds its 90th percentile shows an even more intense warming. In the first forecast period, this index increases everywhere and reaches 40-45% at certain stations during the warm season. By July 2100, the number of such nights in Kakheti region is expected to increase by 60% in July, with the average number of warm nights increasing by 35% and 27% in summer and autumn, and by 22% and 16% in spring and winter respectively.

In contrast with these two indices, the percentage of cold days (**Tx10p**) with daily maximum temperature below its 10th percentile and the percentage of cold nights (**Tn10p**) with daily minimum temperature below its 10th percentile declines in both forecast periods with few exceptions. In 2041-2070, the annual decline in Tx10p and Tn10p is within 0.3-7.0% and 1.6-7.5% respectively. In 2071-2100, the annual decline in Tx10p and Tn10p is within 2.4-8.6% and 0.5-8.1% respectively.

The number of days during the year with daily average temperature above 10^{0}C (**Tmge10**) or below 10^{0}C (**Tmlt10**) are important indices for agriculture. During the first period, the number of days with daily average temperature above 10^{0}C increases on average by 21 days per year. The increase is most intensive in October (4 days on average) throughout the country and in November in Kakheti (5.5 days on average). During the same period, the number of days with daily minimum temperature below 10^{0}C decreases by 21 days, most intensively in October (4 days). In the second forecast period, Tmge10 will increase annually by 31 days, with maximum growth in March (6 days) and November (5 days). Tmlt10 will demonstrate the same pattern, but in the opposite way (i.e., Tmlt10 will decrease).

When daily minimum temperature exceeds its 10^{th} percentile (Cold Spell Duration Indicator/**CSDI**) for at least 6 consecutive days, and in contrast, when daily maximum temperature exceeds its 90^{th} percentile for at least 6 consecutive days (Warm Spell Duration Index/**WSDI**), "cold and hot weather episodes" occur. In the first forecast period, CSDI increases slightly by 0.1-2.6 days at 6 stations only and decreases to 0.7-5.0 days at the rest of the stations. In the second forecast period the change pattern is the same, but the decrease ranges between 1.0 and 6.5 days. The increase in duration of hot weather episodes is much more significant (8-33 days in the first period and 11-84 days in the second period) than the decrease in duration of cold weather episodes.

During the first period, the growing season length (**GSL**) increases from 6 to 33 days, while effective temperature totals **- GDDGrow10** (the sum of degree days with temperature higher than 10^0C) increases from 193 to 529^0C. In the second period, the GSL increases from 8 to 48 days, and the number of degree days increases from 223 to 1239 days. The increase of these parameters in the second period is particularly noticeable in Kakheti.

In May-September, when the maximum or minimum temperature exceeds its 90^{th} percentile for at least 3 consecutive days, heatwaves are formed. Changes in the annual heatwave number (HWN) and heatwave duration (HWD) are very important for the health and agriculture sectors. In 2041-2070, the average HWN increases from 1.0 days (Lagodekhi) to 6.2 days (Stepantsminda), and average HWD ranges from 13.0 days (Bakhmaro) to 46.4 days (Gudauri). In 2071-2100 average HWN increases from 1.5 days (Sagarejo) to 8.3 (Zugdidi), and average HWD increases from 14.8 days (Khulo) to 81.7 days (Sagarejo).

The annual sum of heating degree days (**hddheat18**) and the annual sum of cooling degree days (**cddcold18**) are informative indicators for the energy sector.

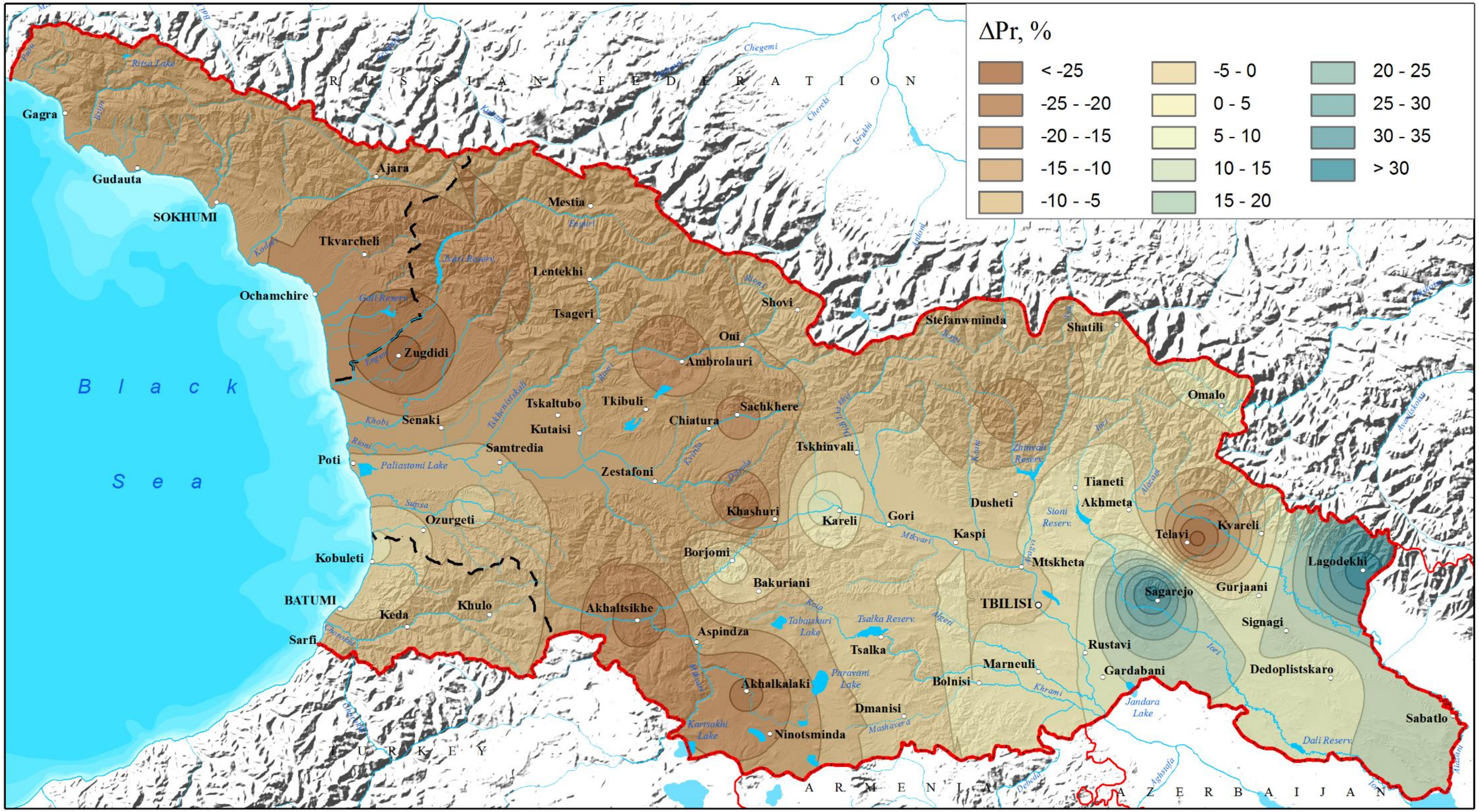
The annual sum of heating degree days decreases in all regions in both periods, ranging within 189-755 in the first period and 327–1097 in the second period. The decrease is particularly noticeable at the high mountain stations, reaching maximum 755 in Gudauri and Stepantsminda during the first period and 1097 in Mestia during the second period. In the second period heating degree days decrease considerably in Kakheti on average from 318 to 776 compared to the first period.

The annual sum of cooling degree days increases in all regions in both periods, ranging with 10–336 in the first period and 13–782 in the second period. The increase is negligible in the mountainous areas (e.g. at the Goderdzi Pass the increase is 10 degree days and in Gudauri it is15 degree days). As compared to the first forecast period, in the second period cooling degree days number increases sharply in Kakheti (on average from 267 to 697) and in Tbilisi (from 264 to 712).

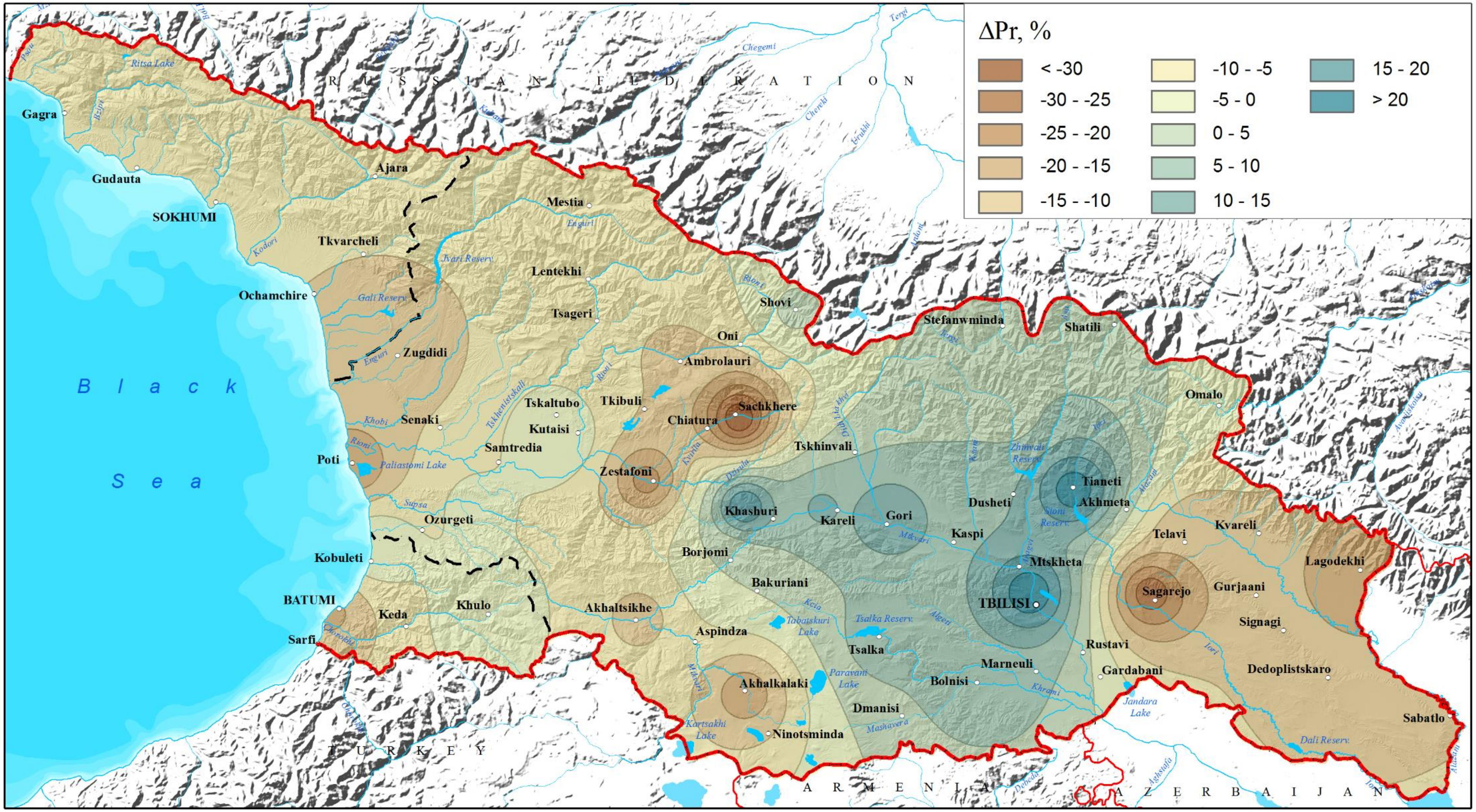
According to the observations, the distribution of **annual precipitation** on the territory of Georgia has the following pattern: maximum precipitation (more than 2,300 mm) occurs at the Black Sea coast of Ajara. Annual precipitation gradually decreases as we move eastward and as the altitude above sea level grows. Precipitation decreases in both forecast periods by different percentages, but the distribution pattern remains unchanged.

In 2041-2070, the annual precipitation in Eastern Georgia will decrease by 9% on average, maximum by 12.3% in Pasanauri and minimum by 5.3 % in Sagarejo. The annual precipitation decrease will be most prominent in Imereti, reaching its maximum in Sachkhere (17.9%). In other regions of Western Georgia, the decrease will range within 3.6-15.3%. Zugdidi and Poti will make the exception with annual precipitation increasing by 8-10%.

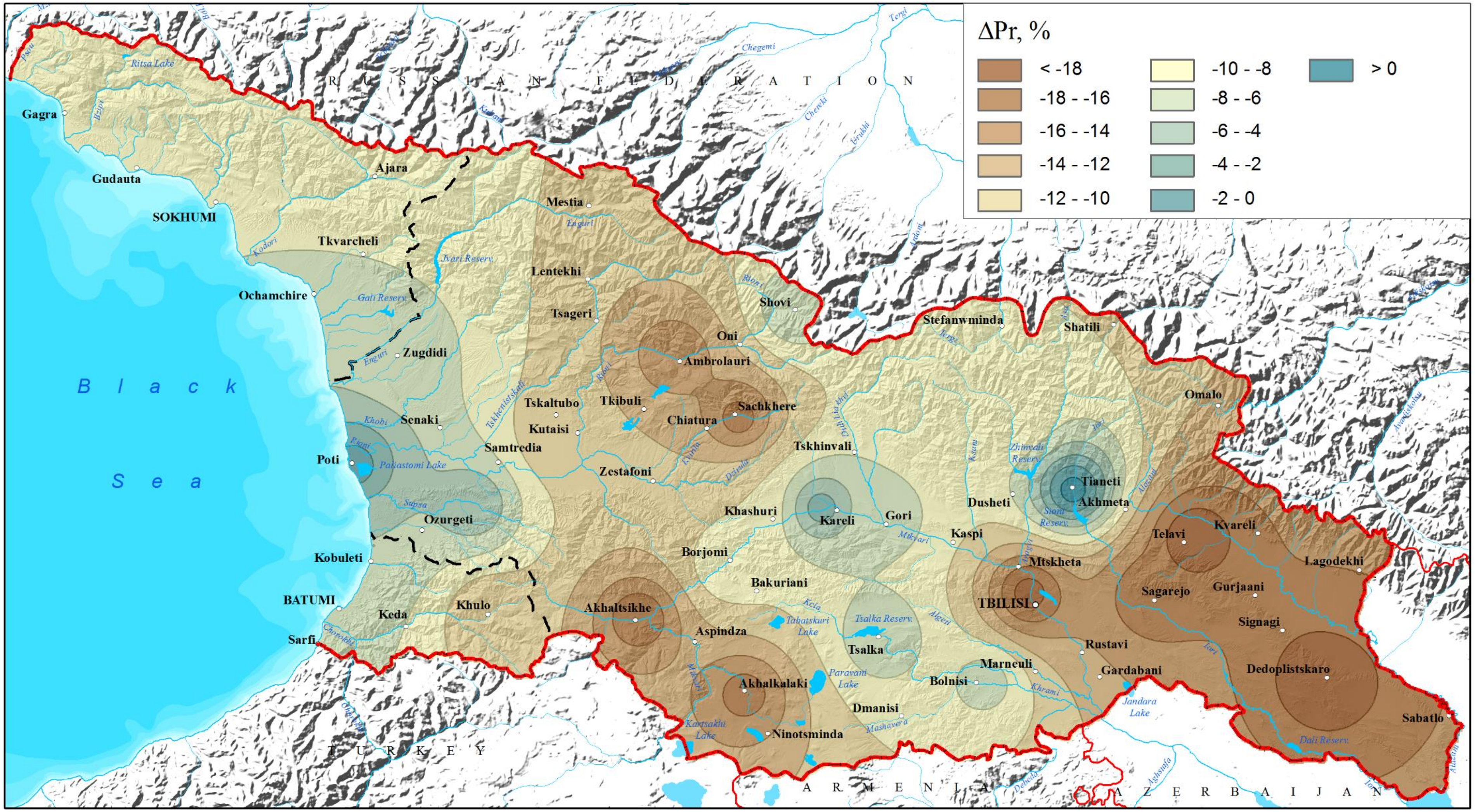
In 2071-2100, total precipitation will change slightly – increase or decrease by 1-6% - compared to 2041-2070. Table B2 in the Annex shows average monthly, seasonal, and annual precipitation in 2071–2100 and its change with respect to the average indices in 1971–2000 by regions and stations.



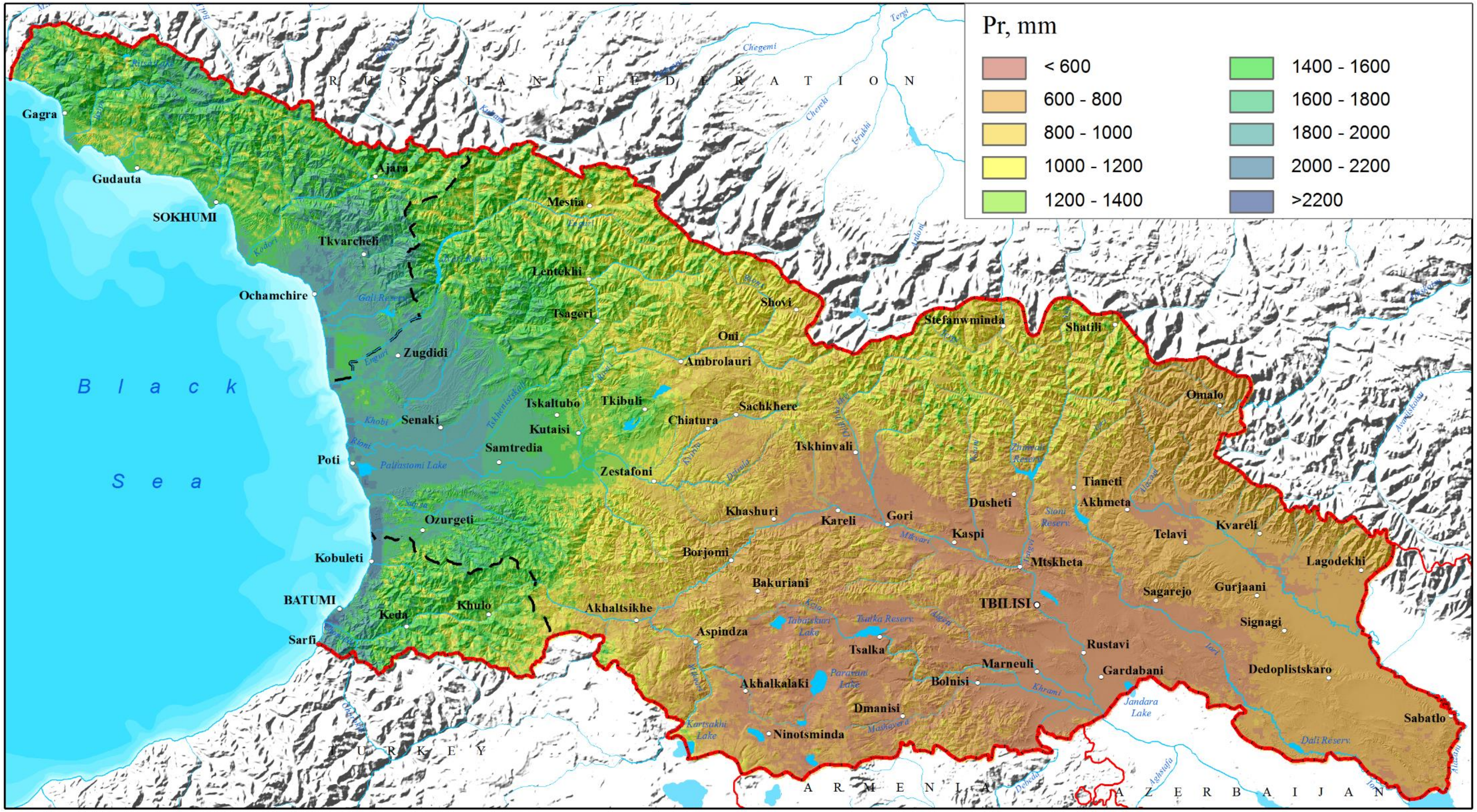
Map 4.2.5: Precipitation change in January between two 30-year periods (1971–2000 and 2071–2100)



Map 4.2.6: Precipitation change in July between two 30-year periods (1971–2000 and 2071–2100)



Map 4.2.7: Change in annual Precipitation between two 30-year periods (1971–2000 and 2071–2100)



Map 4.2.8: Average annual Precipitation in 2071–2100

In 1971-2000, minimum precipitation was in Bolnisi (492 mm) and maximum was in Batumi (2481 mm). In both forecast periods, annual maximum is still expected in Batumi (2363 mm and 2322 mm) and minimum - in Akhaltsikhe (436 mm and 424 mm).

Maximum one-day and five-day precipitation **(Rx1day** and **Rx5day)** decreases at most stations in the eastern and western regions of Georgia during both forecast periods. Rx5day shows the more pronounced decrease, with the exception of Zugdidi and Poti stations, where it increases sharply by 60%. Maximum one-day precipitation increases at about one third of the stations, with the sharpest increase in Zugdidi. At the rest of the stations Rx1day decreases. The most remarkable decrease in one-day precipitation in 2041-2070 is expected in Telavi (64 mm; ≈60%).

R30mm and **R50mm** are extreme precipitation days (over 30 mm and over 50 mm respectively) that increase the risk of floods/flashfloods, mudslides and landslides.

Maximum annual values of these indices are recorded at the Black Sea coast of Adjara and the same is expected in the future, however, the indices will decrease in both forecast periods. R30mm will decrease by an average of 1.4 days, except for few stations where it will increase (mostly in Poti by 4.1 and 0.9 days). R50mm will decrease by 0.3 and 0.4 days respectively in 2041-2070 and 2071-2100. This parameter will also increase slightly at certain stations by way of exception.

Consecutive dry days **(CDD)** and consecutive wet days (**CWD)** indicate length of period with maximum consecutive days when daily total precipitation is below 1 mm and maximum consecutive days when daily total precipitation is at least 1 mm. The first index is needed for water resource management purposes, especially in the areas with shortage of drinking or irrigation water. CDD extension is linked to drought. CWD together with Rx5day is associated with flood hazard. As a rule, only annual values are calculated for these indices.

In 2041-2071, the maximum number of consecutive dry days will decrease at most of the stations in Kakheti (by 2.1-5.6 days), Samegrelo - Zemo Svaneti (by 0.1-2.5 days), and in Tbilisi (by 4.8 days). In these regions the index will decrease by months and seasons, particularly in summer. In other areas, CDD will increase by 1 day on average. CDD will change according to a similar pattern in both forecast periods. At stations where this index drops, the decrease will be less intense and will not exceed 5 days, whereas the index increase process at certain stations will become more intense and 2 days longer (Akhaltsikhe).

The number of consecutive wet days increases in both forecast periods. The increase is particularly notable in Kakheti and Zemo Svaneti (5 and 3 days in the first and second forecast periods). Exceptions are certain highland stations - Lentekhi, Gudauri, Sabueti Mountain, where CWD is expected to decrease by 1 day.

Annual total precipitation implies days when daily precipitation exceeds the 95th percentile (**R95p**) and annual percentage of such days in total precipitation **(R95pTOT)** provide significant information on intensity and annual distribution of precipitation. Both parameters show a downward trend throughout the country, with less contribution from very heavy precipitation days during the first period, when precipitation decreases by 1.4-23% (from 1 mm to 241 mm), with the exception of three stations: Goderdzi Pass, Poti and Zugdidi, where on such days precipitation increases by 1.4-11%, reaching 24-287 mm. The same trend persists at all stations during the second period with precipitation decreasing maximum by 16% (2 mm to 263 mm). The increase in precipitation at the three stations is lower during this period (121 mm; 8 percent).

R99p and R99pTOT indices when Annual total precipitation falls on extremely heavy precipitation days, (daily precipitation exceeding the 99th percentile), change almost similarly to the previous two indices, but the number of such events is smaller, and consequently, their quantitative and percentage changes are less pronounced.

Based on data, minimum **average annual relative humidity** was observed in 1971-2000 in Tbilisi (67%) and maximum (86%) - in Mta-Sabueti.

In the future, in both forecast periods, minimum relative humidity is expected in Kvemo Kartli (70 % on average) and Sagarejo (68%). In 2071-2100, relative humidity will remain the highest in Mta-Sabueti, while in 2041-2070 it will reach maximum (88%) in Kobuleti. In 2041-2070, relative humidity will continue to increase at most stations by 1-5%. 1-2% decrease is expected in Khashuri and Paravani during this period. Table B3 in the Annex provides average monthly, seasonal and annual relative humidity values for 2071–2100 and changes of those values by regions and stations in respect to 1971–2000.

In 1971-2000, **average annual wind speed** varied from 0.4 m/sec (Lagodekhi) to 4 m/sec (Paravani) in Eastern Georgia 2000, and from 0.2 m/sec (Lentekhi) to 5.5 m/sec (Kutaisi) in Western Georgia.

In the future, maximum values of this parameter should be expected in Kutaisi again. The average wind speed will change slightly throughout the country within the range of ±0.5 m/sec depending on season and year. The average annual wind speed throughout Georgia will increase on average by 0.4 m/sec in the first period and by 0.3 m/sec in the second one. No consistent pattern in wind speed change has been identified in terms of geographic location or seasonal variability in either period.

4.3 Agriculture

Georgia’s agricultural sector plays a key role in the country’s economy. Georgian farmers will have an important function in providing one of the fundamental needs of society: safe, secure, and affordable food supply. This underlines the importance of the relationship between climate change impacts on agriculture and food security.

4.3.1 Livestock Farming

Livestock farming is one of the oldest traditional branches of agriculture in Georgia that played and plays an important role in the national economy. This is evidenced by the fact that all livestock species in Georgia are represented by domestically bred species, including endemic ones.

Cattle breeding is an acitivity of particular importance, being one of the main livelihoods for rural population. Despite of rather low productivity of cattle breeds (mostly mixed breeds) in Georgia, rural people tend to keep at least one cow. Average annual milk yeld of a cow is 1400 L in Georgia versus 9,000-11,000 kg in developed countruies (Israel, the USA, the Netherlands, etc.).

Environmental conditions have a direct influence on effective livestock management. Cattle breeding effectiveness depends on species’ genotype, as well as ability of its biological characteristics to adapt to the environment. Enhancement of livestock farming productivity directly depends on establishing of normal living conditions in the environment that is extreme for cattle. Productivity of any cattle species is one of the indicators of its adaptation to the environment.

In this context, it is crucial to find ways for livestock adaptation to the climate change impacts, especially against the backdrop of intensified livestock farming.

Aggravation of interaction between the animal organism and the environment is largely caused by change of climatic conditions to which the animals are accustomed to less favourable ones. The climate change can affect animals [1] in various ways, including:

- Direct impact on the organism (first of all, heat stress);
- Impact on vital nutrients contained in food and water;
- Impact on growth, development and productivity (population) of fodder plants;
- Impact on chemical composition of fodder plants (accumulation of toxic substances);
- Impact on populations of carriers of pathogenic agents (inspects, rodents); the climate change can reactivate dormant and forgotten pathogenic agents or activate currently existing ones; Change of distribution area of diseases and their carriers;
- An overly warm winter can cause spreading of exotic disease carriers (insects) from hot southern countries northward; it can also cause various diseases common in lowlands to move to mountain areas.

The main factor that largely influences animal performance is the environment temperature. Low temperature causes a decrease in the number of white blood cells and phagocytic activity, while high humidity and temperature cause the organism to release heat, leading to hyperthermia - heat stress. High humidity and temperature create favourable conditions for bacterial growth. Keeping livestock in crowded sheds in the absence of adequate ventilation leads to accumulation of toxic gases. High humidity contributes to spreading of respiratory infections. Unfavourable climate conditions and insanitation weaken body defences, lead to intensive bacterial growth and development of various diseases. Dairy foods (first of all milk) produced in such conditions are bacteriologically polluted and dangerous for human health.

Climatic factors can contribute to increase or decrease in growth and development of fodder plants, change biochemical processes and cause accumulation of toxic substances in them, improve or degrade quality of food and water, slow down or intensify reproductive activity of animals, intensify or impede spreading of agents of infectious or invasive diseases. Due to soil dryness caused by the climate change, plants receive insufficient mineral nutrients, causing nutrient deficiencies in animals.

It is also important to discuss the climate change impact on productivity of fodder plants. A change in precipitation structure can intensify soil erosion. Thus, a change in precipitation structure in Adjara has resulted in more intensive and frequent precipitation, causing soil erosion on mountain slopes and a sharp decrease in productivity of meadows and pastures against the backdrop of intensive herbage utilization: currently, meadow hay yield ranges within 10-12 dt/ha against 20-25 dt/ha in 1990s, and pasture yield is even less - 7 dt/ha.

Rise of temperature causes numerous challenges, including livestock watering. Monitoring of cattle watering during hot summer period in Kakheti and Kvemo Kartli showed the daily reduction in water supply parallel to the rise in air temperature. Rain pools often the only sources of water for cattle, gradually get smaller and sometimes completely dry out. Certain puddles, mainly located far from pastures, retain water, which is warm, muddy and polluted with droppings. Animals are reluctant to drink the muddy water, but have to do so, as fodder grass gradually dries in the period of drought and animals feel thirsty after grazing. Due to this, animals develop many pathologies, including digestive disorders (first of all gastric atony), infectious and invasive diseases. This causes a sharp reduction in cattle performance and other serious problems.

Over the past several summers, hot and rainless periods have become longer in Samegrelo region, causing drought and a decrease in fodder grass growth in the meadows. This has resulted in reduced livestock performance and increased incidence of diseases caused by blood parasites. Unlike the previous years, cattle started to develop tick fever during early spring. which was due to early activation of ticks in hot weather conditions. We also witness piroplasmosis activation in early spring in the mountain areas and villages in Samegrelo.

Dairy Farming in Georgia

Milk production has long become the most pressing issue in Georgia's agricultural sector. Statistics show a decrease in liquid milk production against an increase in powder milk import. In the period between 2014 and 2017, total livestock population decreased by 6.2%, the number of cows and buffalo cows – by 15.2%, while milk production – by 10.5%. Milk self-sufficiency ratio is gradually going down too [2].

Table 4.3.1.1: Animal Performance Indices

Index/year	2014	2015	2016	2017
Cattle population, thousand heads	970	992	963	910
Number of milkers (cows and buffalo cows)	563	545	530	518
Milk production, million litres	579	556	530	518
Milk self-sufficiency ratio, %	90	87	82	82

The problem can be addressed through urgent replacement of current extensive livestock farming system with intensive breeding and selection practices alongside with other adaptation measures.

Dairy breeds of cattle, successfully raised in temperate climatic zones, show low performance in countries with hot climate. In order to avoid heat stress and enhance performance, it is necessary to take measures for protecting such breeds from exposure to heat. It has been established that the main reason for the drop in productivity of temperate cattle breeds in tropical and subtropical zones is negative impact of high air temperature (heat stress), alongside with such factors as relative humidity, solar radiation, precipitation, etc. [3–7].

Over the past few years, many farmers in Georgia have been importing European breeds, mainly Holstein – one of the most popular dairy breeds in the world, known for its high live weight, that can be successfully milked two and three times a day. Holstein cows show high milk yields and intensive growth and development in the presence of adequate and balanced feeding [3, 4]. Unlike other breeds, Holstein cows easily adapt to influence of environment conditions, including heat stress caused by extremely high temperature. Yet, in order to show its gene-deep maximum performance potential, the breed needs to be placed in conditions, favourable for its genotype. So it is essential to breed Holstein cattle in conditions that is unusual for them. In general, genetically conditioned animal response predetermines possible degree of animal's adaptation to environment conditions. Disregard of certain adaptation-related peculiarities sometimes impedes adaptation to extreme conditions of the environment [4–8, 10–13].

Heat stress

Impact of hot conditions on livestock health implies heat stress, mainly caused by high temperature and humidity. Accessibility of food and drinking water, as well as change in distribution area of pathogens and/or their carriers, have an indirect impact. The issue of stress from hyperthermia has become particularly crucial for livestock breeding in the context of the climate change.

Light heat stress manifests in sweating and hypersalivation, higher water consumption, heavy breathing, poor appetite. Animals try to stay in shadow. A stronger heat stress causes performance loss and sometimes death (loss) of cattle. In order to adapt to temperature fluctuations, animals have to regulate metabolism; part of energy that animals normally use for milk production or weight gain, has to be used for thermoregulation.

All this may result in reduced production of milk and meat. In general, under the influence of the climate change, cattle performance may increase in warm winter and decrease in hot summer.

Heat stress is measured by Temperature Humidity Index (THI), calculated with help of various formulas, of which the simplest and most common is the following:

$$THI = 0.8 * T + RH/100 * (T-14.4) + 46.4$$

or the alternative option of the same formula:

$$THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T - 26),$$

Where T is environment temperature in °C and RH is relative humidity in percent.

Cattle experience heat stress when THI exceeds animal-specific threshold. THI=71 was accepted as a reference threshold value for heat stress based on research of less productive cattle conducted in 1950s in Missouri University [9]. Based on the research, animals can experience heat stress with THI≥72. The same research offered the following heat stress ranking:

A. 72 ≤ THI ≤ 79) light (cows start feeling heat stress);

80 ≤ THI ≤ 89 moderate (milk yield drops significantly);

THI ≥90 strong (milk yield drops drastically; animals can die).

Further research showed that cattle have become more sensitive to heat stress than they used to be in 1950s. Cattle performance and metabolism have increased as a result of genetic selection, making dairy cows more sensitive to heat stress compared to their ancestors. It is known that high-production cattle is more vulnerable to environment conditions. On the other hand, using less productive cattle would reduce livestock farming effectiveness. [9, 10] show that cattle start experiencing heat stress at THI≥68. It is evident that even at THI=68 heat significantly affects dairy cows, so below there is an alternative heat stress ranking:

B. 68 ≤ THI < 72, Slight discomfort;

72 ≤ THI < 75, Discomfort;

75 ≤ THI < 79 Hazard alert;

79 ≤ THI ≤ 84 Serious hazard;

THI > 84 Critical condition.

Heat stress intensity depends not just on THI values, but also on time during which animals experience the stress. With THI=68 during 24 hours, milk yield per day drops by 2.2 litres [8]. THI is more sensitive to temperature than to relative humidity (Table 4.3.1.2). In case of Georgia, it would be reasonable to use the A ranking for less productive breeds and the B ranking for more productive ones.

Table 4.3.1.2: THI relationship to air temperature and relative humidity

Temperature, ^{0}C	Relative humidity, %						
	30	40	50	60	70	80	90
25	69.6	70.6	71.7	72.8	70.0	80.0	90.0
30	75.1	76.6	78.2	79.8	81.3	82.9	84.4
35	80.6	82.6	84.7	86.8	88.8	90.9	92.9
40	86.1	88.6	91.2	93.8	96.3	98.9	101.4

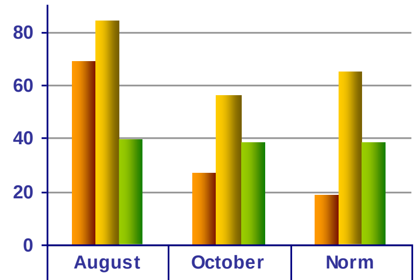
As of today, more than 4000 heads of commercial cattle breeds have been imported to Georgia, including 2200 Holstein, with the largest population in Kakheti Region.

Case study 1

In spring 2016, 100 heads of Holstein calves were imported from Estonia to LLC Shtori, which is used as a research site. The farm uses innovative intensive farming technologies and is located in Pshaveli village, Telavi district, Kakheti Region.

Visual monitoring showed that the animals were sensitive to summer temperature, which was exasperated by poor ventilation in the shed, where they were kept. They developed first signs of heat stress, expressed in acceleration of arterial pulse and breathing. Figure 4.3.1.1 shows indicators of cattle condition in August and October.

Figure 4.3.1.2 shows THI values measured based on Telavi Weather Station's data (temperature and relative humidity) for August (Fig. 4.3.1.2a) and October (Fig. 4.3.1.2b) 2016. Almost through the entire August, the cattle experienced discomfort.



	August	October	Norm
Breathing	69.2	26.5	18.5
Pulse	84.4	56.3	65
Temperature, 0C	39.4	38.2	38.5

Figure 4.3.1.1: Cattle condition indicators in August and October

THI values often were 79≤THI≤ 84, posing potentially serious hazard to livestock health.

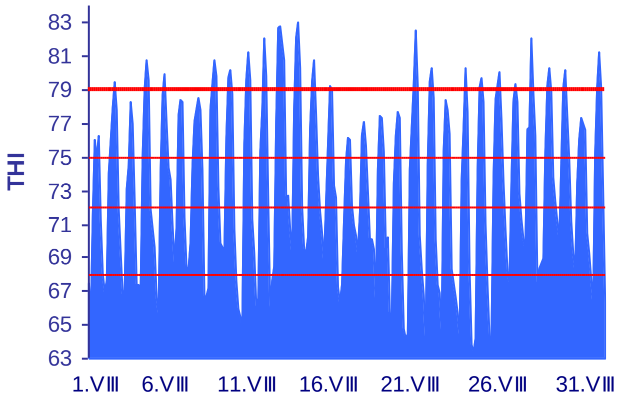


Figure 4.3.1.2a: THI values in August of 2016

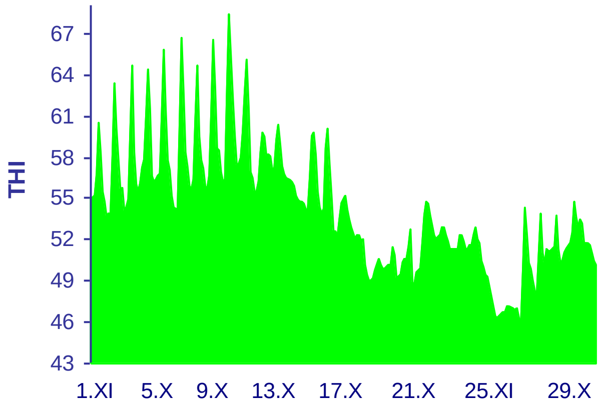


Figure 4.3.1.2b: THI values in October of 2016

Average temperature underrepresents intensity of heat stress, as high daylight temperature is partially neutralized by lower night temperature. Humidity fluctuation is less dependent on time of day; hence, THI values based on average temperature and average humidity are likely to be underestimated.

Case Study 2

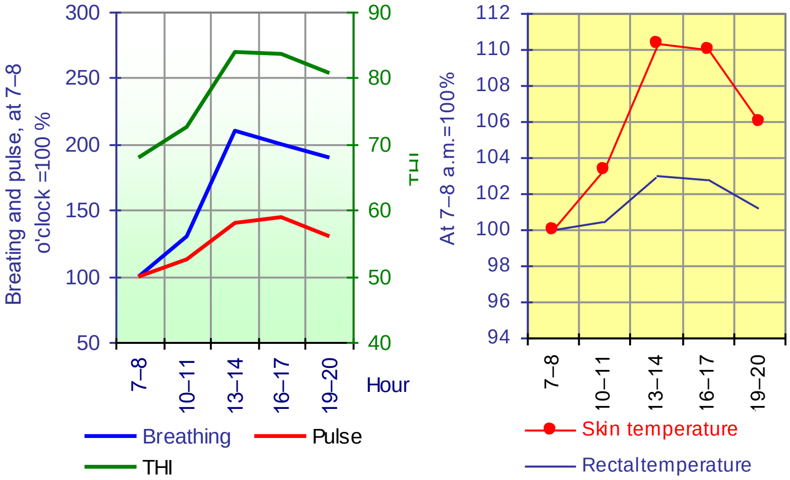
Biological characteristics of Brown Caucasian cattle breed have been studied in the course of research and production operations at a farm located in Khornabuji village, Sighnaghi district of Kakheti. The research aimed at identifying physiological and clinical characteristics of cattle placed in thermally neutral and extremely high temperature conditions. Caucasian Brown is a local breed, developed through crossbreeding with Brown Swiss. Grown cows of Caucasian Brown weigh 400–450 kg, yield is 2500–4000 kg of milk with fat content of 3.8–3.9%.

The farm (research facility) is located in the region with dry subtropical-to-continental climate. In the hottest months (July and August), air temperature reaches 40^{0}C. Precipitation ranges between 500 and 600 mm. During warm months, the cattle grazed for 185-200 days. Analysis of influence of air temperature on physical and clinical indicators showed that pulse and breathing rate increased respectively 1.96 and 1.4 times at 36.2^{0}C as compared to 21.8^{0}C. Although perspiration increased 2.39 times, this is not sufficient for thermal regulation, so, body temperature (rectal temperature) increased by 1.5^{0}C, while skin temperature – by 3.1^{0}C (Table 4.3.1.3).

Hence, in high temperature conditions, thermoregulation mechanism of the Caucasian Brown breed fails to retain normal physiological condition of the body, and heat stress causes a drop in milk yield. Table 4.3.1.3 shows THI values and heat stress indices.

Table 4.3.1.3: Physical indices of milk cows in thermally neutral and extremely high temperature conditions

Time of observation	Morning, 7:00–8:00	Midday, 13:00–15:00
Time of observation	21.8	36.2
Air temperature, ^{0}C	56	38
Relative humidity, %	35 – 46	76 – 90
Breathing rate	55 – 75	80 – 102
Pulse rate	37.8 – 38.7	39.6 – 40.2
Body temperature, ^{0}C	34.3 – 35.7	37.7 – 38.4
Skin temperature, ^{0}C	85 - 109	196 – 253
Perspiration, gr/(m^{2} . hr)	68	84
THI		



Analysis of dynamics of livestock physiological indices at various degrees of heat stress showed that already at 10-11 a.m. the indices increase significantly under the influence of heat. The indices reached the peak by 1-2 p.m. and gradually decreased after 4-5 pm. At night, the animals returned to their normal condition. Between the midday and the evening, THI exceeded 80, which means serious hazard according to the THI ranking.

Figure 4.3.1.3: Dynamics of livestock physiological indices during a day

Increase in temperatures influences morphological composition of blood (Table 4.3.1.4) of dairy cows. Thus, at high midday temperature, the number of red and white blood cells decreases, haemoglobin concentration reduction is less significant.

Table 4.3.1.4: Morphological composition of blood of milk cows at various air temperature

Time of observation	Morning, 7:00–8:00	Midday, 14:00–15:30
Air temperature, ^{0}C	23.5	34.8
Relative humidity, %	56	39
Red blood cells, mln/mm^{3}	5.4 – 6.0	5.3 – 5.8

Time of observation	Morning, 7:00–8:00	Midday, 14:00–15:30
White blood cells, thou/mm^3	6.3 – 6.9	6.0 – 6.8
Haemoglobin, %	9.5 – 11.3	9.4 – 10.7

Case Study 2, Conclusions: (1) Extremely high air temperature has a negative impact on grazing cows during summer. At high temperature, as compared to thermally neutral conditions, milk cows develop accelerated breathing and pulse rates, higher rectal and skin temperature and intensive perspiration. Body temperature of certain cows exceeds 40^0C, which is significantly higher than the physiological norm, thus resulting in heat stress. Milk yields of cows of various productivity changes differently under the influence of heat; (2) dynamics of physiological indices of cows during a day corresponds to air temperature fluctuations. From 8 to 15 percent of the herd have shown rather high thermal resistance and adaptation coefficient, which is extremely important in terms of selection; (3) influence of heat on blood parameters is relatively moderate, but increased air temperature still cause certain changes: namely, the number of white and red blood cells and haemoglobin concentration decrease at midday.

Case Study 2 Practical Recommendations: (1) It is necessary to take measures to protect grazing cattle from heat in summer, which can be achieved by setting up (installing) lightweight sheds in pastures, night grazing, etc. (2) In hot climatic zones, selection should be performed with special focus on thermal resistance abilities, revealed during the research.

The climate Change Impact

Calculations based on data for the period of 1956-2015, provided by 37 meteorological stations, show that average monthly, seasonal and annual temperatures during June-October has increased over the last 30 years (1986–2015) compared to the period of 1956–1985 (see Table A1 in the Annex for details) at all the stations. The most noticeable increase was recorded by all the stations in July-August. The increase in temperature reflects the general trend, but does not determine the temperature regime, so the temperature value is important by itself. In 1986-2015, high temperature was observed across much of Kakheti and Imereti, in Kvemo Kartli, as well as in the lowlands of Samegrelo, Guria and Adjara.

The change in relative humidity is irregular (see Table A3 in the Annex for details). In the above regions, it increases slightly only at several stations, including 6%–8% growth in Kvareli and 6%–7% growth in Tbilisi, and therefore is less important for the growing risk of heat stress.

Proceeding from the above, in most parts of Kakheti, Imereti, and Kvemo Kartli, as well as in the lowlands of Samegrelo, Guria and Adjara the risk of heat stress mainly exists in July and August.

According to the climate scenario, average relative humidity increases in summer at all the stations in both 2041–2070 and 2071–2100 against 1971–2000 (see Table B3 in the Annex for details). In 2071–2100, the most significant increase falls for August. As to the regions, the increase ranges between 5% and 12% in Kakheti (depending on station), makes up 21% in Kvemo Kartli (Bolnisi), 7%-10% in Samegrelo and 11% in Adjara (Kobuleti) excluding the mountain regions.

The average also temperature increases at all stations (see Table B1 in Annexes for details) with significant growth mainly observed during the summer months and occasionally in the first half of September.

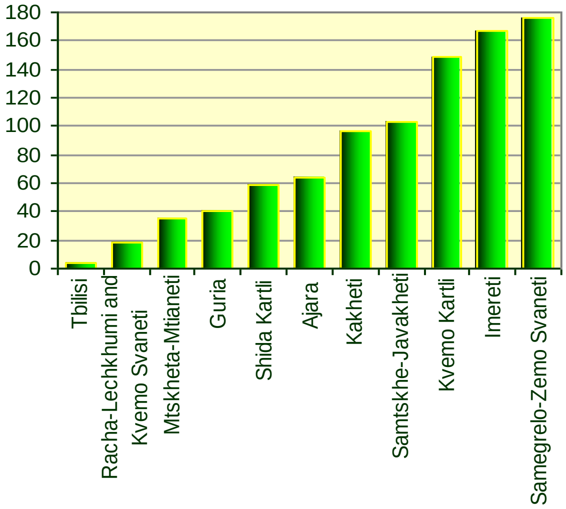


Figure 4.3.1.4: Livestock population by regions

In the future, the risk of heat stress may be caused by average temperatures exceeding a certain threshold value. Lowlands of Kvemo Kartli, Shida Kartli, Kakheti, Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti and Adjara (up to 700-800 meters above sea level) are particularly sensitive in this regard. Short-term periods of heat stress risk may also occur in other regions. The extent of risk depending on the cattle population by regions was also taken into account during the assessment. It is noteworthy that in the future, high-producing cattle will probably be exposed to the highest risk, but other breeds may also experience problems, which may lead to the decline in productivity. It should also be mentioned that at comparatively high altitudes temperature changes will have a stronger impact on low-producing cattle than at lower altitudes. As a rule, cattle living at lower altitudes are adapted to high temperatures better than those living at high altitudes.

Table 4.3.1.5 below shows the maximum monthly temperature values recorded at the stations in June, July and August 2015 by regions, as well as the maximum and minimum values for the same stations in 2050, 2070 and 2100. In order to model the relationship between the maximum monthly temperature and the year of observation, a simple linear regression analysis was used. A confidence interval (CI) was calculated showing the maximum and minimum values, within which the maximum monthly temperature for the forecast year is given with 95% probability. The maximum monthly temperature may exceed the values with remaining 5% probability.

Table 4.3.1.5: Maximum monthly temperature in 2015 and maximum and minimum temperature values calculated for 2050, 2070 and 2100

	Guria /Chokhatauri					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	33.4		34.6		34.9	
2050	39.8	31.1	42.2	30.4	41.1	30.0
2070	40.4	31.1	43.1	30.5	41.9	30.0
2100	41.4	31.1	44.6	30.6	43.2	30.0

	Samtskhe-Javakheti/Borjomi					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	36.2		37.8		39.0	
2050	37.4	30.4	40.4	33.1	41.8	32.3
2070	37.7	30.2	40.8	33.0	43.3	33.2
2100	38.2	29.9	41.4	32.8	45.7	34.5

	Racha-Lechkhumi/Ambrolauri					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	33.8		39.7		40	
2050	37.1	29.9	41.9	33.2	42.1	33.5
2070	37.4	29.7	42.8	33.6	43.1	33.9
2100	37.8	29.3	44.2	34	44.7	34.5

	Tbilisi					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	36.2		37.8		38.5	
2050	37.6	30.2	40.5	33.1	42.1	33.2
2070	37.9	30.0	40.8	33	42.9	33.5
2100	38.4	29.7	41.5	32.8	44.3	33.7

	Imereti/Zestaponi					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	34.0		40.0		40.0	
2050	39.3	31.2	44.6	34.4	43.8	34.3
2070	39.6	30.9	45.7	34.8	44.6	34.5
2100	40.0	30.4	47.3	35.2	46.0	34.8

	Shida Kartli/Gori					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	33.2		36.4		39.0	
2050	35.1	27.5	38.4	30.4	41.8	32.3
2070	35.2	27.2	38.8	30.3	43.3	33.2
2100	35.6	26.7	39.5	30.0	45.7	34.5

	Kvemo Kartli/Bolnisi					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	36.2		37.8		38.5	

	Kakheti/Dedoplistskaro					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	36.4		36.6		40.8	

	Mtskheta-Mtianeti/Pasanauri					
	June		July		August	
	≤	≥	≤	≥	≤	≥
2015	32.5		32.0		34.0	

	Kvemo Kartli/Bolnisi						Kakheti/Dedoplistskaro						Mtskheta-Mtianeti/Pasanauri					
	June		July		August		June		July		August		June		July		August	
	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥
2050	37.9	30.9	40.4	33.1	42.3	33.9	38.7	30.5	41.9	33.5	43.9	34.9	35.2	27.9	37.1	29.3	39	29.1
2070	38.4	30.9	40.7	33	43.2	34.4	40.2	31.4	43.5	34.5	46.0	36.4	36.4	28.5	38.1	29.8	40.4	29.7
2100	39.2	30.9	41.4	32.8	44.8	34.9	42.4	32.7	46.0	36.0	49.2	38.6	38.2	29.4	39.7	30.4	42.5	30.5

	Samegrelo/Zugdidi						Adjara/Kobuleti					
	June		July		August		June		July		August	
	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥	≤	≥
2015	33.3		35.2		36.6		26.5		31.0		31.5	
2050	40.2	30.6	44.5	30.5	42.3	30.2	38.9	22.1	43.9	28.9	39.0	25.5
2070	40.9	30.7	46.0	31.1	43.3	30.4	39.0	21.1	45.8	29.8	39.8	25.4
2100	42.1	30.8	48.4	31.8	45.0	30.7	39.5	19.5	48.8	31.0	41.2	25.2

Alongside with the risk of heat stress, increasing temperature values may cause spreading of pathogens and parasites[90] that spend part of their life cycle outside their "hosts"; this will have a negative impact on cattle. The climate change may cause a shift in location of hotspots or severe outbreaks of diseases, or even spreading of new diseases, which may affect animals that had never encountered such diseases before [15].

Adaptation Measures in Livestock Farming

- Selecting new breeds more resistant to heat stress, new diseases and their carriers; adjusting the production system with the focus on thermal tolerance and genetic improvement;
- Improving animal husbandry practices in cattle breeding field – main focus should be made on revealing and development of useful features of local breeds;
- Monitoring livestock health, removing/easing restrictions on antibiotics if any, intensifying the use of new fodder, food supplements and treatment methods;
- Improving ventilation in livestock keeping facilities;
- Using light colour roofing at farms to reflect sun's energy;
- Improving food reserves by enhancing quality and productivity of natural pastures; enhancing ability to absorb nutrients from food with account of change in its composition under the influence of the climate change;
- Diversifying local food reserves, using high-protein foods;
- Increasing efficiency of water management (storage, supply and use) necessary for intensive livestock faming;
- Improving grazing practices, protecting pastures from sun with help of natural and artificial tools, restriction of grazing during wet period; planting trees in pastures to give more shadow in the long run;
- Delivering water to pastures during dry period, for example, using water tanks;
- Improving land management to reduce impacts from new diseases and their carriers;
- Improving structure of meadows and pastures to increase their resistance to extreme weather conditions, for example, applying mixed structure of land use with inclusion of forest plots;

[90] A parasite is an organism that lives at the expense of a different organism, commonly known as the host, which it can harm and even kill.

- Improving natural grazing lands by increasing their productivity;
- Bringing livestock numbers in compliance with quality food production;

4.3.2 Perennials

Production of perennial crop is one of the oldest, important and traditional branches of the Georgian agriculture. Diverse natural and climatic conditions in the country's regions create the unique potential for growing and marketing of the great variety of local fruits.

The production of grape, hazelnut and citrus has a special role in the country's economy, providing the livelihood for a significant part of the rural population in Georgia. It is noteworthy that wine and hazelnut remain the top ten export positions of the country.

Viticulture

Vine growing and winemaking are ancient activities that have played a special role in creating the country's economic and cultural values. Representative national and international scientific studies, as well as a large diversity of autochthonous species (more than 500) and archaeological and archaeobotanical findings confirm an 8,000-year-old tradition of vinegrowing and winemaking in Georgia.

In the past few decades, the vine growing tradition has seen its ups and downs, but it always had an important function and importance in the country's life. Vinegrowing and winemaking have always played a prominent role and supported the livelihoods and cultural values of Georgian nation.

It is noteworthy that vine is unique in terms of adaptation to environmental conditions. It can be successfully cultivated in climatic and soil conditions where a range of other crops would have lower productivity. Commercial harvesting of grape starts quite early; the yield is already high in the third year, fully maturing in 4-5 years [16–17].

Vine products are used for many purposes. Apart from wine, which is the cornerstone of local grape production, grapes are considered one of the best food products. Apart from carbohydrates, ripe grapes contain significant amounts of organic acids (tartaric, malic, citric acids, etc.), vitamins and other useful substances, such as antioxidants, polyphenols, minerals (potassium, phosphorus, calcium), etc.

The following are some of the indicators characteristic for the Georgian viticulture sector. Table 4.3.2.1 shows grape yields by region.

- Main regions: Kakheti, Imereti, Shida Kartli, Kvemo Kartli and Racha
- Area under vineyards: 28,000 - 32,000 ha (as of 2014)
- Average age of vineyards: 15 - 30 years
- Average annual yield: 160,000 - 230,000 tons
- Leading varieties: Rkatsiteli, Saperavi, Green, Khikhvi, Kisi, Chinese, Alexandrouli, Mujuretuli, Tsitska, Tsolikauri and others
- Cultivation scheme: (2.0 - 2.4 meters) by (1.0 - 1.50) meters

Table 4.3.2.1: Grape Yields by Region

Region	Year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Imereti	43.7	30.3	25	26.3	36.2	36.6	11.7	28.6	21.7	20.9
Kakheti	100	82.7	64.7	98.1	70.8	129.5	124.3	150.3	111	134.8

Region	Year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Racha-Lechkhumi and Kvemo Svaneti									2.8	2.3
Kvemo Kartli									3.4	4.5
Shida Kartli	8.1	16.4	8.6	10.2	13.6	18.7	16.4	15.1	8.4	8
Other regions	24.0	20.7	22.4	25.0	23.3	38.1	20.1	20.4	12.0	10.4
Total	**175.8**	**150.1**	**120.7**	**159.6**	**143.9**	**222.9**	**172.5**	**214.4**	**159.3**	**180.9**

Current and forecasted climate change in key wine-growing regions

The climate change forecasts for the regions of Kakheti and Imereti are based on the analysis of data and forecasts from weather stations. In Kakheti, these stations are located in Kvareli, Telavi, Lagodekhi, Gurjaani, Sagarejo, and Dedoplistskaro; in Imereti, they are in Zestafoni, Kutaisi, Sachkhere, and Samtredia.

The current climate change manifests itself in changes in mean meteorological parameters between two 30-year periods (1986–2015 and 1956–1985). Analysis of the data showed that the mean annual temperature has increased by 0.54^{0}C in Kakheti and by 0.49^{0}C in Imereti (Table 4.3.2.2).

The increase in the **mean air temperatures** in both regions is mainly observed from June to October, whereas in November-December there is a slight decrease in the mean values.

Table 4.3.2.2: Mean air temperature values (Tmean) in Kakheti and Imereti from 1986 to 2015 and changes in temperatures (ΔTmean) vs the period of 1956–1985

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Kakheti																	
T_{mean}, ^{0}C	1.6	2.5	6.6	11.9	16.4	21.1	23.9	23.7	19.2	13.5	7.3	3.0	11.7	22.9	13.3	2.3	12.6
ΔT_{mean}, ^{0}C	0.47	0.54	1.03	0.16	-0.25	0.95	0.68	1.20	0.87	1.06	-0.15	-0.08	0.31	0.94	0.60	0.30	0.54
Imereti																	
T_{mean}, ^{0}C	4.2	4.9	8.2	13.3	17.6	21.1	23.8	24.3	20.6	15.7	9.9	6.0	13.1	23.1	15.4	5.1	14.2
ΔT_{mean}, ^{0}C	0.14	0.16	0.29	0.14	0.03	0.44	1.14	1.56	1.10	1.10	-0.19	-0.06	0.16	1.05	0.67	0.07	0.49

Annual precipitation data show that precipitation in the three municipalities of Kakheti (Telavi, Sagarejo and Dedoplistskaro) was reduced by 15% in summer, yet increased during other seasons (Table 4.3.2.3). It is noteworthy that in Lagodekhi municipality precipitation has increased by 13% during all seasons.

Precipitation in three municipalities of Imereti (Sachkhere, Kutaisi, and Zestafoni) has declined insignificantly in summer (by 2.5%). In other seasons, a slight increase (by 2.5–5%) in precipitation is observed, and the annual precipitation has increased by 2.5%.

Table 4.3.2.3: Precipitation (Pr) in the regions of Kakheti (excluding Lagodekhi) and Imereti in 1986–2015 and changes in precipitation (ΔPr) vs 1956–1985

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Kakheti																	
Pr, mm	21	26	38	62	81	65	42	40	45	52	34	21	181	147	131	68	528
ΔPr, %	3.5	0	-2	5.5	4	-17	-15	-11	0.8	18	16	3	3.3	-15	10	1.8	-1.5
Imereti																	
Pr, mm	99	76	81	65	63	76	54	55	71	82	81	78	210	185	234	253	881
ΔPr, %	18	-4	8.8	-2	7.3	5.3	-7	-5	1	7.8	5	-4	4.8	-2.3	5	3	2.5

The expected climate change is predicted / estimated by means of comparing meteorological data for 2041–2070 (the first forecast period) and 2071–2100 (the second forecast period) with the respective factual baseline data for 1971–2000. The forecasts are based on the climate change scenarios [18].

According to the climate change scenarios, the mean air temperature in both Kakheti and Imereti would increase every month both in 2041-2070 and 2071-2000 compared to 1971-2000. The highest increase is expected in May. In the second forecast period (2071 -2100), the temperature increment in Kakheti would be higher than in Imereti (Table 4.3.2.4).

Table 4.3.2.4: Mean air temperature (Tmean) in Kakheti and Imereti in 2041-2070 and 2071-2100 and changes in air temperature (ΔTmean) vs 1971–2000

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Kakheti	**2041-2070 / 1971-2000**																
T_{mean}, ^{0}C	3.0	4.1	7.4	13.6	19.1	22.5	25.6	25.0	21.2	15.5	9.2	5.8	13.3	24.4	15.3	4.3	14.3
ΔT_{mean}, ^{0}C	2.1	2.4	1.5	1.3	2.7	2.0	1.9	2.1	2.5	2.6	2.1	2.9	1.9	2.0	2.4	2.5	2.1
Imereti	**2041-2070 / 1971-2000**																
T_{mean}, ^{0}C	5.6	6.7	10.7	15.9	20.3	23.5	25.3	25.7	22.7	18.3	12.2	7.7	15.6	24.8	17.7	6.7	16.2
ΔT_{mean}, ^{0}C	2.0	2.4	2.8	2.5	3.0	3.0	2.4	2.6	2.8	3.2	2.6	2.1	2.7	2.6	2.9	2.2	2.6
Kakheti	**2071-2100 / 1971-2000**																
T_{mean}, ^{0}C	3.7	4.7	9.0	15.2	21.1	24.1	27.4	26.7	23.0	16.9	10.9	6.8	15.1	26.1	16.9	5.0	15.8
ΔT_{mean}, ^{0}C	2.8	2.9	3.1	2.9	4.8	3.6	3.7	3.8	4.2	4.0	3.8	3.8	3.6	3.7	4.0	3.2	3.6
Imereti	**2071-2100 / 1971-2000**																
T_{mean}, ^{0}C	5.9	7.2	11.3	17.5	21.5	23.9	26.1	26.3	23.0	18.8	12.7	8.4	16.7	25.4	18.2	7.1	16.9
ΔT_{mean}, ^{0}C	2.3	2.8	3.3	4.0	4.2	3.3	3.1	3.2	3.2	3.8	3.1	2.8	3.8	3.2	3.3	2.7	3.2

In terms of precipitation, the annual amount of precipitation in Kakheti is reduced by 8% in the first forecast period (2041-2070), significantly increasing in winter (by 15%), but dropping in the remaining three seasons, the maximum reduction is noted in spring (by 21%). In Imereti, the decrease in precipitation is almost the same (8-13%) during all seasons (Table 4.3.2.5). In the second forecast period (2071–2100), annual precipitation in Kakheti is reduced by 19%, mostly in spring (by 28%) and in autumn (by 16%), with an increase of 6% in summer only. In Imereti, precipitation drops during all seasons, most noticeably (by 14%) in summer and autumn.

In the first forecast period, the growing season length (GSL) increases by 10-12 days on average in Kakheti and by 12-14 days in Imereti. In the second period, GSL increases by 16-19 days and 16-18 days in Kakheti and Imereti, respectively. GDDgrown, or growing degree days, is the annual sum of active temperature values, i.e. the annual total sum (TM – n) of positive daily difference values, where n a user-defined, location-specific base temperature and TM> n. In case of n = 10^{0}C, GDDgrown increases by 386^{0}C in the first forecast period and by 1,041 ^{0}C in the second period in Kakheti, and by 491^{0}C and 590^{0}C, respectively, in Imereti.

Table 4.3.2.5: Precipitation in the regions of Kakheti and Imereti (Pr) in 2041–2070) and changes in precipitation (ΔPr) vs 1971–2000

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Kakheti	**2041-2070 / 1971-2000**																
Pr, mm	38	44	47	68	79	97	70	64	57	60	50	40	193	231	167	122	713
ΔPr, %	27	7	-21	-12	-28	-14	6.8	-1	-9	-8	-9	16	-21	-5	-8	15	-8
Imereti	**2041-2070 / 1971-2000**																

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Pr, mm	86	66	56	58	50	63	48	53	57	83	74	94	164	163	213	246	786
ΔPr, %	-11	-12	-13	-9	-15	-11	-14	-11	-9	-3	-14	-9	-13	-12	-8	-11	-11
Kakheti	**2071-2100 / 1971-2000**																
Pr, mm	37	40	50	58	71	82	52	58	52	55	48	33	178	192	155	110	634
ΔPr, %	29	-4	-19	-26	-36	-28	-20	-10	-18	-19	-10	-1	-28	-21	-16	6	-19
Imereti	**2071-2100 / 1971-2000**																
Pr, mm	87	67	73	56	51	62	49	48	50	76	74	103	179	159	197	257	792
ΔPr, %	-11	-11	6	-12	-15	-11	-14	-16	-17	-12	-13	-3	-6	-14	-14	-8	-10

WSDI is the warm spel duration index, i.e the annual count of days with at least 6 consecutive days when TX > 90th percentile. In Kakheti, WSDI increases by 26 days in the first period and by 72 days in the second period, and in Imereti, by 12 and 18 days respectively.

TX90p is the percentage of days when TX> 90 percentile. In Kakheti, TX90p increases by 10% in the first and 28% in the second period, whereas in Imereti it increases by 9% and 13% respectively.

Impact of The Current and Forecast Climate Change on Viticulture

Climate change has a significant impact on **phenological phases of the vine**. Scientific studies in Georgia show that phenological processes (flowering, ripening, and maturity) of the vine have accelerated over the recent 30 years, which is due to the fact that the maturity period starts 3-5 days earlier compared to historically observed process. This process is expected to further intensify in future [19].

The expected climate change may have a significant **negative** impact on yields, primarily because of longer drought periods, which would result in significant deterioration of yield characteristics and quality.

Heat stresses weaken the young vine, burn the grape bunches, causes unwanted early maturation, leading to decreased yield and deteriorated quality of the wine.

Lack of humidity and precipitation has a negative impact on photosynthesis and growth of the vine shoots. This may lead to unpredictable changes in the quantity and quality of tannins and anthocyanins, as well as deteriorate secondary metabolites: aroma, content of significant pigments and taste characteristics [20-22].

Increasing number of haily days may also cause a significant damage to viticulture.

Changes in the temperature regime and humidity may **increase the harmful pathogen load on the vine** and thus require increased number and better quality of comprehensive vine protection measures. That could also lead to invasion of new pests or activate local, previously less active ones.

The climate change may lead to **deterioration in the quality of wine brands produced from certain grape varieties,** also to shrinking of existing micro-zones, as well as changes in the range of local varieties [23-25].

Yet current and projected climate changes may also have a number of positive impact on vine production:

The sum of active temperature values would increase, making it possible to grow early-ripening and late-ripening varieties of table grapes, to identify new regions for wine production and to expand the range of varieties, especially those of red grapes [26].

Increase in carbon dioxide (CO_2) concentrations may also have a positive effect on the yield.

Critical winter temperature would decrease, enabling use of new areas for vine production and expansion of varieties.

Recommendations for Vine Adaptation

The following recommendations are proposed to mitigate and adapt to the impact of the global warming on viticulture:

1. Allocate new zones and micro-zones for vine production;
2. Introduce and test drought-resistant rootstocks;
3. Promote introduction of new table and wine grape varieties;
4. Introduce and practice conservation agriculture methods (mulching, minimum tillage);
5. Promote drip irrigation;
6. Support installation of anti-hail nets.

Adaptation Costs and Benefits

Increasing temperature and decreasing precipitation could cause the need for artificial irrigation of vineyards which previously did not require to be irrigated. The expected water shortage could be mitigated by efficient use of existing water resources. **Drip irrigation** is very effective in this regard. The cost of installing a drip irrigation system is estimated as GEL5.5-6.5 mln per 1,000 ha of vineyards. With drip irrigation, a vineyard would bring an additional GEL 1.0-1.2 million annually, which would have a return period of 10 years (the discount rate is 8%, and NPV is GEL1.825 million).

Drought-tolerant vine varieties could be imported, adapted, and tested in pilot scientific projects, and would create new opportunities for farmers involved in viticulture. Such project would not require significant investments and could be successfully implemented with a budget funding of GEL 400,000-500,000, whereas financial losses from drought could be millions of GEL.

Co-financing of anti-hail nets would be an efficient measure to increase yields. The yield from hail-protected vineyards is 8-10 tons per hectare, while harvesting from hail-affected vineyards is almost impossible. The estimated cost of using anti-hail nets would be GEL 50-60 per 1,000 ha, with 50% co-financing. Installation of anti-hail nets would require an investment of GEL 25-30 million, which is expensive, yet the impact would be long lasting and would ensure a return on the investment [27].

Promoting introduction of early-ripening table and wine varieties, allocation of new zones and micro-zones for wine production, development and implementation of resource-saving conservative farming methods would be part of applied research and implementation activities, with a total cost not exceeding 1,000,000 GEL. Yet the economic impact would imply substitution of imported grape and wine varieties by local ones, and increase of export revenues by millions of GEL.

Social Impact

The proposed measures are vital for the development of viticulture and are both economically and socially important. Viticulture is an important and sometimes the only source of livelihood for the rural population of Georgia. Thus, in 2018 only the income of Georgian farmers involved in viticulture reached GEL 300 million (approx. USD 115 million). Measures to mitigate the negative impacts of the climate change would also contribute to a significant reduction in many adverse factors affecting agriculture, such as the decreasing number and aging of the rural population, deterioration of their social status. Viticulture and winemaking offer outstanding opportunities for young people in rural areas to overcome financial problems, realize themselves and achieve the desired well-being.

Hazelnut

Hazelnut is one of the most important agricultural crops for Georgia. Hazelnuts produced in Georgia have very good quality and are highly competitive. Georgia is among the top five hazelnut exporters. Apart from economic benefits, hazelnut is important for the environment in terms of stabilizing degraded or uncultivated soils, especially on slopes, thus reducing the risk of landslides, also stabilizing the water balance in catchments. Hazelnut can be grown in almost all regions of Georgia with appropriate micro-zones. The largest hazelnut producing regions are: Samegrelo, Zemo Svaneti, and Guria. Table 4.3.2.6 shows hazelnut production in 2009–2017. The drop in yields in 2016–2017 was not related to the climate conditions, but rather to pests and fungal diseases.

Table 4.3.2.6: Hazelnut production in Georgia in 2009–2017, thousand tons

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017
Adjara								1.5	2.4
Guria	3.7	3.7	6.8	5.9	9	6.2	6.2	7.2	6.4
Imereti	3.2	2.4	4.8	3.4	5.6	3.2	4.2	3.4	2.8
Kakheti								1.2	2
Samegrelo – Zemo Svaneti	11.4	20.8	15.8	11.8	20.5	20.7	18.8	15.3	7.3
Other regions	3.5	1.9	3.7	3.5	4.6	3.6	6.1	0.7	0.6
Total	**21.8**	**28.8**	**31.1**	**24.6**	**39.7**	**33.7**	**35.3**	**29.3**	**21.5**

Georgia has diverse hazelnuts varieties. Hazelnut plantations mainly include local varieties, primarily Anakliuri, Gulshishvela, Nemsa, Shveliskura, Dedoplis titi, Khachapura, Giffon, and others.

Hazelnut production was particularly developed in the recent 10-15 years. Hazelnuts are grown mainly on small, garden and homestead plots with an area from 0.1 ha to 0.5-1 ha. Homestead plots typically comprise 400-700 trees. Due to the increased demand, there are also larger hazelnut plantations (from 10 ha to 300 ha). In orchards with maintained agrotechnical conditions and favorable environment for hazelnuts, the yield is 1.5 - 2.5 tons per ha, though the average yield is up to 0.8-1 tons per ha.

The current and predicted climate change in Samegrelo and Guria

The impact of the climate change on hazelnut production has been assessed for two main producing regions - Samegrelo and Guria. The climate change forecast is based on the analysis of data received from the Zugdidi (Samegrelo) and Chokhatauri (Guria) weather stations, including current weather data as well as forecasts.

The current climate change manifests itself in changes of the mean weather parameters between two 30–year periods (1986–2015 and 1956–1985). Calculations have shown that the mean annual air temperature has increased by 0.63^{0}C in Zugdidi and by 0.37^{0}C in Chokhatauri; in both locations, the temperature mainly increases in the period from June to October.

Table 4.3.2.7: Mean air temperature (Tmean) in Zugdidi and Chokhatauri in 1986–2015 and changes in the mean air temperature (ΔTmean) vs 1956–1985

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Zugdidi																	
T_{mean}, ^{0}C	5.7	6.6	9.1	13.4	17.2	21.1	23.4	24.1	20.5	16	11	7.5	13.2	22.9	15.8	6.6	14.7
ΔT_{mean}, ^{0}C	-0.04	0.28	0.45	0.26	-0.04	0.77	1.23	1.81	1.37	1.42	-0.08	0.07	0.22	1.27	0.91	0.10	0.63

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Chokhatauri																	
T_{mean}, ^{0}C	5.5	5.8	8.6	13.4	17	20.7	22.3	23.4	20.3	16	10.8	7.1	13	22.1	15.7	5.1	14.2
ΔT_{mean}, ^{0}C	0.13	0.04	0.45	0.43	-0.03	0.45	0.27	1.38	1.14	0.92	-0.32	-0.43	0.28	0.70	0.58	0.07	0.49

Precipitation in Zugdidi has increased significantly in spring and autumn (by 11%) and dropped by 6% in summer. In Chokhatauri, precipitation has dropped in all months except for May.

Table 4.3.2.8: Precipitation (Pr) in Zugdidi and Chokhatauri in 1986–2015 and changes in precipitation (ΔPr) vs 1956–1985

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Zugdidi																	
Pr, mm	153	134	168	128	142	215	154	147	153	182	162	149	438	517	497	436	1888
ΔPr, %	20	-3	11	-4	31	16	-16	-17	1	17	16	-7	11	-6	11	2	4
Chokhatauri																	
Pr, mm	167	133	123	81	83	114	98	113	176	210	179	179	286	325	565	479	1655
ΔPr, %	-10	-21	-10	-16	8	-7	-9	-12	-1	-5	-13	-23	-8	-10	-7	-18	-11

The expected climate change is predicted / estimated by means of comparing weather data for 2041–2070 (the first forecast period) and 2071–2100 (the second forecast period) with respective factual baseline data for 1971–2000.

According to the climate change scenarios, the mean air temperature in both Zugdidi and Chokhatauri would increase every month both in 2041-2070 and 2071-2100 compared to 1971-2000. The highest increase is expected in May. The increase in temperature values would be higher in Chokhatauri.

Table 4.3.2.9: Mean air temperature (Tmean) in Zugdidi and Chokhatauri in 2041-2070 and 2071-2100 and changes in the mean air temperature (ΔTmean) vs 1971–2000

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Zugdidi 2041-2070 / 1971-2000																	
T_{mean}, ^{0}C	6.6	8.1	10.4	14.6	19.3	22.1	24.3	24.1	22.3	18.3	12.0	9.2	14.8	23.5	17.5	8.0	15.9
ΔT_{mean}, ^{0}C	1.9	2.4	1.7	1.3	2.6	1.7	1.5	1.2	2.6	3.0	1.7	2.7	1.9	1.5	2.4	2.3	2.0
Chokhatauri 2041-2070 / 1971-2000																	
T_{mean}, ^{0}C	6.6	7.4	10.8	15.7	19.8	23.2	24.4	24.7	22.2	18.3	12.8	8.6	15.4	24.1	17.8	7.5	16.2
ΔT_{mean}, ^{0}C	2.0	2.3	2.8	2.4	3.0	2.8	2.1	2.3	2.7	3.1	2.4	2.0	2.7	2.4	2.7	2.1	2.4
Zugdidi 2071-2100 / 1971-2000																	
Tmean, ^{0}C	7.2	8.7	10.8	15.5	19.9	22.3	25.3	25.3	22.7	19.0	13.1	9.9	15.4	24.3	18.3	8.6	16.6
ΔTmean, ^{0}C	2.5	3.0	2.2	2.2	3.2	1.9	2.5	2.4	3.0	3.8	2.8	3.4	2.5	2.2	3.2	3.0	2.7
Chokhatauri 2071-2100 / 1971-2000																	
Tmean, ^{0}C	6.8	7.7	11.3	17.0	21.2	24	24.9	25.1	22.4	19.4	13.3	9.2	16.5	24.7	18.4	7.9	16.9
ΔTmean, ^{0}C	2.2	2.6	3.3	3.7	4.4	3.6	2.6	2.7	3.0	4.2	2.9	2.7	3.8	3.0	3.4	2.5	3.1

In the first forecast period, precipitation in Zugdidi increases by 29%, especially in summer, and drops by 11% in spring only. In Chokhatauri, precipitation decreases every month except September and October. In the second forecast period, annual precipitation in Zugdidi decreases by 7%, with most significant drops in summer (by 10%) and autumn (by 16%), and with only a slight increase in spring (by 1%). In Chokhatauri, precipitation drops every month, with an annual decrease of 4%.

Table 4.3.2.10: Precipitation (Pr) in Zugdidi and Chokhatauri in 2041–2070 and 2071–2100 and changes in precipitation (ΔPr) vs 1971–2000

	Month												Spring	Summer	Autumn	Winter	Annual
	1	2	3	4	5	6	7	8	9	10	11	12					
Zugdidi 2041-2070 / 1971-2000																	
Pr, mm	121	155	112	134	107	286	205	226	126	135	220	193	354	717	480	469	2,019
ΔPr, %	-15	15	-18	2	-16	40	15	29	-11	-22	40	19	-11	29	2	7	8
Chokhatauri 2041-2070 / 1971-2000																	
Pr, mm	171	134	86	80	71	110	89	106	170	209	150	192	237	305	529	497	1,568
ΔPr, %	-7	-6	-15	-8	-14	-6	-3	-11	5	11	-20	-11	-13	-7	-1	-8	-7
Chokhatauri 2071-2100 / 1971-2000																	
Pr, mm	106	151	144	162	94	156	150	197	103	106	184	172	400	503	394	428	1,725
ΔPr, %	-26	12	5	23	-26	-24	-15	13	-27	-39	18	6	1	-10	-16	-3	-7
Chokhatauri 2071-2100 / 1971-2000																	
Pr, mm	176	135	108	72	81	118	88	111	154	186	162	221	261	316	502	532	1,612
ΔPr, %	-4	-5	7	-18	-2	1	-4	-7	-5	-1	-13	2	-4	-3	-6	-2	-4

The following climate indices were also used to characterize the climate change:

In the first forecast period, the **growing season length (GSL)** increases by 16 days in Zugdidi and by 9 days in Chokhatauri. In the second period, GSL increases by 25 days and 10 days in Zugdidi and Chokhatauri, respectively.

In the first forecast period, **the number of days with the mean temperature of TM ≤ 10^0C (TMlt10)** is reduced by 36 days in Zugdidi and by 14 days in Chokhatauri, whereas in the second period it drops by 38 days and 42 days, respectively, in Zugdidi and Chokhatauri.

In Zugdidi, the heat wave number (**HWN**) increases by 4.9 during the first forecast period and by 8.3 in the second period, and in Chokhatauri by 3.9 and 4.6 respectively. The heat waves duration (**HWD**) increases by 22 days in the first and by 29 days in the second forecast period in Zugdidi, and by 29 and 37 days, respectively, in Chokhatauri.

GDDgrown, or growing degree days, is the annual sum of active temperature values, i.e. the annual total sum (TM – n) of positive daily difference values (TM> n), where TM is a user-defined, location-specific base temperature. In case of n = 10^0C, the GDDgrown value increases by 376^0C in the first forecast period and by 959 ^{0}C in the second period in Zugdidi, and by 504 ^{0}C and 569 ^{0}C respectively in Chokhatauri.

WSDI is the warm spell duration index, i.e. the annual count of days with at least 6 consecutive days when TX > 90^{th} percentile. In Zugdidi, WSDI increases by 12 days in the first period and by 29 days in the second period, and in Chokhatauri, by 14 and 16 days respectively.

TX90p is the percentage of days when TX> 90^{th} percentile. In Zugdidi, TX90p increases by 9% in the first and by 20% in the second period, whereas in Chokhatauri it increases by 9% and 11% respectively.

Rx1day is the monthly maximum 1-day precipitation. In Zugdidi, Rx1day increases by 61mm in the first and by 70mm in the second period. In Chokhatauri, Rx1day decreases by 17 mm in the first period and by 7 mm in the second one.

Expected Climate Change Impact on Hazelnut Yield

In general, hazelnut is a relatively climate-resistant plant, though still susceptible to the climate change. The climate change would have a significant negative impact on the yields, especially in longer dry periods, which could lead to a substantial decrease in yields and quality. Warmer winters would reduce the winter chill and thus negatively affect the yield.

Heat stresses would decrease the phytosynthetic area of the hazelnut plantations and thus decrease yields. **Increased number of extreme precipitation** in Samegrelo would cause temporary flooding of lowlands. **Changes in temperature regime** would increase the harmful pathogen load and cause the need for more comprehensive plant protection measures. **Stronger hot winds** would increase losses and decrease yield.

Expected changes in the agro-climatic zoning of hazelnut production

The National Adaptation Plan for Agriculture reflects possible changes in the expected agro-climatic zoning of hazelnut production resulting from the climate change [18]. Findings set out in the document are shown in Figures 4.3.2.1 and 4.3.2.2. The zoning considers three agro-climatic zones: Zone 1 - Insufficient heat for hazelnut growing (highlighted in red); Zone 2 - Hazelnut production is possible if sufficiently irrigated (highlighted in light green); Zone 3 - Favorable climatic conditions for hazelnut growing (highlighted in dark green).

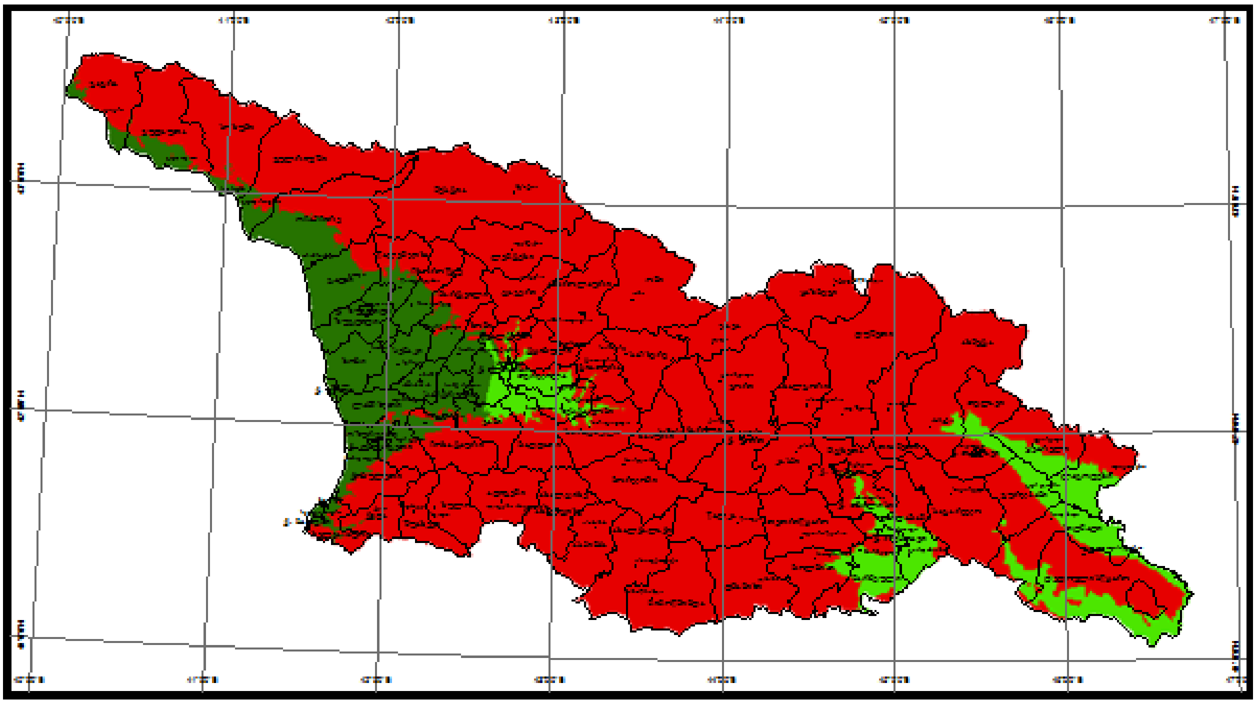


figure 4.3.2.1: Agro-climatic zoning of hazelnut production in 1966-1990

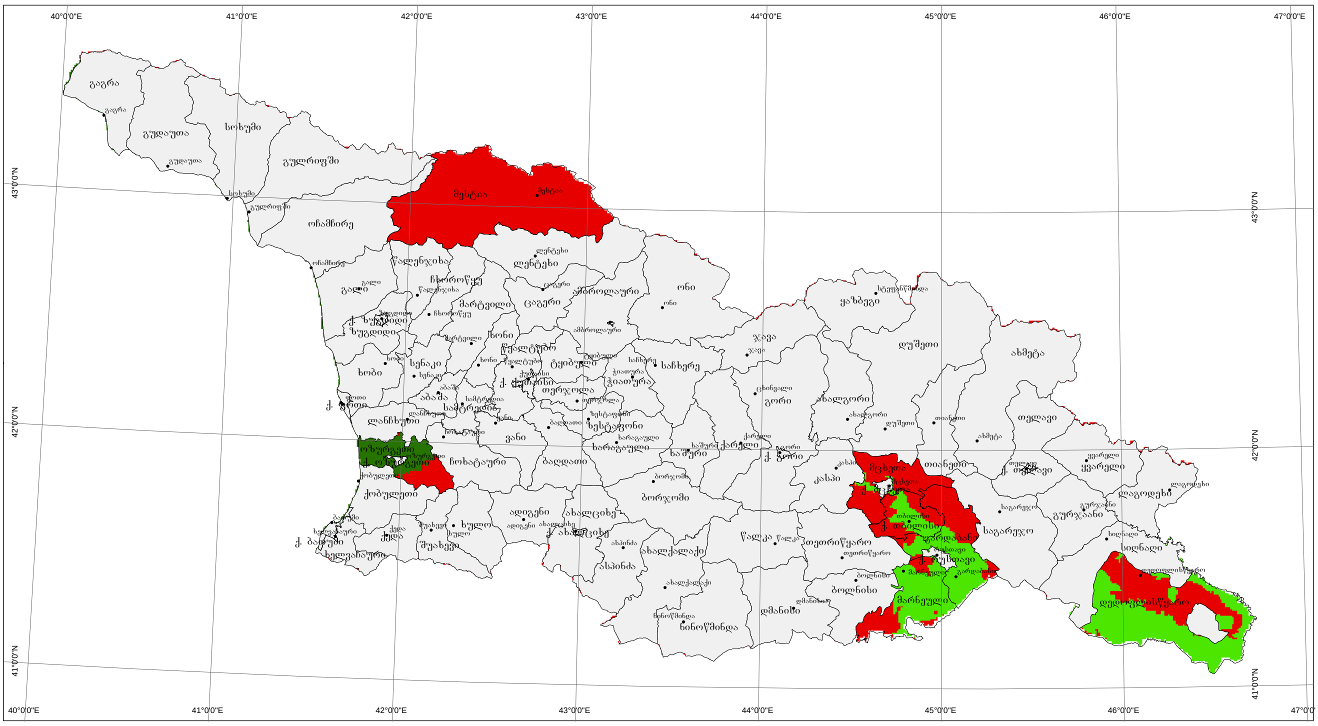


Figure 4.3.2.2: Agro-climatic zoning of hazelnut production in 1991-2015

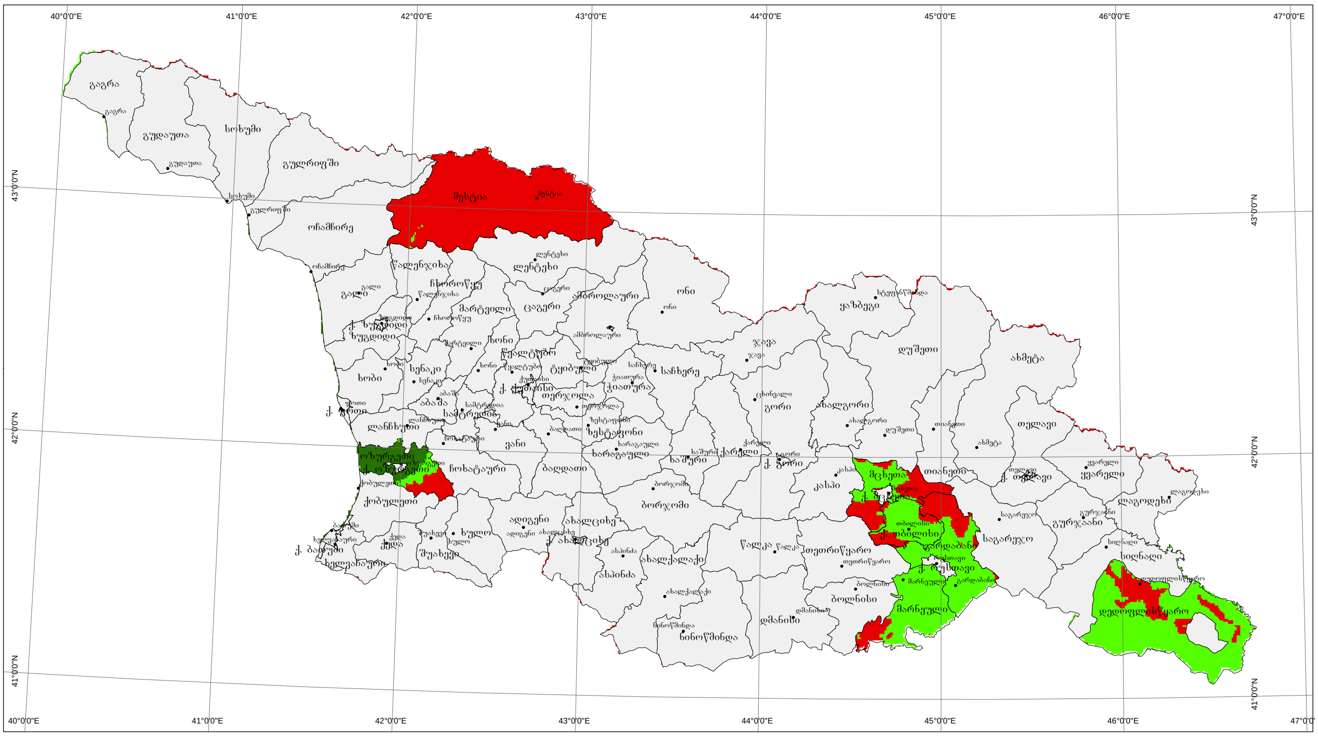


Figure 4.3.2.3: Agro-climatic zoning of hazelnut production in 2071-2100

Table 4.3.2.11 shows areas of the agro-climatic zones where hazelnut can be grown.

Table 4.3.2.11: Areas of zones favorable for hazelnut production in various periods

Period	Zone	Area favorable for hazelnut production, thou ha	
1991–2015	2	761	1,838
2017–2100	3	859	468

In future, Zone 3 would shrink to almost the half of its original size, but the area of zones where temperature would be favorable and hazelnut could be grown if irrigated would increase 2.5-fold. Yet additional research is needed to investigate if irrigation of these areas would be economically feasible.

Recommended Adaptation Measures

Primary activities:

– Collect rainwater for irrigation purposes and use water-saving irrigation methods (drip irrigation, rainwater) as well as promote boring of wells and installation of irrigation systems;
– Support the tools for the prediction, detection and meteorological monitoring of harmful pathogens;
– Support construction of windbreaks;
– Support construction and rehabilitation of drainage canals to remove excess water;
– Raise farmers' awareness and provide agricultural extension services;
– Strengthen insurance systems to reduce wind- and hail-related losses.

Secondary activities:

– Improve agrotechnical measures;
– Use mulching to maintain moisture in soil, using both organic and plastic mulches;
– Apply conservative agriculture principles, e.g. use of greensward between rows;
– Carry out the research of special biopreparations to prevent heat damage and promote their use;
– Provide the population and large farms with high quality substances and other materials needed for agro-technical activities.

Social Impact

The adaptation measures would have a positive and high social impact, as most hazelnut plantations are grown in small homestead gardens. For example, in the municipality of Zugdidi, there are probably more than 15,000 hazelnut plantations. In many cases, hazelnut production is one of the important sources of income for local farmers. Thus, the adaptation measures would significantly improve their social well-being.

Tangerine

Tangerine plantations cover an area of about 11 thousand hectares in Georgia. According to the National Statistics Office of Georgia, the Autonomous Republic of Adjara and Guria are the main tangerine producing regions, with relatively small quantities of tangerines produced in Samegrelo and Imereti. Table 4.3.2.12 shows the production of tangerines by regions of Georgia in 2007-2017. Figure 4.3.2.3 shows the share of the regions in tangerine production in 2007–2017.

Table 4.3.2.12: Tangerine production by region, thousand tons

Region	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Adjara	77.1	30.7	76.5	22.6	43.8	47.3	83.2	48.4	60.8	36.4	43.6
Guria	12.4	16.5	12.1	23.8	7.5	17.3	17.8	20.1	15.3	21.3	10.4
Samegrelo	4.1	4.4	1.9	2.1	1.6	6.0	5.0	3.2	2.2	1.9	0.7
Imereti				0.1	0.2	0.6	1.1	0.1	0.3	0.3	0.2
Total	93.6	51.6	90.5	48.6	53.1	71.2	107.1	71.8	78.6	59.9	54.9

Tangerine is one of the important agricultural products for export. Studies show that tangerines produced in Georgia have prominent quality and properties and are as good as their best foreign analogues.

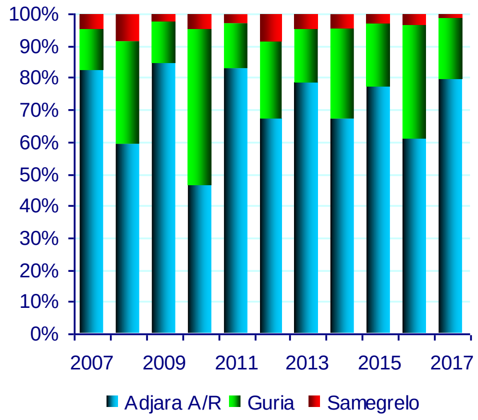


Figure 4.3.2.4: Share of regions in tangerine production in 2007–2017

According to the National Statistics Office of Georgia, average yields were 4.4-9.7 tones/ha in 2007-2017, compared to about 20 tones / ha in the world's leading countries. At present, tangerines are produced primarily in relatively old plantations, with areas ranging between 0.15 ha and 0.25 ha. There is a wide range of tangerine varieties in Georgia; harvest normally starts from the second half of November, yet there is a relatively small share of early-ripening varieties such as Kovano-Vase, Tiakhara Unshui, Kartuli Saadreo and others.

The climate change in Adjara and Guria

The climate change predictions are based on the current and predicted weather data received from weather stations located in two main tangerine producing regions - Adjara and Guria: in Batumi and Kobuleti (Adjara) and Chokhatauri (Guria) .

The expected climate change is predicted / estimated for 2041–2070 (the first forecast period) and 2071–2100 (the second forecast period) relative to the mean values of the 30-year baseline period (1971–2000).

According to the climate change scenario, in both forecast periods, the mean air temperature (T_{mean}) would increase every month and consequently every season compared to the baseline period, in Batumi, Kobuleti and Chokhatauri. The mean temperature difference (ΔT_{mean}) by season is provided in Table 4.3.5.13, which shows that the increase in spring and autumn temperature values exceeds the increase in the other two seasons.

Table 4.3.2.13: Mean temperature values in the forecast period and deviation from the baseline

2041–2100 / 1971–2000		Spring	Summer	Autumn	Winter	Year
Kobuleti	T_{mean} 2041–2100, ^0C	14.3	23.3	17.3	8.1	15.8
	ΔT_{mean}, ^0C	**2.3**	1.4	**2.0**	1.9	1.9
Batumi	T_{mean} 2041–2100, ^0C	14.8	23.8	18.7	9.2	16.6
	ΔT_{mean}, ^0C	**2.4**	2.0	**2.8**	2.0	2.3
Chokhatauri	T_{mean} 2041–2100, ^0C	15.4	24.1	17.8	7.5	16.2
	ΔT_{mean}, ^0C	**2.7**	2.4	**2.7**	2.1	2.4

2071–2100 / 1971–2000		Spring	Summer	Autumn	Winter	Year
Kobuleti	T_{mean} 2071–2100, ^0C	15.4	24.2	18.1	8.7	16.6
	ΔT_{mean}, ^0C	**3.4**	2.3	**2.7**	2.5	2.7
Batumi	T_{mean} 2071–2100, ^0C	15.9	24.3	19.2	9.7	17.3
	ΔT_{mean}, ^0C	**3.5**	2.6	**3.3**	2.4	2.9
Chokhatauri	T_{mean} 2071–2100, ^0C	16.5	24.7	18.4	7.9	16.9
	ΔT_{mean}, ^0C	**3.8**	3.0	**3.4**	2.5	3.1

In both forecast periods, precipitation drops compared to the baseline in Batumi, Kobuleti and Chokhatauri during all seasons, except for the projected 2% increase in precipitation in Batumi in autumn.

Table 4.3.2.14: Average precipitation in the forecast period and deviation from the baseline

2041–2100 / 1971–2000		Spring	Summer	Autumn	Winter	Year
Kobuleti	Precipitation, 2041-2070, mm	275	477	602	603	1,957
	ΔPr (2041-2070; 1971-2000), mm	-16	-13	-21	-2	-13
Batumi	Precipitation 2041-2070, mm	276	490	909	687	2,363
	ΔPr (2041-2070; 1971-2000), mm	-17	-8	2	-5	-5
Chokhatauri	Precipitation 2041-2070, mm	237	305	529	497	1,568
	ΔPr (2041-2070; 1971-2000), mm	-13	-7	-1	-8	-7
2071–2100 / 1971–2000		**Spring**	**Summer**	**Autumn**	**Winter**	**Year**
Kobuleti	Precipitation 2071-2100, mm	540	679	583	2121	
	ΔPr (2071-2100; 1971-2000), mm	-3	-2	-11	-5	-6
Batumi	Precipitation 2071-2100, mm	310	495	814	702	2322
	ΔPr (2071-2100; 1971-2000), mm	-7	-7	-9	-3	-6
Chokhatauri	Precipitation 2071-2100, mm	261	316	502	532	1612
	ΔPr (2071-2100; 1971-2000), mm	-4	-3	-6	-2	-4

The following climate indices were also used to characterize the climate change:

GDDgrown, or growing degree days, is the annual sum of active temperature values, i.e. the annual total sum (TM – n) of positive daily difference values (TM> n), where TM is a user-defined, location-specific base temperature. In case of n=10^{0}C, GDDgrown increases by 455 degrees in the first forecast period and by 535 degrees in the second period in Adjara, and by 504 degrees and 569 degrees, respectively, in Guria.

TX90p is the percentage of days when TX> 90th percentile. In Adjara, TX90p increases by 19% in the first and 30% in the second period, whereas in Guria the increase is 10% and 14% respectively.

HWN (EHF) is the Heat Wave Number (HWN) in May-September, determined by the excess heat factor (EHF). In Adjara, HWN (EHF) increases by 4.6 in the first and by 5.4 in the second period, and in Chokhatauri by 3.9 and 4.6, respectively.

HWD (EHF) is the Heat Wave Duration (HWD) (in days) in May-September determined by the excess heat factor (EHF). In Adjara, HWD (EHF) increases by 27 days on average in the first period, and by 33 days in the second one, whereas in Guria the increase is 29 and 37 days, respectively.

TN10p is the annual occurrence of cold nights, i.e. the percentage of nights with the lowest temperature of TN<10th percentile. In winter, TN10p decreases by 7 days in the first and by 8 days in the second period in Adjara, while in Guria the decrease is 6 and 7 days, respectively.

GDDgrown, or growing degree days, is the annual sum of active temperature values, i.e. the annual total sum (TM – n) of positive daily difference values (TM> n), where TM is a user-defined, location-specific base temperature. In case of n=10^{0}C, the GDDgrown value increases by 455 degrees in the first forecast period and by 535 degrees in the second period in Adjara, and by 504 degrees and 569 degrees in Guria.

In [1] the climate change impact on tangerine yields is considered. According to this document, the data of Adjara meteorological stations collected over many years (1961-2015) demonstrates that in Batumi area still there is no critical temperature that may devastate the tangerine trees, while the main branches were frozen in 1964, 1971, 1983 and in 1993. In Kobuleti winter was extremely severe in 1985 (-13.80C), wich had to make dry the plants; however, fortunately, the frost at that year was preceded by heavy snow of some 1.5-2.0 meters that protected the plants from a total devastation. It should be mentioned that the periods of severe frosts have the trend to reduction. For example, from 1960 to 1985 frosty winters were registered five times, from 1985 to 2000 – tree times, whie from 2000 to 2016 only once, thus showing the reduction of risks of frosty winters.

Reduction of a number of frosty days and of the absolute minimum temperature is also registered according to the periods. From 1966 to 1990 the number of frosty days in Batumi was 7.1; from 1991to 2016 – 8.2; but from 2071 to 2100 it is expected to have reduction of frosty days down to o,4. Within the period 1966 – 1990 the absolute minimum was -7.5^{0}C; in 1991-2015 it was -6.6^{0}C, and in the future, according to the prognosis, due to the climate change the minimum temperature will fall down only to -0.6^{0}C.

Given the above, the expected climate change might have a significant negative impact on tangerine yields, especially in increased drought periods, which would result in reduced yield and poor quality. Warming would also contribute to the prevalence of new diseases and pests.

Current and predicted changes could also have some positive effects:

- Increase of the sum of active temperature values, making it possible to harvest tangerines already in mid-September and grow some medium to late-ripening varieties (Okitsu). It would also enable production of some high-demand citrus varieties that cannot be grown in the current climate condition.
- Decrease critical winter temperatures, making it possible to grow varieties that are less frost-resistant yet more productive;
- Lead to the expansion of areas under the crops and change the zoning.

Recommended Adaptation Measures

- Introduce early-ripening varieties;
- Fill in the niche of ultra-early-ripening tangerine varieties;
- Promote drip-irrigation to prevent heat stress;
- Promote construction of windbreaks;
- Improve drainage systems;
- Refine and adapt agro-technical measures: use mulching technologies to keep moisture in the soil;
- Study and promote the use of specialized bio substances to prevent heat damage;
- If the situation gets worse, use local and regional anti-hail systems;
- Support the study of new tangerine varieties and rootstocks;
- Ensure continuous pest control and monitoring activities by using portable agro-meteorological stations.
- Re-cultivate old plantations.

4.3.3 Cereals

Wheat

Wheat has been cultivated in Georgia since ancient times. Out of 27 domesticated wheat varieties globally identified and described presently, 14 are found in Georgia. Out of these species five are local endems, which originated and were only found in Georgia. By the 1920-30-ies, endemic wheat crops were still predominant and occupied significant area. In 1909-1913, wheat was planted on at least 270,000 hectares, producing on average 190,000 tonnes of grain annually. In 1913, wheat grain production in Georgia exceeded 100 kg per capita. Currently (in 2018) the value of per capita production is much lower being equal to 27 kg (100.1 thousand tonnes/3,727,000).

Old wheat varieties have lost their commercial value due to low yield potential, but their genes that are able to improve adaptation of wheat to external factors (abiotic and biotic) are of great importance for breeding of improved wheat varieties under changing climatic conditions.

In recent years, wheat has been sown on 50,000 ha on average in Georgia with winter varieties occupying almost the entire area of wheat crops. Spring wheat is mostly planted to replace winter wheat after winter kill. Wheat is mainly produced in Eastern Georgia. As much as 65% (35 thousand ha) of the wheat area falls on Kakheti. Wheat occupies particularly large areas in Dedoplistskaro (14,000 h) and Sighnaghi (10,000 ha) municipalities. There are also large areas of wheat crops in Kvemo Kartli (6.5 thousand ha), Shida Kartli (5 thousand ha) and Samtskhe-Javakheti (3 thousand ha).

Wheat areas are mostly rainfed in Georgia, so yields fall significantly in dry years. Under such conditions, the choice of predecessor crops for wheat sown areas is rather scarce. Thus, in the rainfed areas in Dedoplistskaro, wheat is often rotated by sunflower. However the sunflower area is significantly lower than that of wheat (just 2,700 ha). Hence, monoculture is practiced in the most areas of wheat production, which has an adverse effect on soil fertility**.**

Since 1991 up to present, the lowest wheat yield was recorded in 2000 (0.8 t / ha) and was caused by “big” drought, when, according to the Dedoplistskaro Meteorological Station, total precipitation during the wheat growing months (October-June) dropped to the point as low as 183 mm , which is the lowest value recorded in the period from 1961 to 2015. The drought was aggravated by heat, when the mean air temperature rose to 26.2^{0}C, showing the highest point recorded in Dedoplistskaro in July for the given period. Apart from this, wheat yield in 2000 was affected by strong wind that “swept” the seeds and sprouts together with humus off the fields.

A very low wheat grain yield (1.0 t / ha) was also recorded in the year of 2010, which is characterized by the mean annual temperature of 13.3^{0}C being the highest for the period of 1961-2015 (according to the Dedoplistskaro station). The mean temperature in June was also the highest and the winter of 2009-2010 was unusually warm with the mean monthly temperature never falling below 0^{0}C. Because of high temperature, soil dried quickly in spring despite the normal annual precipitation, which slowed wheat growth and development.

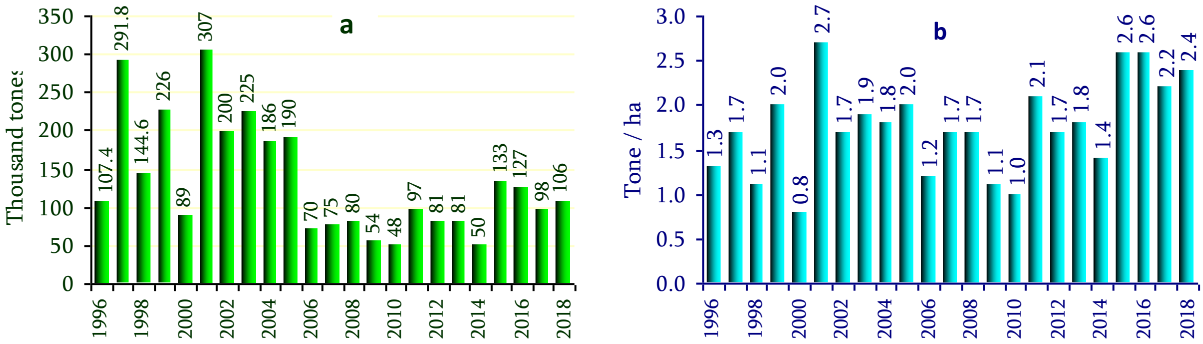


Figure 4.3.3.1: (a)Wheat production and (b) average yield in 1996–2018 in Georgia

Wheat yields increased dramatically in 2001 (2.7 t/ha) and 2015-2016 (2.6 t/ha). In the fall of 2000, the International Aid Program provided high-quality wheat seeds imported from Turkey and the amount of precipitation during the growing season period was rather high. In 2015-2016, the increase in yields was associated to the state aid programs that gave farmers access to loans, quality seeds and other facilities. Relatively high yields were maintained in the following years.

The current Climate Change Impact on Wheat Yields

The current climate change impact on wheat yields has been analysed over two 30-year periods (1956-1985 and 1986-2015), using data provided by the Dedoplistskaro station.

Mean annual temperature values in 1956-1985 and 1986-2015 were 10.6^0C and 11.3^0C respectively, the increase totalling 0.7^0C. During the same period, annual GDDgrown (growing degree days) increased by 8% (from 4182^0C to 4507^0C) in case of n = 0^0C; by 10% (from 2709^0C to 2992^0C) in case of n = 5^0C, and by 17% in case of n = 10^0C[91]. The number of heat waves in Dedoplistskaro increased by 2.2 and their duration - by 31 days. Growing season length (GSL) increased by 14 days.

Annual precipitation increased insignificanlty only by 1% (from 600 mm to 607 mm); however its seasonal distribution has changed: precipitation in summer decreased by 20%, while it increased by 8%, 7% and 20% in winter, spring and autumn, respectively.

The increased temperature alongside with the unchanged precipitation has a negative effect on wheat crops, especially in spring and early summer (in June).

It is noteworthy that the Dedoplistskaro station is located at about 800 meters above the sea level, while wheat is grown at 400-600 meters above the sea level in the same municipality. The difference in altitudes should cause a significant difference in temperature values. To account for this, data from the Eldari (now Karistskali) and Shiraki Meteorological Stations located at about 500 meters above sea level were used. The available (official and processed) information on maximum temperature values recorded at these stations only covers the period of 1950–1964. A comparison of temperature values during these years showed that deviation during the summer months is about 2.5^0C at the Shiraki station and over 3^0C at the Eldari station. This shows that the data provided by the Dedoplistskaro station understate the temperature in the wheat areas. This is also confirmed by the noticeable increase in severe and extreme droughts of agricultural type, which can cause substantial damage to the agricultural sector and require appropriate adaptation measures.

[91] **GDDgrown**, or growing degree days, is the annual sum of active temperatures valuesi.e. the annual total sum (TM – n) of positive daily difference values (TM> n), where TM is the mean temperature and n is a user-defined, location-specific base temperature.

The Climate Change Impact on Winter Wheat Sowing

As evidenced by the research, cited in the reference [28], the period when air temperature decreases from 15^{0}C to 10^{0}C is optimal for sowing winter wheat in Georgia. According to the authors, the optimal period usually lasted for 28 days on average. For example, in Sighnaghi, it would start on October 2 and end on October 27 and almost the same was true for Dedoplistskaro.

The month preceding winter wheat sowing (September) and the month of sowing (October) were much warmer in 1986-2015 than in 1956-1985. The mean air temperature in September was 16.9^{0}C in 1956-1985 and 18.2^{0}C in 1986-2015, while in October it was 10.9^{0}C and 12.1^{0}C respectively. The number of days in October, when the mean daily temperature exceeded 10^{0}C, was 21.4 in 1956-1985 and 24.8 in 1986-2015. In such conditions, plants need more water for growth and development, and moisture stress increases (e.g., sowing in dry soil). However, this pattern was partially mitigated by an increase in precipitation in September (20%), October (14%) and November (32%).

Despite the increase in precipitation, wheat is very often sown during drought in Kakheti. The soil dries fast because of warm weather. Wheat sown in October may frequently fail to develop seedlings before winter comes. Seeds fail to germinate and only begin to develop when winter is over and sufficient moisture has accumulated in the soil, that is, with a 120-150 days' delay. This results in a reduction in GSL, which adversely influences the productivity of each plant; late germination results in low density crops and diminishes yields.

The Climate Change Impact on Wheat Booting, Heading and Ripening

A comparison of temperature regimes in the two 30-year periods in Dedoplistskaro shows that in the period of 1986-2015, the mean monthly temperature was slightly higher in April (0.2°C), lower in May (-0.2°C) and significantly higher in June (1.3°C), as compared to the same months of 1956-1985. The mean maximum temperature in June was higher by 2.1°C. A relatively significant increase in temperature could be observed in the hottest days of April (27.5° C → 30.6°C), May (30.6°C → 32.4°C) and June (34.0°C → 36.4°C).

In 1986-2015 as compared to 1956-1985, total monthly precipitation decreased slightly in April and May (by 7% and 11% respectively) and dropped significantly in June (by 29%). The duration of the longest dry period dramatically increased in June from 20 to 30 days due to the considerable decrease in precipitation. The number of dry days (with minimum relative humidity ≥ 30%) increased to 1.6 days in May and 0.7 days in June.

Hot days in April and May with the air temperature exceeding 30°C negatively affect wheat development. **Booting** is one of the most critical stages of wheat development that begins after the end of hibernation in April. The 30°C heat and the ensuing moisture stress may hamper stem elongation and result in development of short-stemmed, short statured wheat. Heat (or cold) and insufficient soil moisture during the **heading** stage result in underdeveloped wheat heads and sterile flowers. Moisture deficit during the **flowering** stage results in reduction of grain numbers in wheat heads or development of infertile spikes.

With sufficient moisture and normal air temperature (20-22°C), grain formation and filling period (**from flowering to wax ripeness**) lasts for 20-24 days. During this time, grains accumulate 90% of dry matter.

Moisture deficit may impede normal ripening of grains because of early wilting and drying of stems and leaves: grain filling slows down and eventually stops. The movement of assimilates slows down as well and starch content decreases. Grain quality worsens because of insufficient filling and low protein content.

Moisture deficit and high air temperature may reduce the GSL, the wheat plant accelerates its development, passes the growth stages faster and as a result curtails its normal growth (i.e., earlier completes its life-span). It is noteworthy that in certain papers of the 20th century July 15 (reference [29]) is mentioned as the optimal harvest date for Shiraki, which is too late under the present conditions with wheat fields being completely harvested in this area by July 1. Such dramatic shortening of the growing season would have had a negative effect on wheat production if not for introduction of modern drought-resistant varieties that develop faster and ripen before July heat starts.

Drying caused by hot dry winds may have a devastating effect on plants, especially at early stages of seed germination or development. Dry and hot air may seriously harm plants within a couple of days or several hours. In Eastern Georgia, drying is associated with hot and dry winds blowing from the southeast, causing an extreme drop in air humidity and an intensive evaporation. The roots and vegetative cones of plants cannot compensate for water loss or provide new supplies, so capillary action stops, and leaves and heads dry rapidly and die.

Assessment of The Expected Climate Change Impact

Impacts of the expected climate change on wheat yield have been analysed by comparing projected climate parameters for the periods of 2041-2070 and 2071-2100 with climate data of 1971-2000 (provided by the Dedoplistskaro station).

As compared to 1971-2000, the mean annual temperature in Dedoplistskaro will rise by 2^0C to 12.8^0C in 2041-2070 and by 3.6^0C to 14.5^0C in 2071-2100. During the first and the second forecast periods, mean seasonal temperature will increase respectively: in autumn by 2.3^0C and 4.4^0C, in winter by 2.3^0C and 3.6^0C, in spring by 1.8^0C and 3.5^0C, and in summer by 1.7^0C and 3.3^0C.

In 2041-2070 and 2071-2100, annual GDDgrown increases respectively by 11% and 30% in case of $n = 0^0$C and by 20% and 50% in case of $n = 5^0$C. In 2071-2100, the GSL increases by 44 days against 1971-2000.

The heat wave number (HWN) increases by 4.1 in the first forecast period and by 6.5 in the second forecast period. The heat waves duration (HWD) increases by 18 and 49 days correspondingly. The GSL increases by 14 days. The warm spell duration index (WSDI), i.e. annual count of days with at least 6 consecutive days when *TX > 90th percentile*, increases by 17 and 68 days *in* 2041-70 and 2071-2100 respectively.

Total annual precipitation will decrease from 604 mm to 547 mm in 2041-2070 and to 488 mm in 2071-2100. It should be noted that the most significant decrease in precipitation would be observed in spring (25% and 39%) and autumn (2% and 16%).

Since the above indicators are based on Dedoplistskaro station's data and a large part of the wheat areas are located 200–300 meters below sea level in Eldari lowland, the climate change is likely to have an even stronger impact on wheat production.

The increased temperature has negative impact of photosynthesis and respiration and reduces the yield. The optimum temperature for photosynthesis is 20-25^0C; at the higher temperature (35-36^0C), the photosynthesis process completely stops. The significant increase in mean temperature and percentage of hot days, expected in May-June 2071-2100 against 1986-2015 is likely to hamper photosynthesis. Grain formation and filling, beginning after the flowering and largely determining the yield, strongly depend on intensity of photosynthesis. An expected rise in night-time temperature will cause intensified respiration, which will negatively affect wheat growth, development and productivity.

High temperature and moisture deficit in autumn cause drought that adversely affects seed germination and reduces plant density per unit area. It impedes plant germination and reduces the percentage of overwintered plants.

High temperature in spring and early summer in conjunction with moisture deficit has a negative effect on wheat heading, reducing the amount of productive heads per unit area. When drought appears during the booting process, it impedes the growth of wheat to its normal size, while during the flowering stage it reduces the number of grains per plant. High temperature and moisture deficit after the flowering stage cause early ripening, shorten the period during which grains are supplied with nutrients and negatively affect yields.

Wheat diseases. In Georgia, wheat yield is heavily influenced by wheat rust, which appears on leaves (yellow rust and brown rust) and stems (stem rust), and in favourable infection conditions spreads to the heads and spikelets. Yellow rust, which is the most common among the rusts in Georgia, is adapted to relatively low temperatures, so cool nights (11^0C - 13^0C) and relatively humid weather (wet leaves) in the second half of May make favorable conditions for its prevalence. Brown rust and stem rust are activated at higher temperature, usually during hot and humid seasons. The rusts strongly impede photosynthesis and reduce grain yield. During severe infection, yields may drop significantly (as low as 100% in susceptible wheat varieties) and grains formed in such conditions are not suitable for breadmaking. According to the Kobuleti Institute of Phytopathology, studying rust resistance genetics, yellow rust used to be a serious disease of wheat in 1987-1999. Severe outbreaks of yellow rust in Georgia are described in reference [30], according to which five outbreaks occurred in Central Asia and the Caucasus over 15 years (in 1998, 2000, 2005, 2009 and 2010). It has been observed that stem rust, which was localized in Southern Georgia, particularly in Akhaltsikhe region in the 1980s, is now more commonly found in Kartli and other regions. The influence of yellow rust on wheat is likely to weaken with warming, while the influence of brown and stem rust on the contrary will become stronger.

Wheat pests. The Climate change, especially growing of winter temperature, may facilitate the process of overwintering for wheat pests and promote growth of their populations. This may result in stronger negative impact on wheat. It was estimated that pest-induced crop losses, caused by the climate change, can reach 10-25% by 2050 [31].

In the wheat producing regions of Georgia, crops are periodically affected by the following pests :

Hessian fly – these insects are particularly harmful to wheat in Kartli and Kakheti. Its worms damage plants in autumn. In spring, damaged stems bend and entangle, causing a drop in grain yields. Negative impacts of Hessian flies are likely to increase if winter wheat is sown earlier. The best way to control the fly is to sow wheat within optimal timelines.

Ground beetle worm, mainly spread in Eastern Georgia, feeds on winter wheat leaves. Adult species damage grains at the stage of milky ripeness. The main cause of beetle prevalence is planting wheat on the same fields for several years in a row. An effective way to combat the beetles is to plant treated grains, use crop rotation and control weeds.

Bread beetle is a dangerous pest, feeding on wheat flowers in spring. There are several species of bread beetle in Georgia. The beetles destroy ovaries and stamens and damage young grains. They are active at high temperature. Timely and correct agrotechnical measures, soil treatment, weed removal and crops rotation are the ways to control the bread beetle. Pesticides can be used in case of pest outbreak.

In recent years, **wheat aphid** has become widely spread in Georgia. The pests suck juice from plants that eventually dry out. Grain aphids can produce up to 15 generations during a year. They lay eggs in winter and spend winter in weeds and winter crops. The ways to control them include crop rotation and timely soil treatment.

Severe (cold) winter prevents pest populations from growing, while warm temperature make it easier for insects to survive during winter and cause even greater harm to winter wheat.

A research described in reference [32] shows that warming by 1^{0}C will reduce wheat yields by 4.1-6.4%. The negative impact of warming will be the most devastating in rainfed and drought-prone regions like Shiraki and Eldari. The 3.6^{0}C rise in the mean annual temperature, expected in 2071-2100, will reduce wheat yields approximately by 15-25%.

It is also noteworthy that in January 2019 atmospheric carbon dioxide (CO_2) amounted to 411 ppm. According to RCP 4.5 scenario, by the end of the century CO_2 concentration will reach 650 ppm. Since plants use carbon dioxide for photosynthesis, an increase in atmospheric carbon dioxide will increase wheat productivity provided there is sufficient moisture. The research shows that by the end of the century wheat productivity will grow by 4%, although nutritional value of grains will decrease (see reference [33]).

Current and Expected Changes in Agro-Climatic Zoning of Wheat Production

Winter wheat cultivation requires GDDgrown of $2100\text{-}2200^{0}$C and precipitation of 600 mm during the growing season, which starts in September, stops in late November and resumes in early March, when wheat continues to develop until the harvest (end of June in Kakheti, early July in Kartli, August in high mountains). In terms of wheat production, Georgia can be divided in three agro-climatic zones:

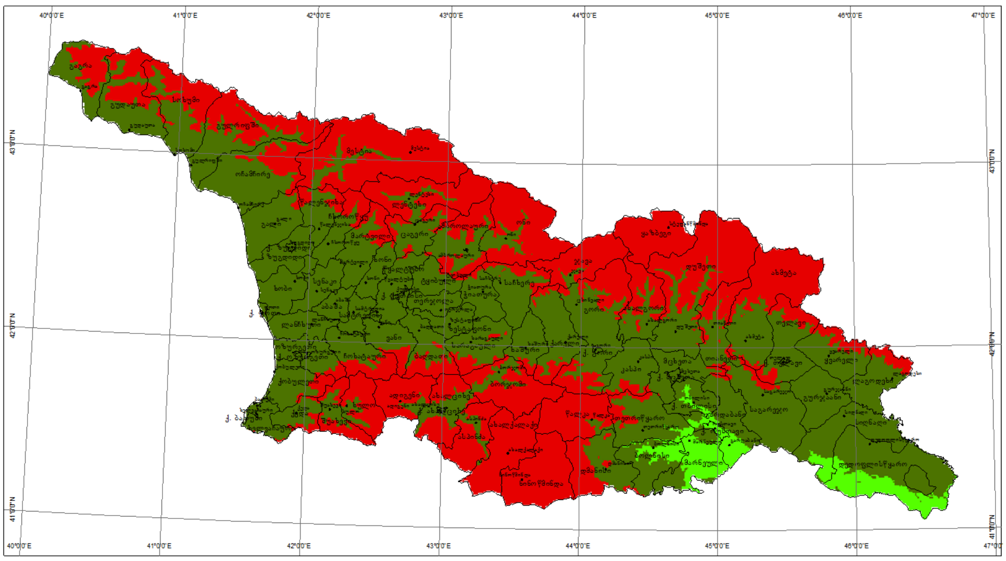
Zone 1: Insufficient heat for winter wheat production. Mean winter temperature is below 0^{0}C or mean annual temperature is below 5^{0}C. This zone mainly covers high mountain regions (markd in red).

Zone 2: Wheat production is feasible if irrigated. Mean annual temperature exceeds 5^{0}C and precipitation is below 450 mm. This zone mainly covers Kvemo Kartli. (marked in light green)

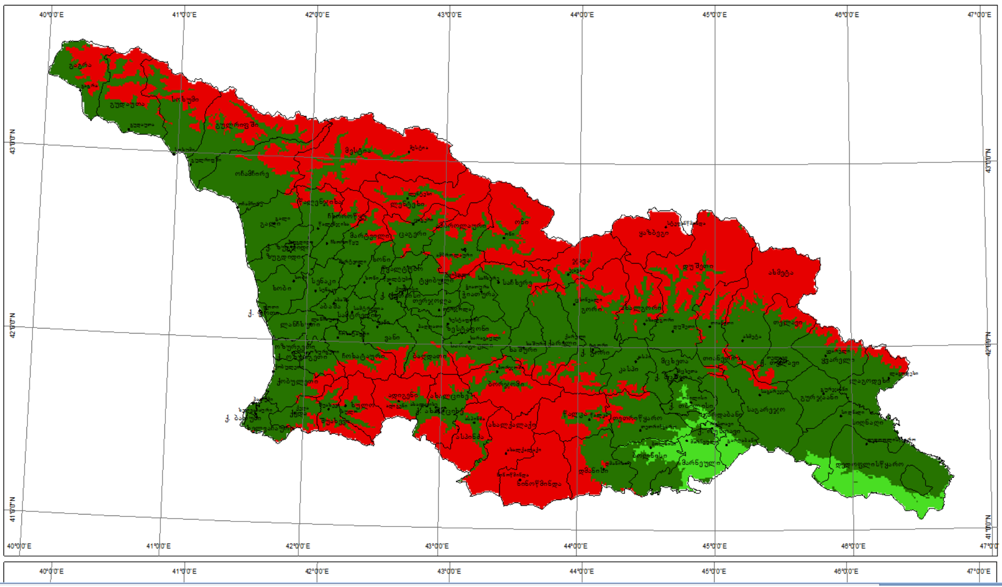
Zone 3: Favorable climatic conditions for winter wheat production. Mean annual temperature exceeds 5^{0}C, precipitation is over 450 mm. This zone includes the main wheat production regions of Georgia (Dedoplistskaro, Sighnaghi, Sagarejo, Gori, etc.). (marked in dark green)

Map 4.3.3.1. Changes in agro-climatic zoning for wheat in 1966-90, 1991-2015 , 2071-2100

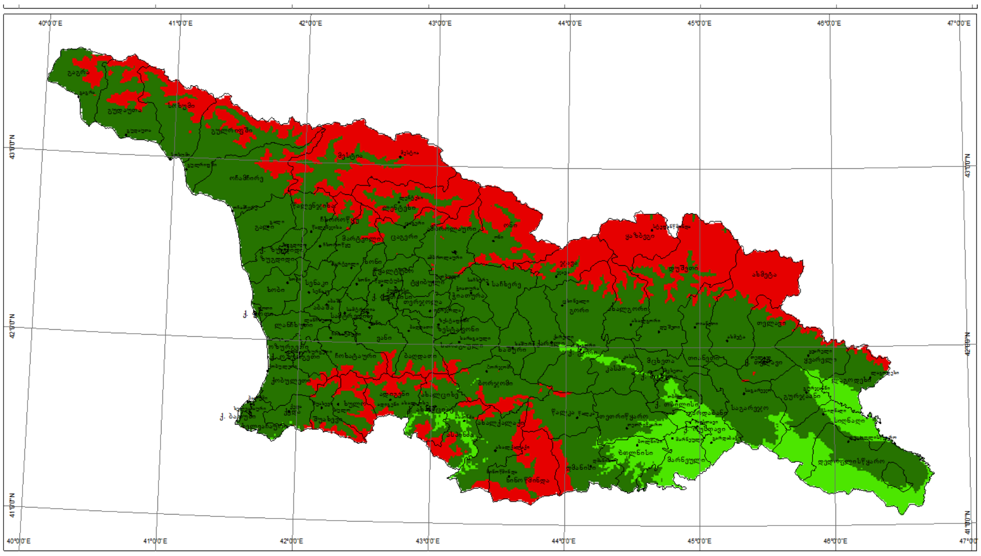
1966-1990



1991-2015



2071-2100



In the both forecast periods, Zone 1 would shrink as a result of warming and the area of lands suitable for wheat growing will increase in the high mountain regions. Zone 2 will expand, as more areas will require irrigation to grow wheat. Zone 3 will expand at the expense of warming in Zone 1, but will partially require irrigation.

Development of Adaptation Measures

The following measures are recommended to enhance wheat resistance/adaptability to expected climate change:

Semi-fallow production system. In Dedoplistskaro, winter cereals are harvested in the middle of summer and are not planted before October. During this period, the wheat stubble fields can be treated as fallow fields, which includes cultivation of soil with harrowing with the main purpose to control weeds. This operation can be repeated if weeds appear before sowing is carried out in autumn. Apart from weed control, harrowing facilitates moisture accumulation in the soil and plant residue mineralization. The grain yield will be 0.2-0.4 tonne/ha higher if stubble fields are cultivated with harrow right after harvest, as compared to fields, which are plowed 20–22 days prior to sowing (according to data of the Kakheti Trial Station). Wheat production cost applying this method remains unchanged or increases slightly by cost of single cultivation.

Sowing at the optimal time. One of the main reasons of low winter wheat yields is incomplete tillering which results in low density crops and finally low yield. In order to ensure successful tillering prior to the onset of winter and ensure maximum rainfall probability, it is reasonable to plant winter wheat at the optimal time, which is October for Dedoplistskaro.

Depth of sowing. Generally, wheat seeds are planted at the depth of 4-5 cm. In less humid soil, just like in windy areas common in Dedoplistskaro, seeds need to be planted deeper (6-8 cm) to prevent them from drying. In shallow sowing, plants develop their growing points too close to the surface, so if wind removes the soil, they can be killed by low temperatures. In addition shallowly sown seeds are more affected by winds compared to deeply sown ones since the wind blows seeds and young sprouts away together with soil and thus causes thinning of crops. Low density crops are easily overrun by weeds and their yields drop significantly. Sowing deeper than 8 cm is not recommended as it impedes emergence germination.

Soil fertilization in rainfed areas. In rainfed dry and drought-prone areas, a single full dose of mineral fertilizers, including nitrogen, should be introduced for root nutrition prior to plowing, and in case this is feasible for some reason, then during sowing. This measure will become more important in the future, since higher temperature contributes to soil fatigue.

Soil packing after sowing. Another necessary measure is soil packing after sowing. Higher soil compaction ensures better seed-soil adhesion, even germination and access of seeds to soil moisture. It also protects seeds from wind.

Snow retention. Snow retention allows to maintain soil moisture and increase resistance of crops to cold in rainfed dry and drought-prone areas; it also protects seeds from erosion in wind erosion areas. Snow can be retained with the help of snow ploughs, and in their absences, with snow compactors.

No-tillage production of dryland wheat. No-till production system promotes accumulation of moisture under dryland conditions. The most important components of this system include sowing without plowing, which means sowing seeds directly into plant residues using a special direct seeder; crop rotation, which in case of wheat implies planting such suitable predessors of winter wheat as grain legumes and maize is a prerequisite for success of this technology. This system also involves mulching for which previous crop residue is used. Combines may have special shredders that chop and distribute plant residues (stubbles, straw, etc.) on the field during harvesting.

Improved varieties. Planting wheat varieties that are resistant to relevant abiotic and biotic stresses is necessary to ensure production stability, particularly in the rainfed areas.

Maize

Maize is a domesticated plant of American origin that has been cultivated in Georgia since the 17th century. “Flint” maize (Zea mays imdurata) was first introduced by Laz ethnic groups to Samegrelo, from where it spread to Imereti. According to Güldenstadt, a famous researcher of the 18th century, in 1770-1773 maize was already cultivated in many areas in Georgia, although millet and panicgrass still remained the basic cereals food in Imereti and Samegrelo. Dent maize (Zea mays indentata) was imported in the 1860s-1870s and rapidly spread throughout Western Georgia.

At the turn of the 19th and 20th centuries, in the lowlands of Western Georgia, semi-dent maize emerged as a result of mixture of flint and dent maize species. By that time maize had already become the main staple food in Western Georgia.

In Eastern Georgia, maize proliferation continued from the end of the 18th century to the middle of the 19th century. Two maize ecotypes were formed there: mountain maize and rainfed maize. At the beginning of the 20th century, semi-dent maize and its improved variety "Imeretian hybrid" were cultivated across the Alazani River in Kakheti and in the irrigated lands of Kvemo Kartli.

1909-1913 data show that maize had a higher economic importance than wheat in Georgia, covering at least 380,000 ha and its production being equal to 460,000 tonnes. Maize production exceeded 200 kg per capita. Georgia used to export almost 90,000 tonnes of maize grain to Western Europe.

In 2018, maize occupied 72.8 thousand ha in total with the largest portion of maize fields (23 thousand ha) being located in Samegrelo-Zemo Svaneti. In Western Georgia, farmers mostly cultivate “local” open-pollinated varieties, such as Ajameti White, Abashuri Yellow, and others. The varieties yield about 2-3 tonnes per hectare, and their grain is used for both food and feed.

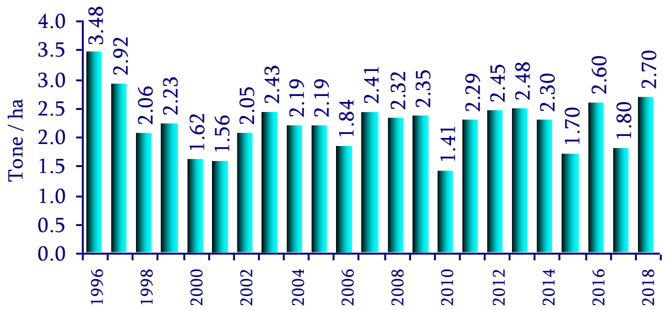


Figure 4.3.3.2: Maize yields dynamics in 1996-2018

In contrast to Western Georgia, maize needs irrigation in the eastern regions with the exception of the areas, where annual precipitation is fairly high. In East Georgia, maize is mainly used for feed. Over recent years, high-yielding foreign hybrids have rapidly spread in Eastern Georgia. In 2018, maize grain yield reached 4.9 t / ha in Kakheti.

The year 2010 witnessed the lowest maize yield since Georgia became independent (1.41 t/ha countrywide and 1.1 t/ha in Samegrelo-Zemo Svaneti). That year, annual GDDgrown was as high as 2825 degrees (n = 10^{0}C) in Zugdidi, the administrative centre of Samegrelo-Zemo Svaneti region, setting a record for the period of 1961-2015. The mean monthly (and mean maximum) temperature of May, June, July and August 2010 were the highest over the last 50 years. Maize, which is a relatively heat resistant crop that can still photosynthesize at around 35^{0}C was affected by moisture deficit with the amount of precipitation during the growing season one of the lowest since 1961. Maize was also strongly affected by drought in 2001, when its yields dropped to 1.56 tonne per ha.

Maize distribution and environmental requirements

Maize can grow in various climatic conditions thanks to a wide range of available varieties and hybrids and good adaptability, conditioned by different GSLs (some varieties need 60-70 days from emergence to maturity, while others need more than 20 weeks). It takes 140-150 days for the most common varieties to mature in the lowland areas. The higher in the mountains, the quicker maize matures because of a shorter GSL and frostless period. Thus, maize varieties common in Svaneti mature in 80-90 days.

Low temperature and duration of the frostless season are the limiting factors for maize cultivation. Thus, farmers almost do not cultivate maize where the mean air temperature of the hottest month is below 19^{0}C (according to the Zugdidi station, the mean temperature in August is 24.2^{0}C) or where the mean minimum temperature of the hottest summer is below 13^{0}C.

Maize production is mainly developed in the areas, where the hottest month isotherms range between 21^{0}C and 27^{0}C and frostless period lasts from 120 to 180 days. In such areas, maize yields are usually higher when temperature of summer months are close to their long-term annual mean or below it. Yields drop when summer is hotter than usual [34].

Maize is cultivated in areas where annual precipitation ranges between 250 and 5000 mm. Maize consumes from 500 to 840 mm of water depending on climate and soil characteristics. Irrigation can increase maize yields even if annual precipitation is relatively high, like in the Kolkheti Lowland, where it reaches almost 1800 mm and where maize normally is not irrigated. Even in such areas, maize yields can be increased by using irrigation during dry summer. Abundant precipitation is not a limiting factor for maize production if good drainage is available; however, it is known that excessive rain at early stages of maize development can cause reduction in yields.

Maize harvest requires dry weather, as dry grains do not develop Giberella spp., Diplodia zeae and other pathogens during storage.

Maize is planted on different types of soils. However sandy loams with pH ranging from 5.5 to 8.0 are the best for this purpose. Acidic soils may hamper maize production. In areas with abundant rainfall, soils should be light and permeable, as flooding causes chlorosis and yield losses. In favourable climatic conditions, maize rapidly develops and needs to be supplied with sufficient nutrients prior to the flowering stage. To produce 1 tonne of grain, maize plants consume 24 kg of nitrogen, 4 kg of phosphorus and 23 kg of potassium from soil [35].

The Climate Change in Zugdidi Municipality

The impact of the climate change on maize yields has been analysed by comparing climate parameters of two 30-year periods (1956-1985 and 1986-2015) based on the data provided by the Zugdidi Meteorological Station. Mean annual temperature values in 1956-1985 and 1986-2015 were 13.1^{0}C and 14.7^{0}C respectively, the increase making 0.63^{0}C. During the same period, annual GDDgrown increased by 5% (from 5270^{0}C to 5549^{0}C) in case of n = 0^{0}C; by 8% (from 3532^{0}C to 3809^{0}C) in case of n = 5^{0}C, and by 12% in case of n = 10^{0}C. Annual precipitation increased by 4%, from 1814 mm to 1888 mm, while distribution of precipitation has partially changed by season: declined by 6% in summer, and increased by 11%, 11%, and 2% in spring, autumn, and winter respectively.

The Climate Change Impact on Maize Growth and Development

Pre-Sowing Period

Weather conditions favourable for sowing imply sufficient soil moisture reserves. Such reserves can accumulate from moisture unconsumed by the preceeding crop, as well as from rain and snow falling in autumn, winter and early spring, when evaporation is less significant. According to the Zugdidi station, mean temperature in winter and spring 1986-2015 were 6.6^{0}C and 13.2^{0}C respectively, exceeding the mean temperature values of the same seasons in 1956-1985 by 0.1^{0}C and 0.22^{0}C. Total precipitation in winter and spring during the period of 1985-2015 was 436 mm and 438 mm respectively, exceeding total precipitation in the corresponding seasons of 1956-1985 by 2% and 11%. The impact of the climate change on soil water accumulation in winter is insignificant.

Sowing Time and emergence

It has been stated that maize can be planted in spring when the **mean daily temperature rises above 10^{0}C** and the air and soil are sufficiently warm and humid [36]. In order to secure high yields under such conditions, during 10 days preceding the day of sowing, the sum of temperature values should range between

80^{0}C and 100^{0}C, with total precipitation of 10-60 mm and number of days with precipitation exceeding 5 mm should be 1-. days with. In the US and Europe (including Ukraine and Russia), there is a clear trend to sow maize at 10^{0}C -12^{0}C.

In Georgia, maize is actually planted when the mean daily temperature is well above 10^{0}C, ranging between 12^{0}C and 14^{0}C. As a rule, the sum of temperature values in the period from the optimum sowing time (when the mean daily temperature is 10^{0}C) to the actual sowing time is 330-880^{0}C and the amount of precipitation is 105-185 mm. In various regions of Georgia, such conditions appear at different times. Thus, in Zugdidi, the actual sowing time is May 5 (the optimum sowing time being March 24) and the sum of temperature values in the period from March 24 to May 5 is 530^{0}C, while the amount of precipitation is 164 mm.

Soil moisture above 15 mm in the 0-10-cm soil layer can be considered as favourable condition for seed emergence, but even in such conditions, seeds do not emerge if soil temperature is 7-8^{0}C. They germinate in 7-9 days when soil temperature rises to 11-12^{0}C and in 2-3 days when it reaches 18-22^{0}C. In April-May, soil temperature usually is 1-2^{0}C higher than the air temperature.

Maize seeds germinate in 8-10 days at 16-18^{0}C and in 18-20 days at 10-13^{0}C. In wet soil, it takes seeds 5-6 days to emerge if the temperature is 21^{0}C. An increase in sowing depth causes a one-day delay in emergence per every 2.6 cm.

According to the Zugdidi station, mean daily temperature values in April and May 1986-2015 were 13.4^{0}C and 17.2^{0}C respectively, which is 0.26^{0}C higher and 0.04^{0}C lower than in April and May 1956-1985 – the change was insignificant. April and May are warm enough for emergence of maize. Precipitation declined slightly in April (by 4%) and increased significantly in May (by 31%).

It follows from the above, that the current climate change has not had a negative impact on maize yields, and the shift in maize planting from late March to early May is rather caused by the lack of equipment and logistical problems than by the climate warming. The slight shortening of the GSL (by 5 days) observed in 1986-2015 cannot explain the one-month delay in sowing.

Vegetative Development (from emergence to flowering)

The emergence phase ends when seeds run out of storage nutrients and plants start independently acquiring nutrients and water. If maize is planted on May 5, it will emerge on May 22, and flowering will start on July 7 [37].

Maize cannot resist frost. The air temperature of -1.7^{0}C damages, while -4.4^{0}C kills young shoots. In 1986-2015, the mean minimum temperature in March, April and May increased by 0.5^{0}C, 0.2^{0}C and 0.2^{0}C compared to the same months of 1956-1985, while absolute minimum temperature in these months increased by 5.5^{0}C, 0.4^{0}C and 0.2^{0}C and it is equal to -5.2^{0}C, -2.2^{0}C and + 2.7^{0}C, respectively.

Precipitation declined slightly in April (4%) and increased significantly in May and June (34% and 29%, respectively). Therefore, maize plants do not experience moisture deficit at the time of planting. It is noteworthy that if the weather is dryed the post-emergence phase, maize develops longer roots that reach deeper into the soil and can more effectively provide the plant with moisture at later stages of development (thus making the plants more drought resistant). When the soil is dry, mulching between the rows contributes to root elongation, while mulching soil with high moisture content reduces root elongation rate.

At the late stage of vegetative development, which takes place in July (August), maize grows very rapidly and consumes a lot of water. It is noteworthy that during this period maize growth rate more than ever depends on the daily temperature. In hot regions, the correlation between maize yields and mean July-August temperature is negative, while in cool areas it is negligible. The optimum air temperature for maize production depends on precipitation: the higher precipitation, the higher should be the temperature for securing the maximum yield. For example, if expected maximum precipitation in July is 50 mm, the optimum air temperature is 21^{0}C, and in case of 150 mm it is 25^{0}C. In 1986-2015 in Zugdidi, total precipitation in July and August decreased by 16% and 17% to 154 mm and 147 mm respectively as compared to 1956-1985. The air temperatures in July and August during the period of 1986-2015 increased by 1.23^{0}C to 23.4^{0}C and by 1.81^{0}C to 24.1^{0}C respectively as compared to 1956-1985.

Flowering, Pollination and Ripening

Heat influence on stomatal closure is particularly strong when the air temperature exceeds 35^{0}C. Mean maximum temperature values in July, August and September have increased by 1.7^{0}C and 2.3^{0}C due to the current climate change, while absolute maximum temperature values have increased by 2.9^{0}C, 1.4^{0}C and 3.6^{0}C to 42.4^{0}C, 39.9^{0}C and 40.4^{0}C. In the same months of 1956-1985, hot days made up 10.6%, 10.4%, and 10.1%, while in 1986-2015 they made 20.8%, 28.7%, and 22.8% respectively. High temperature at the ripening stage cause early ageing of plants and moisture deficit.

High temperature in September and October accelerates ripening, while low temperature slows it down. In dry years, moisture deficit or high temperature in these months reduces the yield of late varieties of maize and hybrids. In humid years, rainfall in September and October doesn't not affect maize grain yield but delays ripening of grains. Grains are preserved well if their moisture content does not exceed 13-14%. If sowing is delayed grains sometimes fail to dry properly before harvest, and it is necessary to dry maize ears before thrashing. The same is true for late varieties.

Negative Impacts of The Expected Climate Change

The expected climate change impacts on maize yields have been analysed by comparing data for two 30-year forecast periods (2041-2070 and 2071-2100) with the corresponding indicators of the 30-year baseline period (1971-2000), using data provided by the Zugdidi station.

According to the climate scenario, the mean temperature in Zugdidi will increase by 2^{0}C to 15.9^{0}C in 2041-2070 compared to 1971-2000, while in 2071-2100 it will increase by 2.7^{0}C to 16.6^{0}C. During the same period, the mean temperature will increase in autumn by 2.3^{0}C and 3.2^{0}C respectively, in winter by 2.3^{0}C and 3.0^{0}C, in spring by 1.9^{0}C and 2.5^{0}C, and in summer by 1.5^{0}C and 2.2^{0}C.

The GDDgrown increases by 9.6% in 2041-2070 and by 23.4% in 2071-2100 in case of n = 0^{0}C; and by 12.7% in 2041-2070 and by 32.3% in 2071-2100 in case of n = 5^{0}C. As compared to 1971-2000, the growing season will increase by 16 days in 2041-2070 and by 25 days in 2071-2100. Both in 2041-2070 and 2071-2100, early spring frosts will end in March and the air temperature will not drop below 0^{0}C in April.

The number of heat waves in Zugdidi will increase by 4.9 in the first forecast period (2041-2070) and by 8.3 in the second period (2071-2100). The duration of heat waves in these periods will increase by 22 and 29 days respectively. The warm spell duration index (WSDI), i.e. annual count of days with at least 6 consecutive days when *TX > 90th percentile,* increases by 12 (9%) and 29 days (20%) *in* 2041-2070 and 2071-2100 respectively.

In light of such significant warming, total annual precipitation will increase from 1800 mm to 2019 mm in 2041-2070 and decrease to 1725 mm in 2071-2100. It should be noted that in 2071-2100 the most significant decrease in precipitation will be in May, June and July by 26%, 24% and 15% correspondingly.

Summing up the abovementioned, maize production and production practices will be influenced by the following factors by the end of the 21st century,: a) reduced frequency of frost in early spring and late autumn; b) faster accumulation of the mean daily temperature exceeding 5^{0}C (GDDgrown) resulting in accelerated growth and ripening of plants; c) increased frequency of hot days (≥35°C) in summer (during flowering and pre-flowing period); and d) moisture deficit in May and in the summer months.

By the end of the 21st century, it will become possible to sow maize much earlier, for example, in late March or early April, without exposing it to frost damage risk. Because of early sowing and faster accumulation of GDDgrown, maize varieties will mature before cold weather is established in autumn, and thus the need for drying wet ears prior to thrashing will disappear. The use of early maturing hybrid varieties will provide opportunity to produce two crops in a season.

An increased frequency of hot days and moisture deficit will adversely affect photosynthesis. The stress caused by stomatal closure will grow, causing premature ageing of plants. With such stress lasting for several days in a row, yield loss can reach up to 4% per day. An increased frequency of hot nights will cause intensified respiration, which will also negatively affect maize yields.

The faster accumulation of GDDgrown will shorten the life cycle and adversely influence maize productivity. It has been calculated that the climate warming by one degree causes maize yields to drop by 12-17% [38].

The Climate warming, especially an increase in winter air temperatures, will create favourable conditions for an increase in pest populations, which can have adverse impacts on maize yields. It has been estimated that pest-induced yield loss caused by the climate change may reach 10-25% by 2050 [39].

An increase in atmospheric carbon dioxide will have little effect on maize development, as maize is characterized by C4-photosynthesis.

Current and Expected Changes in Agro-Climatic Zoning of Maize Production

The GDDgrown necessary for maize cultivation is 1700-2800^{0}C; varieties that are intermediate in terms of the growing season lenght require 2200^{0}C. Growing both early and late varieties requires 800 mm precipitation. The maize production zones have been identified based on the requirements of the intermediate varieties.

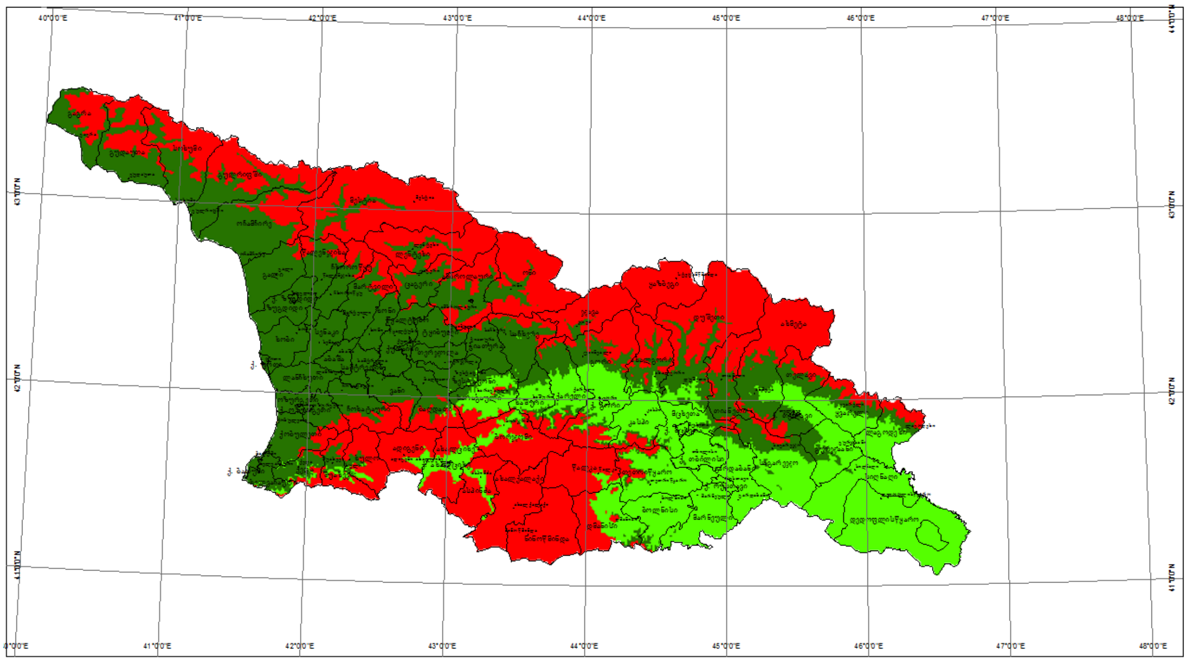
The territory of Georgia can be divided in three agro-climatic zones:

Zone 1: Insufficiently warm for maize production (mean temperature of the hottest month is below 20^{0}C). (marked in red)

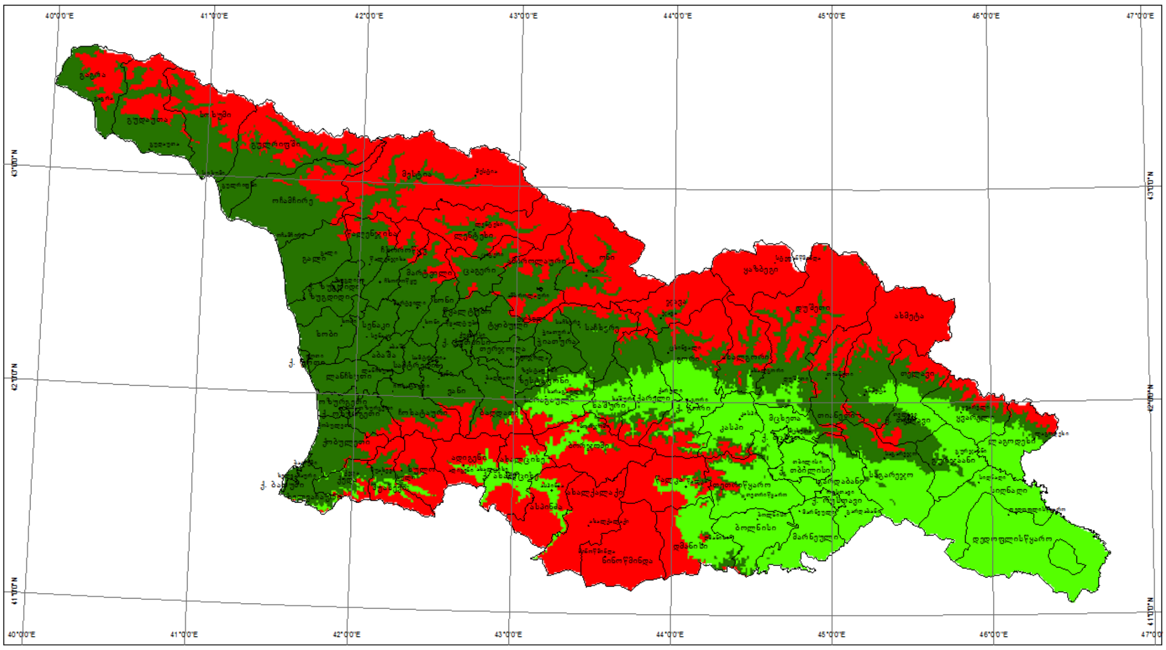
Zone 2: Maize production is feasible with irrigation (mean temperature of the hottest month exceeds 20^{0}C). (marked in light green)

Zone 3: Favourable climatic conditions for maize production (annual precipitation totals or exceeds 800 mm). (marked in dark green)

1966-1990



1991-2015



2071-2100

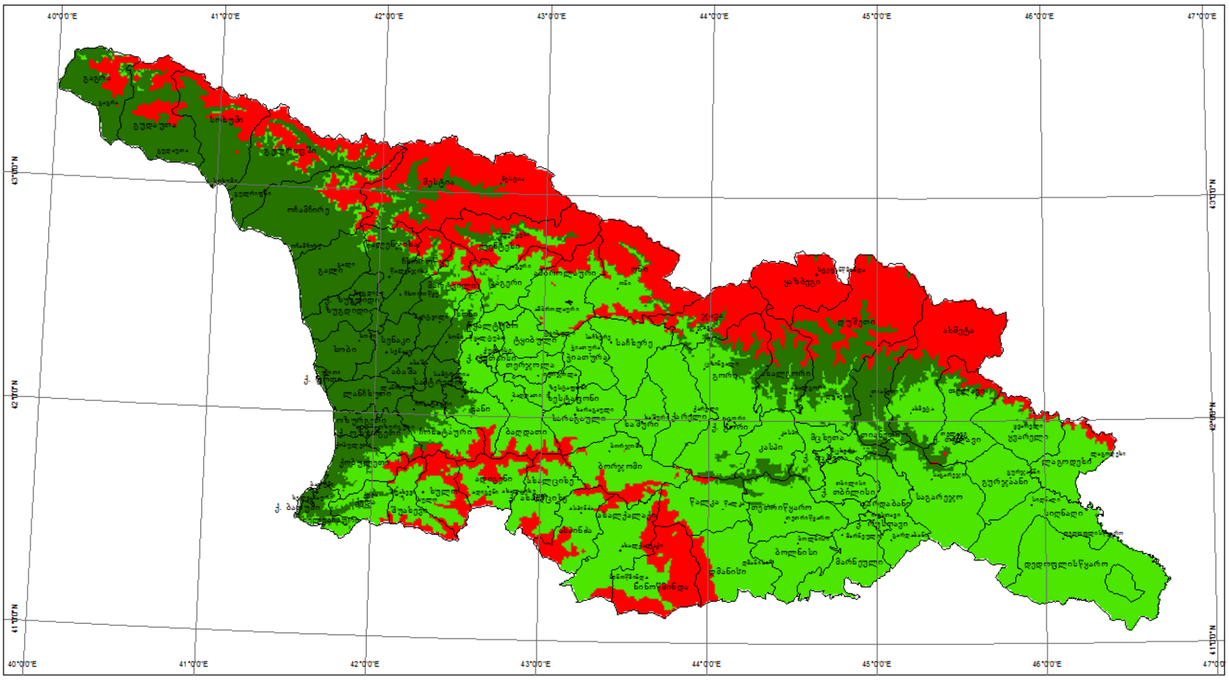


Table 4.3.3.1 shows areas of agro-climatic zones, where maize can be grown in the two 30-year periods.

Table 4.3.3.1: Areas of zones favorable for maize production (in ha) in two 30-years periods

Zone	Period	
	1991-2015	2071-2100
II	1,643,400	3,528,000
III	2,568,800	1,742,200

During the second forecast period (2071–2100), the area where maize production is feasible with irrigation will expand significantly, while the area where maize can be cultivated without irrigation is likely to shrink. The areas favorable for maize production may grow at the cost of mountainous areas, which will become warmer but have sufficient precipitation for rainfed cultivation of maize . Therefore, growing maize in these areas will be economically more efficient in the future.

Recommendations

Early Sowing of Maize

The Climate warming will allow to plant maize earlier than it is done presently - by March 15-25. In the second half of March, maize will no longer be exposed to frost risk. Early maize will utilize moisture accumulated in the soil more effectively and will pass most of its vegetation phases before the evaporation intensifies under the influence of summer temperature. Flowering of local modern cultivars (ripening in 140-150 days) will end by July and the whole development cycle will be over by late August. Thus, the most critical periods of maize development (e.g., active growth and flowering) will avoid the hottest month - July. There will be no more need to dry ears, as they will be harvested at the end of August.

Tillage

Choosing proper tillage time is very important for maize production. Considering moisture deficit in irrigated areas, land should be tilled in the autumn to promote accumulation of moisture in soil during winter, which will be used by plants at the beginning of the growing season. In the areas with soil moisture deficit, only surface tillage is necessary prior to sowing, while in areas with abundant precipitation, tilled soil may get "packed" because of rainfall and may require repeated tillage before planting. Therefore, different tillage recommendations have been developed for various conditions. Considering the current climatic conditions, in high-lying areas of the Kolkheti Lowland and in the Imereti Lowland, maize field should be plowed in the autumn or winter, while in more humid areas (below Samtredia), it should be plowed in late winter or early spring. Podsolic and eroded soils common in Western Georgia shall be tilled during the same period. The climate warming will cause an increase in moisture deficit in Western Georgia and shift tillage to earlier dates for soil to accumulate moisture during winter and plants to use it in spring.

Soil fertility management

With the climate warming, organic matter mineralization in soil will speed up and more fertilizers will be needed to sustain maize production. In particular, it will be necessary to apply 20-30 tonnes of fertilizers per hectare once in two or three years. In the years when no manure is used, approximate doses of mineral fertilizers to be applied for maize production in Western Georgia are N180-210 P90-120 K60. Phosphate-potassium fertilizers are applied prior to tillage. As to nitrogenous fertilizers, half a dose should be applied during the first tillage and the other half during the second one. In the years when manure is applied, doses of mineral fertilizers should be reduced.

In order to improve podsolic soils, lime fertilizers shall be applied in soils that are tilled to the depth of 32-35 cm in summer or autumn. Such fertilizers should be applied in spring, once in 8-10 years, in the following proportions: limestone 4-8 t/ha, liquid manure 8-10 t/ha or dolomite lime 3-4 t/ha. Along with the lime fertilizers, complete mineral fertilizers shall be applied. After fertilization, it is necessary to harrow the soil to the depth of 12-15 cm.

Crop rotation

After sowing, it is necessary to pack soil with a soil packing roller, especially if soil is dry at the seeding depth. In case of soil crusting, the field should be harrowed at the 3-4-leaf stage. Harrowing improves soil aeration, kills young and emerging weeds and helps to maintain soil moisture. Harrowing should be done during the hot time of a day, when maize plants are less brittle. Maize field shall be cultivated first at the 3-5-leaf stage and for the second time 10 or 12 days later to the same depth. In irrigated areas, the second cultivation should be replaced by interrow hoeing, which will facilitate irrigation. This should be accompanied by application of nitrogen fertilizers.

Irrigation

In dry years in Western Georgia, maize needs one or two irrigations, the first one performed one week before the initiation of ear and the second– during grain filling. The commonly used furrow irrigation is conducted by creating small parallel channels along the field side in the direction of predominant slope and supplying water to the channels using pipes and siphons.

Predecessor crops

In Western Georgia, maize monoculture has been practiced for many years and although maize can relatively well grow as a monoculture, long-term research and experience show that the best predecessor for maize in

Western Georgia can be soybean, a blend of oats and annual legumes sown in the previous year for green feed and hay, as well as winter intermediate crops (winter rape, turnip). Soybean is one of the most promising predecessor: as a legume crop, it enables nitrogen accumulation in soil and reduces the amount of fertilizers to be applied to maize fields.

4.3.4 Pastures

About 44% (more than 3 million hectares) of the whole territory of Georgia is designated as agricultural land which also includes pastures and meadows. The total area of hay meadows and pastures makes up 1,940,400 ha, out of which 1,796,600 ha is covered by fields and pastures. It should be noted that more than 70% of the country's grasslands is located in its eastern part (mainly in Kakheti and Javakheti).

Natural grasslands are an important and integral part of Georgia's biodiversity, at the same time they play a major socio-economic role.

Pic. 4.3.4.1: Mountain pastures in Georgia

Georgia's pastures are in great danger. The process of degradation is intensifying, mainly due to human activities. This is accompanied by the negative impacts of the climate change. Pasture degrades when the rate of destruction of vegetation exceeds the recovery rate, which in most cases eliminates the ability of natural self-regeneration of vegetation cover. The degradation process became even more intense in 1990s when grazing became uncontrolled and disorganized. As a result, about 700,000 ha of pastures have been degraded in the eastern part of the country. With the transition to the market economy, a significant portion of the pastures were leased, the grazing management and monitoring system got completely disintegrated, and grazing became completely uncontrollable and chaotic.

Unfortunately, the rate of degradation of vegetation on natural pastures is significantly higher than the recovery rates, which in most cases precludes the ability of natural self-regeneration of vegetation cover.

The current state of grazing can now be described as critical due to uncontrolled anthropogenic pressure on the one hand, and climate change, on the other hand. In addition to adverse environmental impacts, degradation of pastures has a negative impact on the socio-economic status of the country. Livestock is the main source of income in the mountainous regions of Georgia. The greater is the degradation of pasture, the lower is the productivity of livestock.

Core issues of Georgia's natural pasture

Most of the pastures are overgrown (low productive), degraded and overgrazed, largely due to the lack of pasture management. The core issues are as follows:

- 48% of the state-owned pastures (about 1.1 million ha) are leased and their use (animal load, calendars, turnover, etc.) is not regulated, thus, the pastures are overstocked and uncontrolled;
- some of the pastures in the country are privatized and used in unsustainable manner (despite the existing ban, the pastures have been privatized indirectly). The status of privately owned pastures is unknown;

- The former Soviet maps are used for the spatial distribution of pastures; these maps are significantly outdated and do not reflect the present reality, and a significant proportion of leased pastures are not registered in the e-registry;
- Legislation and state programs do not define the institutional framework for sustainable use of pastures. The lease agreements do not include environmental requirements against pasture degradation. The resulting environmental problems are causing soil erosion and grazing degradation.

The climate change has a very negative impact on pastures. Alpine and semi-arid grasslands are particularly susceptible to the climate change. Clearly, rising temperature will have a profound impact on high-altitude low temperature-adapted plant species. They are expected to be replaced by thermophilic (heat-loving) species the prevalence of which was limited by low temperature. Thus, following this process, serious shifts in vegetation of alpine meadows and later in subnival complexes are expected.

Due to the lack of reliable studies, little information is available on the possible impact of the climate change on Georgia's high mountain meadows. There is also very little information on winter pastures in arid and semiarid ecosystems, totaling to 57,000 hectares. During the winter, more than 400,000 sheep (almost half of the total number of sheep in the country) and cattle are grazing on these pastures vulnerable to the climate change. Such high concentration of livestock and intensive use of pastures leads to overgrazing, which causes degradation of the areas, and the impact of the climate change is an additional risk factor.

Subject to the foregoing, the situation of grazing in many regions has reached the critical point. Immediate measures are needed on grasslands that are already in dire straits in order to mitigate climate risks and to avoid irreversible processes.

The poor state of pastures is reflected in a number of strategic documents:

The Rural **Development Strategy of Georgia** (adopted in 2017) reflects the number of main challenges facing Georgia: the lack / absence of adherence to sustainable pasture management principles; and high risk of transition to irreversible degradation if grazing is continued.

The **Rural Development Strategy** (adopted in 2015) considers the urgent task of grazing management to implement research of natural grasslands and to preserve species and diversity for the purpose of establishing stable food base for livestock. The national target of the **National Biodiversity Strategy and Action Plan of Georgia** (adopted in 2014) is B.4, 2020; by 2020, the management of agricultural ecosystems and natural grasslands is improved.

Third National Environmental Action Programme of Georgia (2017-2021) also considers pasture erosion and soil degradation as a serious problem, indicating that "the ecological status of Georgia's soil cover faces serious challenges."

The Second National Action Plan to Combat Desertification (2014-2022) states that "improper use of pastures, excessive degree of grazing beyond the permitted limit and non-existence of proper vegetation alternation have led to the erosion processes in high mountain pastures."

Basic types of pastures and their descriptions

Meadow vegetation is prevalent in Georgia. Especially large areas are occupied by meadows in mountainous areas (sub-alpine, alpine and subnival zones). A significant part of the meadows belongs to the category of secondary meadows, probably formed as a result of deforestation and human farming.

According to the classes of vegetation formations, high mountain meadows are divided into typical high mountain meadows, subalpine meadows and alpine meadows. The formations differ in both the species of origin and the degree of development of herbaceous vegetation (plant height, biomass, etc.).

Typical high-mountain meadows

Typical high mountain meadows cover territories 1800 meters above sea level and are mainly composed of perennial herbaceous plants (grains, shoots, legumes, etc.) that form turf. Certain types of meadows are usually dominated by one or two species, although there are also types where three and four species predominate.

Subalpine Highlands

Subalpine highlands occur in isolated areas starting at altitudes of 1600-1700 meters and on average occur on slopes at altitude of 2200-2300 meters, on plateaus or gentle slopes. It is noteworthy that the growth of plants on this type of meadows begins at the end of spring, at the beginning of the rainy season and lasts up to 30 days. Subalpine vegetation is relatively abundant in western Georgia, where precipitation is much higher than in eastern Georgia. This type of meadows is characterized by the absence of multicycle differentiation and the absence of turfs. Species composition is relatively poor and is mainly represented by plants that are morphologically capable to achieve gigantic size (Heracleum, Symphytum, etc.).

Alpine meadows (carpet-like alpine meadows)

Carpet-like alpine meadows represent fragmentally small plots at an altitude of 2700-3200 meters above sea level, located on plains, humid depressions or gentle slopes. Due to the high altitude of carpet –like meadows the snow melts very late, leaving the vegetation period of the plants very short. Due to harsh conditions, herbaceous species do not grow high and do not exceed 5 cm. Species are mostly represented by various grasses, with insignificant number of grains and sedges.

Low mountain and valley meadows

Low mountain and valley meadows are usually associated with human activities or natural disasters. As a result of these processes, the vegetation of the forest has disappeared and the meadows were formed as a result of the succession. The forest is characterized by the ability to produce turf surfaces. As a result, quite stable meadow cenozoites are created, which are used extensively for domestic cattle grazing, and (in the process of permanent grazing) the process of restoring forest habitats is either hampered or proceeds very slowly. The vegetation of the mountain meadows is quite diverse. Here we find meadows rich in Festuca Montana, Menyanthes trifoliata, Agrostis, Fabaceae and other types of vegetation.

Relatively small valley meadows are typically developed in the area of former valley forest and floodplain forests. There are meadows rich in cereal-shrub plants, where cereal and leguminous plants prevail, as well as humid meadows that are mostly found along the rivers and lakes.

Steppes

A significant part of winter pastures in Georgia is classified as steppe and semi-desert.

Steppes are common in the driest regions of Georgia. Steppe vegetation is dominated by perennial turf producing herbaceous plants. In humid periods, phytocenoses of steppe are prevailed by short-life cycle vegetation plants (ephemerals and ephemeroids).

Semi-deserts

The semi-desert formations, characteristic to winter pastures in Georgia are found on the Eldar Plains and Kvemo Kartli plain, as well as on the Shirak Plain and Alazani Valley within 200-800 meters above sea level, and usually in the areas where rainfall ranges from 200-400 mm. The semi-deserts of Georgia are not distinguished by wide phytocenological diversity.

Natural meadow habitats of Georgia

In recent years, new classification systems have been developed - a habitat assessment system, largely used by EU member states. Plant communities are treated as the basis for habitat classification, and the key indicator for the sustainable use, management and threat of biological resources is the habitat rather than order of priority and sensitivity of plant communities. The use of these new classification systems fosters rapprochement between the EU and Georgia, the introduction of sustainable use of biological resources and the principles of effective management and deepening links between scientific circles.

According to EUNIS habitat classification flatsheet, the grasslands in Georgia belong to the **E-group habitats**:

E1.1. Inland sand and rock with open vegetation:
E1.2. Perennial calcareous grassland and basic steppes:
E1.2E. Irano-Anatolian steppes:
E1.4. Mediterranean tall-grass and Artemisia steppes:
E2.1. Permanent mesotrophic pastures and aftermath-grazed meadows:
E2.2. Low and medium altitude hay meadows:
E2.32. Ponto-Caucasian hay meadows:
E2.5. Meadows of the steppe zone:
E2.7. Unmanaged mesic grassland:
E2.8. Trampled mesophilous grasslands with annuals:
E3.4. Moist or wet eutrophic and mesotrophic grassland:
E3.5. Moist or wet oligotrophic grassland:
E4.1. Vegetated snow-patch.
E4.13. Ponto-Caucasian snow-patch grassland:
E4.2. Moss and lichen dominated mountain summits, ridges and exposed slopes.
E4.3. Acid alpine and subalpine grassland:
E4.44. Ponto-Caucasian alpine grassland:
E4.442. Caucasian alpine grassland:
E5.1. Anthropogenic herb stands.
E5.2. Woodland fringes and clearings and tall forb stands.
E5.3. Pteridium aquilinum fields.
E5.4. Moist or wet tall-herb and fern fringes and meadows:
E5.5 - Subalpine moist or wet tall-herb and fern stands
E5.5A. Pontic-Caucasian Highland Communities:
E6.2 Continental inland salt steppe

Impact of the climate change on Georgia's natural grasslands

The climate change is one of the most significant challenges facing the world today. It is recognized that biodiversity and the climate change are interconnected phenomena. Georgia's grasslands are mainly natural ecosystems. Consequently, preservation of natural vegetation is a crucial factor for their functioning and sustainability, considering the risks posed by the climate change, and is important for both biodiversity conservation and agricultural development.

Monitoring of temperature and other climate parameters throughout Georgia since the beginning of the twentieth century has demonstrated that the signs of the climate change in Georgia have been evident since the 1960s and are becoming increasingly rapid and sharp.

The current and expected climate change is described in **Sub-chapters 4.1 and 4.2**, Annexes A1-A4 and B1-B4, respectively, reflect present state and expected changes in mean temperature values, precipitation, relative humidity and wind speed.

Between the two 30-year periods (1956-1985 and 1986-2015) the average annual near-ground air temperature in the country has risen almost everywhere, various regions ranging within 0.25-0.58^{0}C, an average value on the territory of Georgia being 0.47^{0}C. On the whole territory of Georgia over the next two thirty years periods (2041–2070 and 2071–2100) compared to 1971–2000, significant warming is expected every month. In the first period the annual warming in various regions is within the range of 1.90C to 2.80C and in the second period within 2.70C - 3.60C. Decrease of precipitation or change in rainfall periods is expected in certain regions which will significantly affect the ecosystems of Georgia.

The rate of extreme events (floods, floodplains and landslides) has increased. The intensity and frequency of droughts (especially in eastern Georgia) have also increased.

Agroecosystems are the economic basis of Georgia's agriculture. The climate change events are likely to have a major impact on agricultural development and productivity. These risks are mainly related to temperature rise, changes in precipitation volume and character, extreme climate events (droughts, floods, hurricanes, strong winds). The main risk categories imply the change in vegetation period and the volume of rainfall during these periods, which has a very negative impact on crop yields. Increased number of droughts and their duration also belong to a number of serious problems.

As noted, a significant portion of the mountain pastures are now highly eroded due to intensive grazing, causing the topsoil to be washed away and the turf formation to stop. Due to the above, biomass on such pastures is significantly reduced. Plants of high nutritional value such as: violet barley (Hordeum vulgare), reed grass (Calamagrostis), meadow fescue, timothy (Phleum), clover species, Medicago, etc. are substituted by the following species of root hemiparasites, useless as feed: Ranunculus species, Pedicularis, Rhinanthus, etc.

The negative effects of the climate change may differ in various regions. The most serious impacts are expected for alpine, arid and semi-arid ecosystems where most of Georgia's natural grassland is found.

High mountain ecosystems are home to many unique species. Most of these species are adapted to low temperature and are often native endemics. Increasing average temperature caused by the climate change can be especially dangerous for species prevailing in Georgia's high mountain natural meadows, as vertical migration of heat-loving species to high altitude areas is expected.

Along with average annual temperature rise, vertical elevation of existing temperature barrier will be shifted to relatively higher mountain zones. This will stimulate vertical migration of heat-loving plants (especially xerophytic vegetation).

This will especially concern alpine vegetation, which may be reduced, and in certain cases (especially in the nival zone), the above processes may lead to complete disappearance of certain communities, which will significantly alter the productivity of mountain pastures.

Such events have already been observed in the European Alps and in the Caucasus Mountains, where more than 60 sites are being monitored under the long-term observation program GLORIA (similar observations are being conducted by the Ilia State University research teams in the Caucasus). These trends are also observed in Georgia; they present a great threat of changes in the structure of phytocenosis of pastures (especially extinction of local endemics) and may be a precursor of the change in pasture structure [40-41.

Significant impacts on the structure of pasture vegetation communities may be caused by the shifting of the precipitation periods, which may also be followed by shifting of vegetation periods or change in their duration.

In the process of continuous grazing, the plant is under constant stress, and due to the scarcity of water resources it is no longer able to regenerate lost leaves or other parts. At the same time, it is important to take into account the fact that animals prefer certain types of vegetation during feeding, which are subject to selective pressure during grazing. As a result of constant stress and water shortage, such herb plants are unable to regenerate, flower, seed, ripen and germinate. Eventually, the number of feed plant varieties on the pasture decreases, followed by reduction of the "seed bank" of feed varieties in the soil. On the other hand the species, which are less grazed, reproduce faster. . Accordingly, the change in rainfall periods will have a significant impact on the vegetation process and lead to the further increase of weed infestation process. All of this significantly changes pasture species composition, results in prevalence of no-feed species (weed infestation) and reduction of feed biomass of pastures.

A number of climatic parameters also clearly indicate to the possible changes. For example, a study of the GDDgrow10 Index for the municipalities of Georgia, which mostly comprise both summer and winter pastures, showed that the climate change is expected to significantly increase the amount of heat energy received by pasture vegetation. This parameter determines both the correlation of heat-loving plants to the species in the plant community and their vegetation rates. All of this will ultimately affect the types of pastures and their ability to produce sufficient quantities of vegetable biomass needed for livestock.

The climate change can also have a significant impact on the factors causing erosion of natural grasslands. As is commonly known, pastures and grasslands of the Greater Caucasus Mountain Range, in Georgia are usually located on difficult, strongly segregated steep slopes of 10–30 degrees, with an average elevation of some 3500 meters above the sea level in some parts of the Greater Caucasus.

Precipitation, their intensity and periods are important factors in the development of water erosion. The ongoing processes of depletion, denudation, erosion, landslides, mudflows have a negative impact on summer pastures, which is further aggravated by relatively high continental climate, low snow cover and, most importantly, unregulated grazing.

A single day precipitation volume has significantly increased in certain months, which will enhance the processes of water erosion in the highlands.

It should also be noted that some positive effects are also expected. Anticipated rise in temperature and a decrease in annual precipitation will lead to formation of typical alpine pastures, leading to the invasion of dry xerophilic plants and their expansion due to climatic conditions, mainly on the southern slopes. It should be noted that such an expansion can have a positive effect on grazing pastures, as highland steppe vegetation (provided there is no severe erosion) has a high nutritional value.

A survey was carried out in a number of mountainous regions of Georgia with the assistance of the Food and Agriculture Organization of the United Nations (FAO) to assess pasture yields and impacts of the current and expected climate change. The Intergovernmental Panel on The Climate Change (IPCC)'s A1B scenario was applied when simulating the future climate. Climatic parameters (atmospheric precipitation, maximum and minimum air temperature, standard evapotranspiration) were obtained by scaling the general circulation model (ECHAM4.1 climate scenario data) to the region using the Regional Dynamic Climate Model (RegCM).

This study was based on FAO AquaCrop model and the experts' report. For each region, the model simulated four different periods: two current 25-year periods (1966-1990 and 1991-2015) and two 30-year forecast periods (2021-2050 and 2070-2099).

Studies have shown that according to the selected scenario of the climate change (A1B), the potential productivity of natural grasslands can be expected to increase throughout the forecast period. Maximum growth of pasture natural grasses is expected in Kakheti by 35-40% and 75-80%. The least significant changes are expected in Upper Svaneti, whereas yields in the Kazbegi region may on the contrary become unstable.

According to the selected scenario of the climate change (A1B14), potential productivity of the autumn wheat will grow, both, with and without irrigation. Irrigation effect is particularly significant for the cultivated areas on saline soils in current 25-year period while in the first prognosis period the effect is relatively lower.

Simultaneous examination of the model with respect to real statistics (two current 25-year periods (1966-1990 and 1991-2015) showed that there was an actual decrease in the pasture productivity rather than an increase (according to unofficial statistics available from literary sources) [42]. The authors of the study explain this result not due to the climate change, but due to inappropriate land use and inconsistent management, including lack of nutrients in pasture soils, inadequate timing of grazing, scything, etc.

Rangelands located in **arid and semiarid ecosystems** are also at high risk. Model studies have shown that these types of ecosystems will inevitably be strongly affected by the climate change [43].

The average amount of precipitation on pastures in arid and semi-arid zones ranges between 300mm, the average annual air temperature is 12-14^{0}C. Dry and bedding soils mainly house Artemisia, absinthium, and other perennial turf-generating herbaceous plants, with coverage often not exceeding 30-40%.

In such regions, precipitation is expected to decrease and temperature to increase, which should be followed by substitution of the existing species by the invasive thermophilic species, more resistant to lack of precipitation [44].

Prolonged or more frequent periods of drought that will occur as a result of forecasts should lead to a decrease in vegetation growth and in some cases even cause disappearance of certain plants. Amidst prolonged droughts, the fire risk is expected to increase, followed by the destruction of vegetation and soil erosion. As a result, the risk of desertification may accelerate in such regions, which is unfortunately often an irreversible process [45].

Particular complications may occur in areas of eastern Georgia, such as Dedoplistskaro and Sighnaghi, where there are quite a few winter pastures. Winter pastures, unlike summer ones, are relatively scarce in Eastern Georgia, and they are mostly concentrated in Shirak. Actually, quite a large part of the sheep is grazed here, making the pastures extremely overstocked.

It should also be noted that more than 80% of pastures located in Dedoplistskaro are already degraded and some are at significant risk of desertification.

Pasture management under the climate change

The purpose of pasture management is to implement measures to maintain optimum vegetation cover and soil fertility. A well-managed and well-maintained pasture will provide livestock with sufficient forage and energy throughout the season. Proper management reduces erosion, preserves biodiversity, improves nutrient turnover and water supply. Most importantly, proper grazing management is an important prerequisite for reducing risk to the climate change and grazing sustainability.

The introduction of sustainable management principles provides the livestock sector with inexpensive and easily accessible biological resources, which in turn contributes to maintaining agricultural sustainability, mitigating the climate change risks, adapting to them and at the same time ensuring the social interests of the population.

Proper management of pasture does not only imply cattle regulation. Lack of management rather than excess of grazing cattle is the main factor to damage the pastures. Proper management involves primarily maintaining the optimum amount of vegetation in the pasture, protecting it from overstocking, keeping grazing regime and calendar. As a result of these measures, it is possible (in some cases more than 2 times) to increase the number of cattle on pasture, without deteriorating vegetation.

At the same time, the climate change is important in planning and implementing pasture management measures to ensure that the natural ecological balance of vegetation cover of meadows is maximally maintained, contributing to the sustainability of the pasture as a natural ecosystem, productivity growth and overall improvement.

It is also important to improve and manage cultural pastures, which should be planned and implemented with full conservation interest in mind and based on the need for long-term pasture maintenance. It should also be noted that the management of natural and cultural pastures have different features. . In the case of cultivated pastures, the goal of management may be to achieve maximum productivity through minimal costs, while in the case of natural pastures, the task of maintaining ecological balance and biodiversity is at the forefront.

In the case of cultural pastures, various measures to improve pastures (for example, the cultivation of species with high nutrition value or cultural varieties, etc.) may be undertaken, but such actions are relatively limited in natural pastures (especially in protected areas). It should also be borne in mind that the natural grazing management system does not require significant financial costs and is economically justifiable compared to pasture improvement major activities.

With respect to pasture management, it is noteworthy that part of this most important resource of the country lies within the so-called "**Emerald Network**". The Emerald Network is a pan-European ecological network with the goal to preserve the biodiversity of Europe. Its establishment is one of the requirements of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979), also known as the Bern Convention. The Emerald Network is one of the main mechanisms for its implementation. The Emerald Network Sites are subject to a special and yet relatively flexible management regime, which is to ensure the long-term conservation of species and habitats protected under the Bern Convention.

The European Commission has developed guidelines for the management of Emerald Network sites under the climate change, which are provided in the Guidelines on Climate Change and Natura. “Dealing with the Impact of Climate Change on the Management of the Natura 2000 Network of High Biodiversity Value Areas ”, 2013.

The management principle calls for measures to ensure "favorable conservation status" of species and habitats distributed on the site, which enhances the ecosystem's ability to adapt to the climate change. (A favourable conservation status is a condition when a habitat has sufficient area and quality and a species has a sufficient population size to ensure its survival in the medium to long term, along with favourable future prospects in the face of pressures and threats). As a result of this approach, it is expected that a well-functioning ecosystem and its components will be able to regain their original status promptly after extreme climate events.

The main measures include the following:
Reduce existing pressures;

Maintain ecosystem heterogeneity;

Enhance ecosystems and species resilience;

Manage fires, floods and other extreme events;

Develop the protected areas, emerald network sites, bird sites, create zones connecting the buffer sites;

Control of invasive alien species;

- Integrate the climate change adaptation measures into sector policy documents.

Effective grazing management is also an important issue for Georgia's protected areas, with over 100,000 hectares of pastures, including winter pastures in Vashlovani Protected Areas, as well as summer pastures in Tusheti, Khevsureti, Borjomi-Kharagauli, Javakheti and Lagodekhi.

Given the specificity of the protected areas and natural conditions, the climate change adaptation measures, including measures to increase pasture productivity and improve overall condition are limited. In order to preserve biodiversity and restore natural ecosystems, only surface improvement measures can be undertaken in protected areas, as the management of such pastures requires preservation of the ecosystem and species diversity.

As opposed to the basic measures, no costly reclamation activities, sowing and other activities can be undertaken when planning adaptation activities for pastures in protected areas. Grazing management in protected areas is an integral part of protected area management plans, and improvement of floristic composition is permissible provided existing natural grassland species are preserved.

Despite the lack of experience and institutional capacity available at present, with support from international organizations and local partners, protected areas are already undergoing programs aimed at sustainable grazing management, including the climate change adaptation measures. As of 2019 initial assessment of pastures in Vashlovani and Lagodekhi Protected Areas has been conducted and initial management plans prepared. The same process is going on in Borjomi-Kharagauli National Park and Tusheti Protected Areas. These experiences can be used and shared by other areas of Georgia as well.

Conclusions

1. Georgia is distinguished by its diversity of natural grasslands, the conservation of which is of great importance both in terms of agricultural sustainability and biodiversity;
2. Events provoked by the climate change are likely to have a very serious impact on agricultural practices. It is expected that the quality of pasture degradation will increase both in mountainous regions of Georgia and in semiarid ecosystems, the vulnerability of which to climate change is confirmed by studies conducted in Georgia;

3. The expected scenarios largely differ and depend on the geographical location and climatological features of the region. In the case of Georgia, the risks are mainly related to the average annual temperature rise, precipitation volume and periods, extreme climate events (droughts, floods, hurricanes, strong winds);
4. The preservation of natural pastures requires the maximum preservation of the natural state of species and habitats and the conservation of ecological balance. Maintaining a natural balance increases the ability of the ecosystem to adapt to the climate change and allows the livestock sector to provide cheap feeding;
5. Today the Georgian legislation does not specify the institutional and legislative framework for sustainable use of pastures. Pasture utilization is not controlled and the principles of sustainable pasture management are not observed. A significant portion of the pasture is overstocked;
6. Environmental problems provoked by regular grazing cause soil erosion and significant degradation of pastures, which in turn increases the risks associated with the climate change;
7. A significant part of Georgia's pastures falls within the protected area system and the international ecological network 'Emerald Network', which necessitates the addition of pasture management, including the need to adopt international regulations;
8. Pasture management exceptions are protected areas of Georgia where pastures are managed according to management plans developed on the basis of international recommendations. The experience of protected areas can be used as an exemplary pilot program to promote introduction of sustainable pasture management elements throughout the country;
9. Within the given scenario, it is important to develop adaptive capacities for pasture climate change impacts in order to conserve biodiversity and sustain livelihoods for locals.

Recommended Adaptation Measures

7. Establishment of a state system (structure) responsible for grazing management that takes into account the ecological requirements of natural and cultural pastures (meadows) and the climate change scenarios, which is a prerequisite for mitigating the impact of the climate change on Georgia's pastures;
8. Monitoring of pasture status throughout the country, as well as assessing the impacts of the climate change and developing management recommendations at both national and municipal levels;
9. Developing grazing management plans to improve the effectiveness of meadow management and ensure adaptation to the climate change;
10. Integrating pasture management issues into municipal the climate change adaptation plans;
11. Taking into account the following principles and guidelines when developing pasture management plans:
    - **Legal environment:** The relevant state structure (or structures) is responsible for grazing management and the use of grazing land. Sub-lease of rangelands (grazing lands) is prohibited.
    - **Grazing management** primarily involves maintaining the ecological status of grazing by determining the permissible grazing load and determining the grazing regime (calendar, rotation principle, etc.).
    - **Creating conditions necessary for vegetation restoration.** When developing a plan, the vegetation period and the amount of rainfall and the respite of certain sections of grassland should be taken into account. Current and predicted climate change must also be taken into account;

- **Improvement of grazing condition**: Grazing management measures include sowing, mowing, fertilizing, weeding, irrigation and more. At this time, it is necessary to discuss the planned activities with the stakeholders; to filter these activities in terms of practical feasibility, based on criteria such as financial viability, socio-economic impact and practical achievability , as well as real opportunities for key actors.
- **Pasture Monitoring**: The relevant government structure monitors the pasture continuously and ensures adherence to the terms of the lease agreement.
- **Pasture Participatory Management**: Grazing decision-making process will be carried out through participatory management - intensive consultations with key stakeholders.

General goals and objectives of the pasture management plan

The plan should cover the following issues:

- Preservation of natural resources and biodiversity through ecological management and traditional grazing practices;
- Improving ecological status through sustainable grazing management;
- Supporting introduction and implementation of pasture management best practices (e.g. maintaining existing vegetation at a rapid, so-called exponential growth stage, which ensures large amounts of plant biomass along with grazing. This approach allows for more forage);
- Increasing food production (increased share of leguminous crops);
- Increasing organic matter in the soil;
- Reducing the pressure of pests and diseases;
- Excluding washing out and loss of the fertile soil layer;;
- Access to and use of natural resources through participatory management, including involvement of property owners, communities, civil society organizations, local government and other relevant government agencies in decision-making and grazing management.

4.3.5 Soil Erosion

Georgian soils are distinguished by great diversity. The following main types of soil are common in Georgia: mountain-meadow boggy soils, mountain-meadow boggy-carbonate, mountain-meadow brown podzolic soil, mountain-meadow peat and loamy, yellow and yellow podzolic, mountain-forest meadow, red soil typical, red soil podzolic, silt marshy soil, boggy soil, meadow wetland, mineral swamp, lowland black soil, bituminous complex, alluvial soils.

Water erosion occurs in all natural climatic zones throughout Georgia: from humid subtropical to alpine zone. Wind erosion only occurs in Eastern Georgia, mainly in Gere Kakheti and Shirak.

Water erosion

Water erosion is of great intensity and is reaching dangerous proportions in the hilly and foothill parts of the humid subtropical and arid zones of Georgia. It is estimated that up to 200-300 tons of soil per hectare is sometimes washed away from the slopes of 10 – 20^{o}, the depth of water wells often reaches 0.5 meters and more. Under certain conditions, such aquifers will gradually turn into ravines and gallies.

In the dry subtropical climate of Eastern Georgia, water erosion on vegetation-covered slopes is more intense, which is due to the low resistance to soil erosion prevalent here. In this region, during heavy rains on slopes of 6-12°, 30-40 tons of soil are washed from one hectare annually, and up to 100-200 tons of soil during heavy rains.

Two reagions are reviewed here: Shida Kartli in Eastern Georgian and Zemo Imereti in Western Georgia.

Universal Soil Loss Equation model (RUSLE) of European Commission's Joint Research Centre has been used for assessing risks of soil erosion by water [46, 48-49]. The model allows assessing erosion risks and identifying hotspot at large areas, including territories of continents, countries, regions, and municipalities.

A – soil loss caused by erosion is calculated by the following equation:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \qquad (1)$$

Where

R is rainfall erosivity factor /climatic factor of erosion development, (MJ mm)/(ha · h);

K is soil erodibility factor/measures soil sensitivity to erosion, (t · ha/(MJ · mm);

L is slope length factor (dimensionless);

S is slope steepness factor (dimensionless);

C is cover management factor (dimensionless); and

P is support practices factor (dimensionless).

R–factor measures rainfall's kinetic energy and intensity, as precipitation is the driving force of erosion. Rainfall's kinetic energy is calculated by dividing the rain gauge chart into equal intervals, measuring kinetic energy for each interval and summarizing them. R-factor is calculated by multiplying the kinetic energy by the maximum rainfall intensity during a period of 30-minutes for each rainstorm.

R-factor is related to terrain elevation by means of regression equation. R-factor map has been created using the above model, based on a digital map of Kvemo Kartli.

Terrain elevations in the region range from 440 m to almost 4000 m. Arable lands fall within the range of 450-1500 m. R-factor varies from 100 to 400 m across the region, including 379-402 in the low-mountain zone of Kvemo Kartli, 303-379 in the high-mountain forest zone, 247-278 in the subalpine zone and 100-211 in the alpine zone.

Soil grain size distribution strongly influences erosional resistance of soil. As a rule, the coarser the grains, the weaker the soil resistance. Unstructured clay and loamy soils are the most erodible ones. They are weakly permeable, float on the flow surface and form a crust on the soil surface. Highly permeable sandy soils are less erodible.

Soil erodibility factor (K-factor) is a ratio of the amount of soil washed from a land plot with 22.13 m slope length and 4.5 degrees slope angle to R-factor. At the same time the plot remains bare fallow throughout the year. Based on the given model, K-factor is calculated using the corresponding nomograph [47].

Shida Kartli's K-factor map has been created based on the region's soil map and field and laboratory surveys. The map shows that in the forest zone K-factor ranges between 0.013 and 0.022; in the alpine and mountain meadow zones it is 0.002-0.013; while in the lowland (meadow brown and alluvial soils) it is as high as 0.022-0.027. Yet, there are no high risks of soil erosion by water in these areas because of insignificance of the slope steepness factor.

Topography is one of the main factors for water erosion forming and development. It influences soil erosion through such subfactors as slope length and steepness. Soil erodibility increases with slope steepness and length. The longer the slope, the bigger the catchment basin area [55] and the surface runoff. In case erosion process takes place, the upper third of the slope gets most affected, while slope wash sediments accumulate in its lower third [48-51]. Slope steepness has a stronger influence on soil loss than slope length.

The influence of topography on soil erodibility is reflected by the combined LS-factor, where L is the length and S is the steepness of the slope. The influence of LS-factor on soil loss is particularly strong in the mountain regions.

With other erodibility factors being equal, L-factor reflects the influence of slope length on soil loss that equals a ratio between soil washed from a slope of the given length and soil washed from the 22.13-m-long slope (the so-called standard plot). S-factor reflects the influence of slope steepness on soil loss and equals a ratio between soil washed from a slope of the given steepness and soil washed from the slope with the angle of 5.14 degrees (the so-called standard plot).

An electronic LS-factor map has been created using the given model. In the study area, the steepest slopes (35-45 degrees and above) occur in the middle and upper reaches of the rivers Ksani, Didi Liakhvi and Patara Liakhvi. It has been established [9] that slope length shortens as its steepness increases. The lowland and alpine zones of Shida Kartli are characterized by low LS-factor (5-15), while in the mountain forest zone LS-factor is high and very high (100-200).

The cover management factor (C-factor) accounts for how land cover, crops, agrotechnology practices, and crop management affect soil loss. C-factor equals a ratio between soil washed from a given plot with a given vegetation cover, type of crop and tillage practice and soil washed from the reference plot, where soil erodibility factor is determined.

The RUSLE modelling [46] can use remote sensing methods. In this case, the following method has been used: since the study area is rather large and C-factor includes areas with different types of vegetation, a land use map was initially created using remote sensing data (satellite data). Next, Normalized Difference Vegetation Indices (NDVI) were determined for different lands. NDVI quantifies *vegetation* by measuring the difference between near infrared light (strongly reflected by *vegetation*) and red light (absorbed by *vegetation*). In this research, we used one of the NDVI-based C-factor determination methods [48-49]. In particular,

$$NDVI = (NIR - IR)/(NIR + IR) \qquad (2)$$

Where:

IR is red light and NIR is near infrared light.

$$C = \exp(-\alpha \cdot NDVI / \beta) \qquad (3)$$

$\alpha = 2$; $\beta=1$. C value ranges from 0 to 1.

Based on the RUSLE method, C-factor values have been calculated for certain crops in Shida Kartli municipalities as shown in Table 4.3.5.1.

Table 4.3.5.1: C-factor values for certain crops and their groups in Shida Kartli municipalities

Municipality	Winter crops	Spring crops	Maize	Potato	Sugarbeet
Khashuri	0.595	0.430	0.508		0.553
Gori	0.647	0.399	0.533		0.518
Kareli	0.595	0.430	0.508		0.553

Municipality	Winter crops	Spring crops	Maize	Potato	Sugarbeet
Kaspi	0.647	0.399	0.533		0.518
Tskhinvali	0.605	0.426	0.558	0.681	0.583
Akhalgori	0.612	0.337	0.565	0.642	0.640
Kornisi (Znauri)	0.565	0.333	0.583		0.665
Java	0.502	0.344	0.513	0.665	

C-factor values for Shida Kartli have been calculated using Table 4.3.5.1 and satellite data according to the above method. There is a linear relationship between the above parameter and soil loss from erosion, in particular: the smaller the C-factor, the smaller is the soil loss. As a rule, C-factor is relatively high in arable lands, and in Shida Kartli it ranges between 0.02 and 0.35. In the mountain meadow and mountain forest zones, covering more than a half of the region's entire territory, C-factor is within the range of 0.0001-0.02.

In the RUSLE model, P-factor accounts for control practices that reduce the erosion potential of runoff. It equals a ratio between soil washed from the plot, where supporting conservation practices are applied, to soil washed from the plot, where tillage and sowing down the slope are practiced. P-factor values are mostly represented in tabular form [50-51].

According to the RUSLE, P-factor is associated with slope steepness: the steeper the slope, the higher the risk of soil erosion and the higher the P-factor. A P-factor map has been created, using the digital terrain model. In the mountain forest zone P-factor is within 0.84-1.0 because of high steepness of slopes; in the alpine and foothills zones steepens decreases to 5-15 degrees and P-factor is 0.12 on average; while on arable lands in the lowland, P-factor ranges from 0.10 to 0.19.

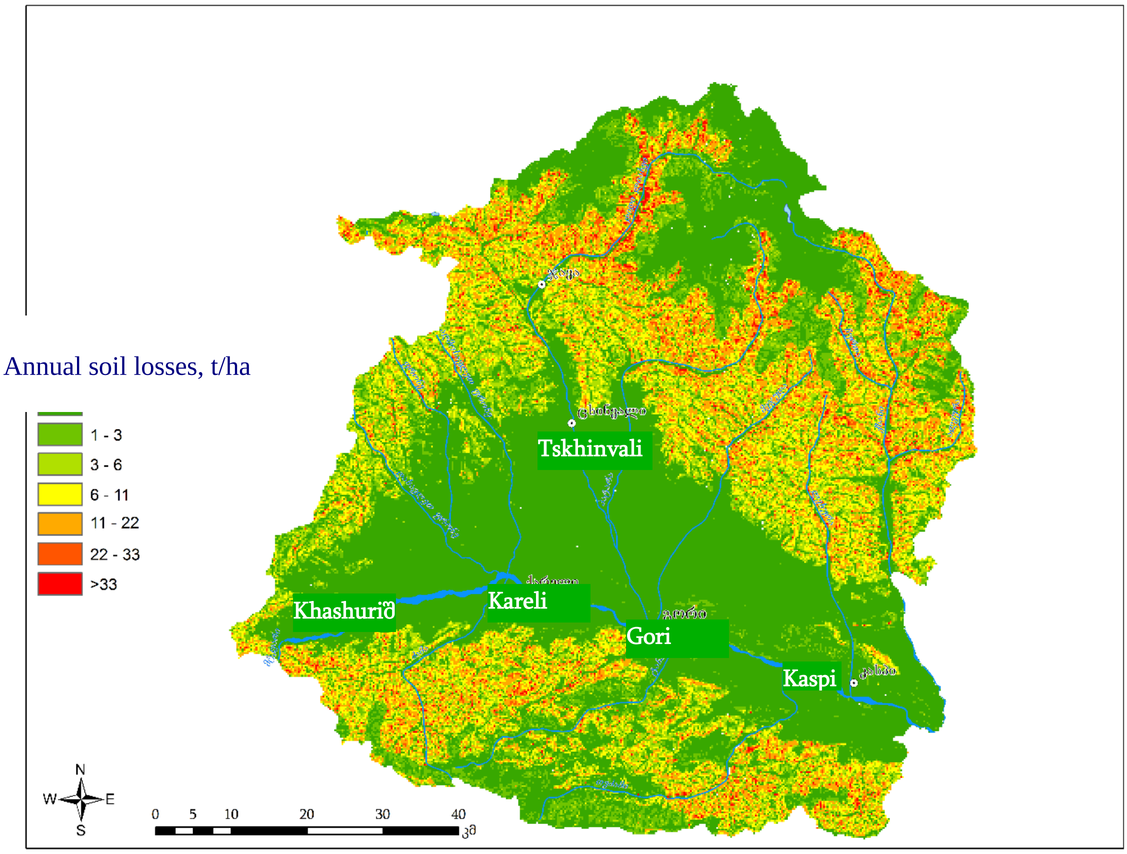
Based on the RUSLE method and the above factors, corresponding maps are developed and factor values are multiplied together to establish land loss values from water erosion (t/ha). Figure 4.3.5.1 shows a map of potential average annual soil loss from water erosion in Shida Kartli.

According to our findings, annual soil loss from water erosion in Shida Kartli's lowland and alpine zones is 0-6 tons per hectare. In the foothills, medium- and high-mountain areas soils are characterized by rather high erodibility and in certain areas soil loss exceeds 33 t/ha. In the mountain forest areas, with brown forest soil thickness being 50-70 cm, soil loss tolerance does not exceed 3-4 t/ha.

Degrees of soil degradation have been categorized based on the given soil loss tolerance values and using the Global Assessment of Human-Induced Soil Degradation (GLASOD) model, developed by the Ministry of Agriculture and Agri-Food of Canada [52-54] (Table 4.3.5.2).

Table 4.3.5.2: Relationship between soil degradation and erodibility

Soil layer thickness	Soil loss from water erosion (t/ha) and degrees of soil degradation			
	Weak	Moderate	Strong	Extreme
Above 150 cm	6-11	11-22	22-33	>33
101 – 150 cm	5-9	9-18	18-27	>27
51 – 100 cm	4-6.7	6.7-13.4	13.4-20.1	>20.1
25-50 cm	3-4.5	4.5-9	9-13.5	>13.5
Below 25 cm	<2.2	2.2-4.4	4.4-6.8	>6.8
Soil quality	No or insignificant reduction in yields	Reduction in yield of annual crops	Drastic reduction in yield due to significant thinning of soil surface	Unusable



Map 4.3.5.1: Potential soil loss from water erosion in Shida Kartli

Table 4.3.5.3 shows weakly, moderately, strongly and extremely degraded land areas in Shida Kartli by municipalities. The total area of lands with various degree of degradation is 198,876 ha, making 29.1% of the region's total area. In Kurta, Akhalgori and Java municipalities, one in 4 hectares of land is weakly, strongly or extremely degraded. Almost 7,000 ha are strongly or extremely eroded. It is obvious that strongly or extremely eroded lands are mainly located in mountain municipalities. It has been established that one in three hectares of land across Shida Kartli is degraded to a certain degree.

Table 4.3.5.3: Weakly, moderately, strongly and extremely degraded land areas by municipalities, Shida Kartli

Municipality	Total area	Degradation degree and area, ha									
		Weak	%	Moderate	%	Strong	%	Extreme	%	Total	%
Khashuri	56,187	6,979	12.4	4,281	7.6	686	1.2	243	0.4	12,188	21.7
Kareli	118,090	12,796	10.8	9,882	8.4	11,492	9.7	644	0.5	34,813	29.5
Gori	141,137	8,536	6.0	6,298	4.5	981.8	0.7	311	0.2	16,126	11.4
Kaspi	79,609	7,665	9.6	7,095	8.9	1,288	1.6	554	0.7	16,602	20.9
Kurta	98,633	16,813	17.0	17,240	17.5	3,732	3.8	1,288	1.3	39,073	39.6
Akhalgori	94,785	19,336	20.4	19,695	20.8	4,413	4.7	1,747	1.8	45,191	47.7
Java	95,059	12,621	13.3	15,688	16.5	4,392	4.6	2,180	2.3	34,882	36.7
Total	**683,501**	**84,745**	**12.4**	**80,179**	**11.7**	**26,985**	**3.9**	**6,968**	**1.0**	**198,876**	**29.1**

Potentially erodible soils have been surveyed in the mountain region of Zemo Imereti in Western Georgia, including Zestaponi, Chiatura and Sachkhere municipalities. Similarly to Shida Kartli, the survey used the RUSLE model [46] and field research data [56-57].

According to the findings, average annual soil loss from water erosion in Zemo Imereti's mountain zone (Khevijvari village) was 12 tonnes, while in the foothills and hills (Kitskhi village) it was 15 tonnes (Table 4.3.5.4).

Table 4.3.5.4: Soil loss caused by water erosion in Zemo Imereti (t/ha) [53]

Option	Mountains	Foothills and hills
Bare fallow	42.93	43.55
Maize	20.70	16.12
Oats	4.13	14.43
Total	22.59	24.70
Arable lands	12.32	15.28

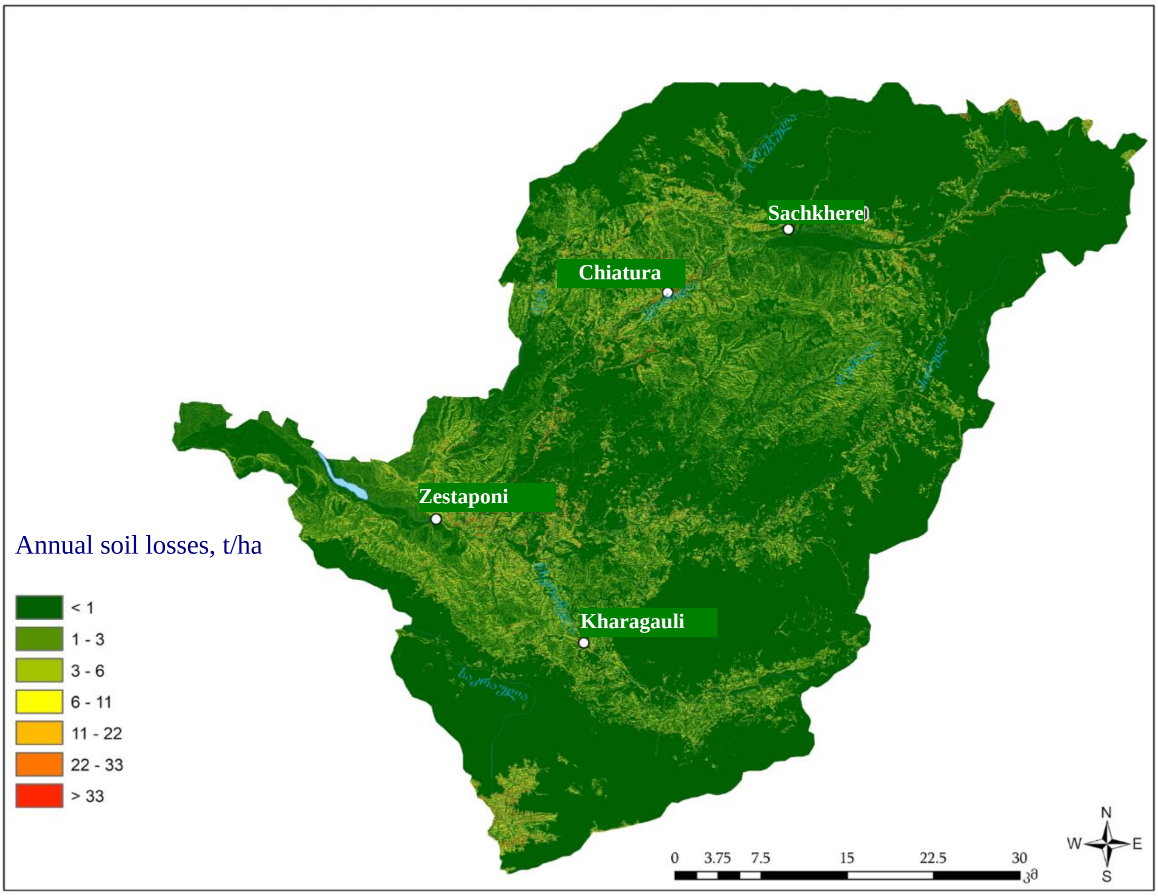
In order to establish erosion intensity, suspended sediments were examined in the Chkherimela river basin (Table 4.3.5.5) [59], showing that annual average soil loss from water erosion in arable lands was around 10 tonnes.

Table 4.3.5.5: Erosion intensity in the river basins in Zemo Imereti [14]

River /Settlement	Basin area, km^2	Total denudation		Average annual soil loss t/ha	
		Thous. t	mm/year	Basin	Arable lands
Chkherimela-Kharagauli	398	132	0.4	3.32	9.5

Based on the RUSLE model, GIS and satellite data, electronic maps of the RUSLE factors and a map of potential soil loss from water erosion in Zemo Imereti have been created.

Based on the above method, it has been established that 13.3% (43,414 ha) of total lands in Zemo Imereti are degraded to a certain degree; 6,143 ha are strongly and extremely degraded, while 16,260 ha are weakly and moderately degraded. Water erosion is particularly intensive in Chiatura municipality, where 22% of total lands are degraded. In other municipalities, erosion processes are almost equally intensive, causing various degree of degradation of 10.7-12.3% of lands.



Map 4.3.5.2: Potential soil loss from water erosion in Zemo Imereti

Table 4.3.5.6: Weakly, moderately, strongly and extremely degraded land areas in Zemo Imereti municipalities

Municipality	Total area	Degradation degree and area, ha									
		Weak	%	Moderate	%	Strong	%	Extreme	%	Total	%
Zestaponi	91,486	7,687	8.4	2,145	2.3	638	0.7	810	0.9	11,280	12.3
Kharagauli	90,557	5,701	6.3	2,810	3.1	941	1.0	898	1.0	10,351	11.4
Chiatura	54,993	7,623	13.9	2,933	5.3	799	1.5	864	1.6	12,219	22.2
Sachkhere	89,435	6,284	7.0	2,087	2.3	592	0.7	601	0.7	9,564	10.7
Total	**326,471**	**27,295**	**8.4**	**9,976**	**3.1**	**2,970**	**0.9**	**3,173**	**1.0**	**43,414**	**13.3**

Projected Climate Change Impacts on Water Erosion

According to the climate scenario, climate parameters in Shida Kartli and Zemo Imereti are expected to change significantly in 2041-2070 and 2071-2100 as compared to 1971-2000. Tables 4.3.5.7 and 4.3.5.8 show mean temperature and precipitation values in 2071–2100 and deviations from the mean values of 1971–2000 at two typical stations in each Shida Kartli (Khashuri and Gori) and Zemo Imereti (Sachkhere and Zestafoni) regions.

Table 4.3.5.7: Mean air temperatures (Tmean) in 2071–2100 and changes in temperatures (ΔTmean) vs 1971–2000

Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Sum.	Aut.	Wint.	Year
Khashuri	Tmean, ^{0}C	0.6	1.7	7.1	13.9	17.5	21.8	23.4	23.2	20.6	13.6	7.8	3.1	12.8	22.8	14.0	1.8	12.9
	ΔTmean, ^{0}C	1.9	1.3	3.0	3.5	3.2	4.0	2.6	2.6	3.9	2.6	2.8	2.3	3.2	3.0	3.1	1.9	2.8
Gori	Tmean, ^{0}C	1.5	2.8	8.0	14.9	17.7	22.4	24.6	24.1	19.9	14.9	8.2	3.5	13.5	23.7	14.3	2.6	13.5
	ΔTmean, ^{0}C	2.1	2.5	2.9	3.7	2.6	3.6	2.6	2.3	2.3	3.2	2.7	2.3	3.1	2.8	2.7	2.3	2.7

Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Sum.	Aut.	Wint.	Year
ΔTmean, ^{0}C		**2.0**	**1.9**	**3.0**	**3.6**	**2.9**	**3.8**	**2.6**	**2.5**	**3.1**	**2.9**	**2.8**	**2.3**	**3.2**	**2.9**	**2.9**	**2.1**	**2.7**
Sachkhere	Tmean, ^{0}C	2.8	4.4	8.9	15.6	19.7	22.2	25.0	25.1	21.1	15.7	9.7	5.2	14.7	24.1	15.5	4.1	14.6
	ΔTmean, ^{0}C	2.5	3.1	3.3	3.8	4.0	3.2	3.2	3.2	3.0	3.5	3.4	3.0	3.7	3.2	3.3	2.9	3.2
Zestaponi	Tmean, ^{0}C	6.1	7.6	11.7	17.6	21.7	24.5	26.6	26.9	23.8	19.7	13.2	8.9	17.0	26.0	18.9	7.5	17.3
	ΔTmean, ^{0}C	2.1	2.9	3.3	3.6	3.8	3.3	3.1	3.2	3.2	4.0	3.0	2.9	3.5	3.2	3.4	2.6	3.1
ΔTmean, ^{0}C		**2.3**	**3.0**	**3.3**	**3.7**	**3.9**	**3.2**	**3.1**	**3.2**	**3.1**	**3.8**	**3.2**	**2.9**	**3.6**	**3.2**	**3.3**	**2.8**	**3.1**

Table 4.3.5.8: Precipitation (Pr) in 2071–2100 and changes in precipitation (□Pr) vs 1971–2000 in percentage

Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Sum.	Aut.	Wint.	Year
Khashuri	Pr, mm	69	45	35	39	55	81	48	40	31	38	69	56	129	169	139	171	608
	ΔPr, %	8	-4	2	-18	-13	17	11	2	-18	-27	11	-11	-11	12	-10	-2	-3
Gori	Pr, mm	34	29	26	36	53	70	50	32	21	32	49	35	115	152	103	98	467
	ΔPr, %	-2	-5	-11	-27	-13	9	15	-5	-28	-25	3	-6	-17	8	-15	-5	-7
Sachkhere	Pr, mm	68	54	65	64	74	79	53	53	59	74	70	85	203	185	203	206	797
	ΔPr, %	-16	-15	10	-19	-20	-15	-34	-26	-23	-16	-18	-8	-12	-24	-19	-13	-17
Zestaponi	Pr, mm	135	107	111	80	59	84	54	59	61	100	117	167	250	197	279	409	1134
	ΔPr, %	-14	-17	8	-13	-24	-14	-22	-16	-24	-17	-12	2	-8	-17	-17	-9	-12

The mean annual air temperature in Khashuri (Shida Kartli) during the 30-year period of 2071-2100 is 12.9^{0}C, which is 2.8^{0}C higher than the mean temperature recorded in 1971-2000. In the warmest months of the year (May-September), the increase makes 3.2^{0}C. The mean annual air temperature in Gori is slightly higher than that in Khashuri, reaching 13.5^{0}C, but the increase in temperature is a little bit lower in Gori, with the deviation from the values recorded in 1971-2000 being 2.7^{0}C both for the mean annual temperature and the warmest months' temperature.

In Khashuri, the mean annual precipitation during the period of 2071–2100 is 608 mm, marking a slight decline (3%) against 1971-2000 year period. In summer precipitation increases by 12%, and in spring and autumn it declines by 11% and 10% respectively. In Gori, the average precipitation in the given period declines by 7%. In summer, it is increased by 8%, while in spring and autumn it declines by 17% and 15% respectively.

In the foothills of the northern part of Upper Imereti (Sachkhere), the expected annual decline in precipitation during the period of 2071–2100 is 17% compared to the average precipitation values of 1971–2000 years. In terms of annual distribution, precipitation decline can be observed in all seasons, including the most significant decrease in summer (24%) and autumn (19%). A dramatic (23%) increase in precipitation can be expected in autumn, which may increase the likelihood of erosion processes.

In the foothills in the western part of the region (Zestaponi), the expected annual decline in precipitation in 2071–2100 years period is 12%. Precipitation decline also can be expected in all seasons, with potential 17% decline in summer and autumn, when erosion hazard is the highest. The mean annual temperature increases by 3.1^{0}C; increases in temperatures are observed during all seasons, ranging between 2.8^{0}C and 3.6^{0}C.

In general, the expected decrease in precipitation during the period of 2071–2100 does not necessarily mean decrease in erosive processes. The predicted warming is likely to increase the soil surface temperature, which will cause its drying, facilitate soil particle movement and intensify erosion. As a rule, high temperature and low precipitation in dry areas also result in poor production and rapid oxidation of organic matters. Low organic matter content leads to poor aggregation and low aggregate stability, which in turn is a cause of high potential for water and wind erosion [60].

Based on the above, the impact of the climate factor on water erosion in Shida Kartli and Zemo Imereti may increase slightly in the future. Other factors (vegetation, surface cover, soil management and erosion prevention) may have more tangible impact, though it is impossible to make any projections.

Wind Erosion

The Wind Erosion Equation (WEQ) was the first empirical model to assess soil erosion by wind. It calculates potential average annual erosion rates (t ha -1 year) [61,62].

$$E = f(I, K, C, L, V) \qquad (1)$$

Where E is the potential annual soil loss, t / (ha·yr).

f is an indication that the equation includes functional relationships that are not straight-line mathematical calculations;

I is the soil erodibility, expressed as potential annual soil loss in (t /ha/yr) a wide, unsheltered isolated field with bare, smooth, level, loose and non-crusted surface where the climatic factor C is 100 such as Garden City, Kansas,

K is the surface roughness factor which is a measure of the effect of ridges made by tillage and planting devices, or other means of creating systematically spaced ridges which absorb and deflect wind energy and trap moving soil particles.

C is an index of climatic erosivity, specifically expressed by wind-speed and surface soil moisture. The factor for any given location is based on long-term climatic data and is expressed as a percentage of the C factor for Garden City, Kansas, which has been assigned a value of 100 [63];

L is the unsheltered (without protective vegetation cover) , weighted travel distance (in m) along the prevailing wind direction;

V is the equivalent vegetation cover expressed by relating the type, volume, and orientation of vegetation.

EF - Soil erodibility factor

The soil erodibility factor is related to the percentage of non-erodible surface soil aggregates larger than 0.84 mm in diameter [64]. Percentage content of sand, sludge, clay, organic matter (humus) and calcium carbonates should be determined in the study region. . The soil erodibility factor is calculated by the following equation [61]:

$$EF = 29.09+(0.315 \cdot S_A +0.17 \cdot S_i + 0.33 \cdot S_A / CL - 2.59 \cdot OM - 0.95 \cdot CaCO_3) / 100 \qquad (5)$$

where

EF	soil erodibility factor (fraction),
S_A	sand content (%),
Si	loamy content (%),
CL	clay content (%),
OM	organic substance content (%),
$CaCO_3$	calcium carbonate content (%).

K – Surface Roughness Factor

The roughness factor is a significant factor affecting wind dynamics. Surface roughness and soil erosion are negatively correlated, but surface roughness prevents air and sand particles from moving through the air stream.

V – Vegetation Cover Factor

Wind erosion is sensitive to surface vegetation cover because vegetation affects the near-surface wind velocity. Vegetation parameters such as height and foliage cover (leaf area) are therefore essential for assessing wind erosion. However, information on plant height and density is not always available. [65-66]. For the purpose of this research, we used remotely sensed Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI) data. The NDVI data were derived from MODIS satellite records of red and near-infrared radiation. LAI was defined by the following:

$$LAI = 2.745 \cdot NDVI - 0.201 \quad (8)$$

where LAI is the leaf area index, NDVI is the normalized difference vegetation index obtained from data sets for MODIS Terra Vegetation Indices.

C – Climatic Factor

Wind speed (V_z) and soil moisture (W) are taken into account. It is well known that transport of soil by wind is directly proportional to the third degree of wind speed and is inversely proportional to the square of soil moisture. Therefore, the local wind erosion climatic factor, based on the third degree correlation of mean wind speed at the altitude of the weather cock with the soil moisture squared, was chosen as an indicator of the complex impact on soil loss. Data on the mean yearly and monthly wind velocity are given in climatic data records, while soil moisture data are virtually unavailable.

PE is the precipitation-effectiveness index of Thornthwait [64].

$$PE = 0.316 \cdot \sum [Pi / (1.8 \cdot Ti + 22)]^{10/9} \quad (6)$$

where

Pi – monthly precipitation in mm;

Ti – average monthly air temperature, ^{0}C.

The climatic factor equation is expressed as:

$$C = 386 \cdot Vz^3 / (PE)^2 \quad (7)$$

where Vz the average annual wind velocity, m/s.

Forecasting of Wind Erosion in Gare Kakheti and Shiraki

Soil erodibility factor (EF) and erosivity factor (I, ton/ha/ yr) for Gare (Outer) Kakheti soils are listed in Table 4.3.5.9. Soil erodibility factor, which is determined by the granulometric composition of soils, humus, or organic matter, as well as CaCO3, is an index of soil erosion resistance. It is also noteworthy that calcium-rich soils are characterized by depletion, relatively less resistant to wind erosion.

Table 4.3.5.9: erodibility factor and erosivity factor for soils in Gare Kakheti and Shiraki

Soil	Depth, cm	Percentage					EF, %	I, t/ha
		Humus	Sand	Loam	Clay	$CaCO_3$		
Gray-cinnamon soil with calcareous earth, Gareji	0-10	3.1	26.9	38.4	31.6		68	74.3

Soil	Depth, cm	Percentage					EF, %	I, t/ha
		Humus	Sand	Loam	Clay	$CaCO_3$		
Gray-cinnamon soil with calcareous earth, Samgori	0-10	3	43.6	28.7	24.7		65	68.2
Humus-sulfate soil	0-10	0	43.6	29.9	26.5		60	57.0
Black earth with small depth humus	0-10	6.4	83.9	6.6	3.1		59	52.9
Red soil, Krtsanisi	0-13	0	10.8	45.3	43.9		57	49.7
Humus-carbonate soil	0-10	5	36.3	46	9.4	3.3	56	46
Light gray-brown soil, black field	0-10	1.9	17.2	42.1	38.8		54	41.7
Brown earth	0-10	3.3	70.1	8.4	5.7	12.5	52	37.2
Leached brown soil	0-12	0	35.7	32.9	31.4		46	21.7
Dark gray-brown soil, Udabno	0-10	4.2	24.4	36.8	34.5		40	7.6
Open steppe soil, red soil	0-10	1.3	32.1	29.5	27.3	9.7	39	6.0

C – Climatic Factor of Wind Erosion in Gare (Outer) Kakheti and Shiraki

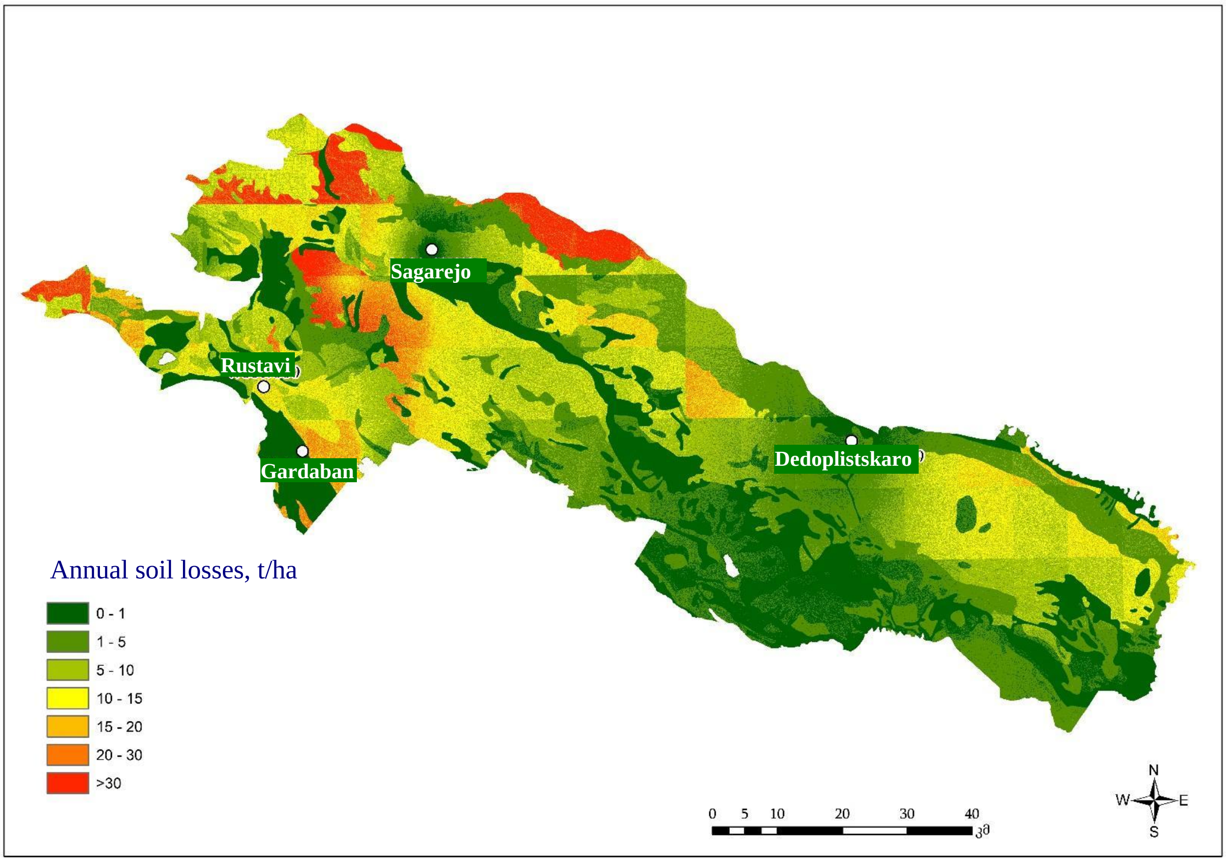
On the basis of the weather stations located in the study area, the values of the climatic factor of wind erosion and their yearly trends were calculated.

Table 4.3.5.10: Average Years-Long Values of Climatic Factor of Wind Erosion (C) in Gare (Outer) Kakheti and Shiraki

No	Weather station	Period	Average Years-Long Values of Climatic Factor
1	Airport, Tbilisi	1984 - 2004	25.76
2	Varketili	1961 - 1990	6.18
3	Udabno	1961-1990	4.54
4	Iormughanlo	1955-1958	3,78
5	Dedoplistskaro	1965 - 1994	0.58
6	Shiraki	1965-1992	0.51
7	Sagarejo	1961 - 1990	0.33

In accordance with the method of wind erosion prediction given above, a map of potential soil loss from wind erosion for Gare (Outer) Kakheti and Shiraki was drawn (Map 4.3.5.3).

The map shows that the outlines of the areas where average annual soil loss as a result of wind erosion is 5-30 tons or more per year are located in the western and northwestern part of the Region. The average annual soil loss from wind-driven erosion in the central and southeastern part of the Region is generally 0-5 t/ha per year, which reaches 10-20 t/ha within certain contours.



Map 4.3.5.3: Map of potential soil loss from wind erosion for Gare Kakheti and Shiraki

The research shows that in the study region, 14.3% of the total area is not degraded. On the territory of Shiraki and Dedoplistskaro, 4,392 hectares are moderately and heavily degraded erosion, which is 1.8% of Dedoplistskaro municipality area (Table 4.3.5.11). Particularly large areas were degraded to varying degrees in Gardabani Municipality, with 27,792 hectares of highly degraded land (3.9% of the municipality's total area) and 65,243 hectares of moderately degraded land (22.4% of the total area). Land degradation is also rather intense in the municipalities of Sagarejo and Gurjaani, where 51.1% (77,228 ha) and 45.9% (15,624 ha) of land, respectively, are moderately and heavily degraded. In total, 46.2% of the land in the study area is, on average, highly and very strongly degraded, amounting to 289,357 hectares. 39.5% (247,468 hectares) of the region's land is slightly degraded and 14.3% (89,804 hectares) is not degraded.

Table 4.3.5.11: Areas of lands degraded by wind erosion in Gare (Outer) Kakheti and Shiraki according to municipalities

Municipality	Total area, ha	Degradation level, ha/%									
		N/A	%	Slightly	%	moderately	%	highly	%	very strongly	%
Dedoplistskaro	247,805	48,997	19.8	131,131	52.9	63,285	25.5	4,044	1.7	348	0.1
Sagarejo	150,939	18,394	12.2	38,252	25.3	67,946	45.0	9,282	6.1	17,065	11.3
Sighnaghi	92,308	17,723	19.2	52,717	57.1	18,272	19.8	2,369	2.6	1,227	1.3
Gurjaani	34,025	2,348	6.9	9,166	26.9	13,977	41.1	1,647	4.8	6,890	20.2
Gardabani	101,552	2,345	2.3	16,202	16.0	55,213	54.4	10,030	9.9	17,762	17.5
Total in regions	626,629	89,804	14.3	247,468	39.5	218,693	34.9	27,372	4.4	43,292	6.9

Forecast of development of wind erosion in Gare (Outer) Kakheti and Shiraki due to the climate change

In Eastern Georgia, in the zone of high wind erosion (Outer Kakheti and Shiraki), by 2100, the average air temperature is expected to rise by 3.5 degrees in spring, by 4.0 degrees in summer and autumn, and by 3.4 degrees in winter.

Precipitation and consequently soil moisture reduce the possibility of wind erosion. Wind erosion processes in Outer Kakheti and Shiraki occur during winter and spring. By 2100, in the spring, the precipitation decrease in Outer Kakheti and Shiraki is projected to be 36-39%, which is quite significant (Outer Kakheti - 89 mm, Shiraki - 77 mm). Precipitation decrease is followed by drying of the soil, especially the top layer. Sweeping and erosion of dry soil requires less wind velocity. Since the climate change requires a considerable amount of time to change soil properties, therefore, we need to use analysis of a more mobile and variable parameter causing wind erosion, - climate factor (C) change analysis, in order to predict the development of wind erosion.

The wind erosion climatic factor (C) in the area of Tbilisi Airport from 2045 to 2100 has slightly downward trend . Minimum values of C factor were observed between 2061-2065 and 2091-2095 periods (4.0-4.8). The magnitude of the C factor from the period of 2095 to 2100 continues to rise sharply (C = 9.2).

As opposed to this, the trend of wind erosion climate factor (C) in the suburbs of Sagarejo is upward. The value of this factor will increase by 50% by the end of this century.

A similar tendency has been observed in the vicinity of Dedoplistskaro. The trend of wind erosion climatic factor (C) is also upward here, and will rise by 40% by the end of the century.

The study found that the wind erosion climate factor (C) is maximized in the vicinity of Varketili-Tbilisi airport. The above-mentioned factor is also characterized to areas that include the Vaziani-Sartichala area, the northwestern part of the Iori River upstream and the areas adjacent to Udabno. To the south-east of the Iori River, the value of the wind erosion climatic factor (C) decreases and does not even reach 1 unit, although the wind erosion in the area is rather widespread.

Therefore, against the background of climate change, by 2100, the manifestation of wind erosion, its strength and frequency, will definitely increase in Gare (Outer) Kakheti and Dedoplistskaro-Shiraki.

The Climate Change Adaptation Measures - Measures to combat soil water erosion

Maintaining the intensity and potential increase of water erosion under the climate change requires the introduction and implementation of appropriate adaptation measures. The technology implies a number of traditional methods of soil treatment and seeding to protect against water erosion:

- Contour ridging is the simplest but effective measure of erosion protection;
- Deep soil tillage results in increased water permeability of soil, which reduces surface runoff and consequently reduces soil washout;
- Deep stripping of soil is a very effective but energy-energy extensive measure. Therefore, such activities can be performed once every 2-3 years, alternating with normal tillage;
- Furrow tillage - Commonly used for growing on fall, autumn crops. Furrow slices can be 15 - 60 cm deep, distance between them reaching 100-150 cm;

- Arranging water catchment facilities. Conducting watershed research - In the areas of strong water erosion processes, in order to provide protection against soil erosion, the arrangement of water catchment or anti-erosion facilities in cross-contour slope direction is quite effective;
- Discrete soil treatment (plowing) - To regulate surface water flowing down the slope it is necessary to conduct discrete soil treatment. It is conducted for industrial or plowing crops during their cultivation;
- Cross-cut sowing of agricultural crops. At broken down (fragmented) complex slopes most effective is cross-cut sowing, when the first stripe is sown in the direction of slope inclination, and the second – along the contour
- Stripe sowing of crops. Plants sown in stripe are more resistant to soil erosion processes than usually sown plants;
- Arrangement of buffer stripe at plots under hoeing plants after harvesting the perennial and annual plants (winter wheat, rye, mix of cereals with leguminous plants)
- Stripe by turns disposition of crops is used for protecting soils from water and wind erosion. In case when the width of buffer stripes and the distance between stripes is equal, this represents another anti-erosion technology – the stripe disposition of plants and contour-stripe farming.
- Sowing of interim crops. In the foothill and mountain zones of Georgia, particularly in Western Georgia, after harvesting plants in autumn, interim crops are sown to protect the soil from erosion. In early spring the biomass of these crops is tilled down into the soil, and later on the major plant is sown at the plot.

Adaptation Measures for the Climate Change in the Wind Erosion Zone:

- Development of windbreaks is the most effective way to avoid the harm caused by the wind erosion. Construction of new windbreaks and rehabilitation of the existing degraded windbreaks shall be considered as the most necessary measure in this regard;
- Soil surface mulching after harvesting with crop residues is the most common and effective anti-wind erosion measures. Basic soil treatment by preserving the vegetation (crop residues) on the soil surface is a process of soil belts reclamation, as they are conducted with special tools;
- Chiseling: A chisel is a tool for reclaiming soil belts with incomplete cutting of the soil layer across the width of applying it. After chisel plowing, up to 60% of the weed seed were found on the soil surface. Chisel plowing by mixing the soil degree is better than flat-cut plowing, but is beyond the moldboard plow. Compared to other basic soil treatment techniques, its main advantage is the low energy consumption;
- In Western Europe, the “Paraplau” plow rippers with inclined rack are used for basic tillage return. One promising way to treat the soil is to reduce the impact on the soil - to reduce the number of its treatments by arranging operations. It is most commonly for soil treatment before and during sowing.

4.4 Glaciers

Glaciers are important climatic and economic resources of Georgia. They contain large amounts of freshwater and play a decisive role in water regime and regional climate forming.

It has been stated that glaciers are rapidly shrinking under the influence of modern climate change [67]. Glacial melting causes an increase in intensity and frequency of natural disasters of glacial and hydrological nature, sea-level rise and river run-off change [67].

Georgia's Second and Third National Communications to the UN Framework Convention on Climate Change analyze the climate change influence on glaciers, particularly those found in Zemo Svaneti and Kvemo Svaneti regions of Georgia. The papers explain that available information is incomplete, as complexity of glaciological research makes concurrent monitoring of all glaciers impossible; it is also noted that the certain findings are based on a number of assumptions.

The uncertainties found in the above communications can be reduced significantly if glaciological research is carried out with the help of satellite remote sensing (SRS).

Glacier Monitoring with Satellite Remote Sensing (SRS)

Following a large-scale glaciological research, conducted in 1960-1970 in the former Soviet Union, glaciers of Georgia were catalogued and systematized as part of the Caucasian glacier system [68].

After the collapse of the Soviet Union, permanent and field glaciological monitoring has stopped in Georgia, and over recent years, occasional observations have been conducted. In order to give a science-based response to glacier melting caused by the climate change, it is necessary to use a high-resolution SRS for two reasons. First, currently it is impossible to carry out the costly ground observations at a necessary scale; and second, in resource- and time-constrained environment, SRS allows conducting simultaneous glacier monitoring on large areas with the required resolution and accuracy in conditions of limited resources and restricted time.

SRS has made it possible to identify the main characteristics of glaciers in Georgia: maximum length, area, minimum and maximum heights, firn line altitude, ablation and accumulation areas. This has been achieved through the integral use of available historical data, schematic illustration of glaciers archived in the above glacier catalogue [68], field research findings and expert knowledge [69-73]. It should be noted that this approach involves the SRS data quality assessment and quality assurance (QA/QC) procedures.

It utilizes high-definition (15-30 m) SRS images, particularly Landsat data, and 15 m definition satellite data from the National Aeronautics and Space Administration (NASA) and Global Land Ice Measurements from Space (GLIMS).

Satellite data are processed with the help of various GIS software, including the most effective Google Earth program providing high-definition (0.5−0.8 m) satellite images that allow identifying glacier contours with a high precision.

The Climate Change Impact on the Glaciers of Georgia

The modern climate change has a significant negative impact on glaciers, causing their rapid degradation, which is evident from the change of glacial basin characteristics (glacier number and area), melting of small glaciers with the area of 0.1 - 0.5 km^2, and retreat of big glaciers with the area exceeding 2 km^2. These are effective indicators of the regional climate change.

The climate change impact on glacial basins in general and small glaciers in particular can be measured by comparing glacial basin contours and areas, established with help of SRS in 2012-2016, with data of the same basins contained in the glacier catalogue. The almost 50-year difference between the SRS and the catalogue data allows to provide an effective assessment of changes in glacial basins.

Certain small and medium-sized glaciers in the satellite pictures can only be identified with the help of schematic illustrations given in the catalogue. Glacier identification was followed by defining areas and quantity of all glaciers within the glacial basins. It became obvious that in some cases areas established by SRS exceeded corresponding areas featured in the catalogue, which could mean that areas of those glaciers have increased despite the global warming, or, which is more likely, the catalogue data were inaccurate.

In order to clarify the situation, glacier areas identified based on the SRS data were compared to areas of the same glaciers reflected on topographic maps of the former Georgian SSR. The inaccurate data were recorded in relation to 108 glaciers located in Western Georgia (26.4% of all glaciers found in Western Georgia according to the catalogue), including 39 small glaciers, and 7 glaciers located in Eastern Georgia (5.3% of glaciers found in Eastern Georgia according to the catalogue), including 5 small glaciers. Areas of all these glaciers according to the SRS data were smaller than that featured on the topographic maps. Hence, map data were accepted for the research purposes instead of the catalogue data, and they clearly prove the degradation of the glaciers under the influence of the global warming.

There are 12 glacial basins in Georgia: 6 in each western and eastern parts of the country. The number of glaciers in glacial basins in Western and Eastern Georgia, their areas and distribution by river basins according to the catalogue and the current SRS data are given in Table 4.4.1 below.

According to the catalogue, there were 409 glaciers in the glacial basins in Western Georgia, covering the area of 456.1 km^2. Based on the current SRS data, there are 323 glaciers (79% of the number specified in the catalogue) covering the area of 331.2 km (72.6% of the area specified in the catalogue) in Western Georgia.

According to the catalogue, there were 132 glaciers in the glacial basins in Eastern Georgia, covering the 86.9 km^2. According to the current SRS data, the number of glaciers is 60 (45.5% of the number specified in the catalogue) and their area has shrunk to 45.8 km^2 (52.7% of the area specified in the catalogue).

Table 4.4.1: Glacier distribution by basins

Western Georgia							Eastern Georgia						
Glacial basins	Number of glaciers			Glacier area (km^2)			Glacial basins	Number of glaciers			Glacier area (km^2)		
	Cat.	SRS	Δ	Cat.	SRS	Δ		Cat.	SRS	Δ	Cat.	SRS	Δ
Bzipi	13	9	4	7.1	3.2	3.9	Liakhvi	22	4	18	6.6	1.6	5
Kelasuri	3	1	2	1.5	0.7	0.8	Aragvi	5	1	4	1.6	0.3	1.3
Kodori	120	91	29	68.5	39	29.5	Tergi	68	35	33	67.5	39.5	28
Enguri	194	153	41	305.2	236.4	68.8	Asa	3	3	0	1.4	1	0.4
Khobistskali	3	1	2	0.4	0.1	0.3	Arguni	6	1	5	1.0	0.1	0.9
Rioni	76	68	8	73.4	51.8	21.6	Pirikita Alazani	28	16	12	8.8	3.3	5.5
Total	409	323	86	456.1	331.2	124.9	Total	132	60	72	86.9	45.8	41.1

Hence, under the influence of the global warming, the number and area of glaciers by river basins has reduced and the reduction has been more significant in Eastern Georgia than in the western part of the country.

Melting of small glaciers has been estimated based on the abovementioned methods that included identifying small glaciers on the SRS images, establishing their areas and correcting the inaccurate catalogue data concerning 39 small glaciers (16.5% of glaciers in the catalogue) in Western Georgia and 5 small glaciers (4.8% of glaciers specified in the catalogue) in Eastern Georgia. It should be noted that comparison of contours of small glaciers determined with help of SRS to those featured on the soviet topographic maps allowed validating and visualizing of the current state of each small glacier and snowfield. That is, it allowed to identify whether the size of a small glacier remained unchanged, melted and turned into a snowfield or completely disappeared during the 50-year period.

This approach has allowed establishing historic and current data on small glacier distribution by river basins (Table 4.4.2).

According to the catalogue, there were 236 small glaciers in Western Georgia. SRS helped to establish that a number of small glaciers featured on the topographic maps have disappeared. According to SRS, there are 102 small glaciers (43.2% of small glaciers that used to exist) left in Western Georgia, while 134 small glaciers have either shrunk and/or turned into snowfields, or completely melted.

According to the Soviet catalogue, there used to be 104 small glaciers in Eastern Georgia (Table 4.4.2). Now, under the influence of the global warming, the number has decreased to 31 (29.8% of small glaciers that used to exist), while the rest 73 glaciers have either turned into snowfields or completely melted.

Table 4.4.2: Number of small glaciers according to the catalogue and SRS

№	Western Georgia				Eastern Georgia			
	Catalogue Data	SRS data			Catalogue Data	SRS data		
		Small glaciers	Snowfields	Extinct Glaciers		Small glaciers	Snowfields	Extinct glaciers
1	38	20	37	0	13	10	5	0
2	52	25	57	2	2	2	0	0
3	55	17	90	1	12	3	6	3
4	11	5	13	1	24	2	9	13
5	14	5	10	2	47	13	30	11
6	8	4	5	1	6	1	10	0
7	14	5	24	1	-	-	-	-
8	8	2	20	3	-	-	-	-
9	5	2	7	2	-	-	-	-
10	12	5	9	1	-	-	-	-
11	16	12	8	0	-	-	-	-
12	3	0	4	1	-	-	-	-
Total	236	102	284	15	104	31	60	27

Consequently, it has been established that the number and area of small glaciers in Western and Eastern Georgia have decreased. Melting of small glaciers is more intensive in Eastern Georgia compared to the western part.

Retreat dynamics of large glaciers are measured by determining terminus retreat rate based on the SRS data. In order to find the simple solution, the glaciers, with termini free from debris have been selected for the research purposes. Field research findings for the Gergeti (Tergi basin, Eastern Georgia) and Adishi (Enguri basin, Western Georgia) glaciers, stored at the National Environmental Agency have been used for assuring quality of SRS-based measurements of termini retreat rates. Table 4.4.3 shows characteristics of these glaciers based on SRS and the catalogue.

The maximum length of the Gergeti glacier is 7.1 km according to SRS, and 8.5 km according to the catalogue, meaning that over the last 50 years the glacier has shortened by 1,400 m or 28 m per year. The length of the Adishi glacier has decreased by 16 m.

Table 4.4.3: Characteristics of the Gergeti and Adishi Glaciers

Glaciers	Characteristics											
	Length (km)		Area		Height						Ablation area (km^2)	
					Minimum		Maximum		Firn line			
	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.
Gergeti	7.1	8.5	5.2	8.3	3,091	2,870	4,936	5,030	3,771	3,650	1.5	2.3
Adishi	7.1	7.9	9.3	9.9	2,400	2,310	4,931	4,000	3,475	3,430	–	–

The method for measuring termini retreat rates for large glaciers is given in [71]. The method uses various Landsat sensing data; however, the results strongly depend on the data processing level. Data acquisition date and cloud amount are taken into consideration, although in some cases images with rather high cloud amount can also be representative.

Figure 4.4.1 features SRS-based schematic illustration of the retreat of the Gergeti and Adishi Glaciers. Glacier locations in various years are contoured in different colours. Glacier retreat distances have been calculated by drawing a white curve across the contours of the Gergeti and Adishi Glaciers against the satellite images dated by August 15, 2015 and August 24, 2016 respectively.

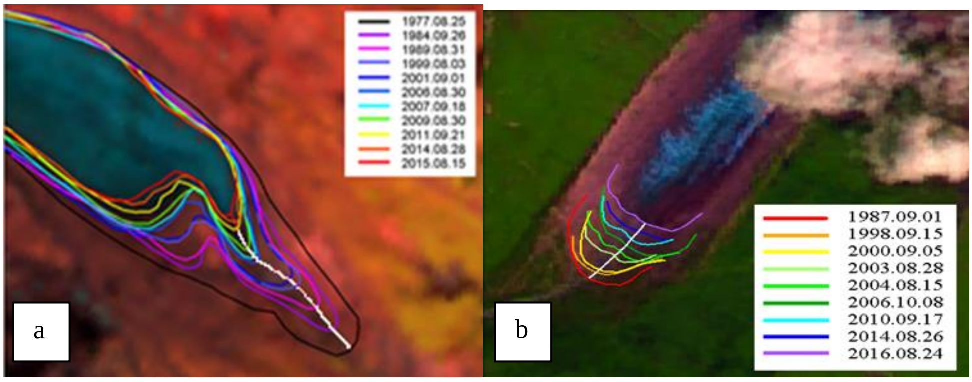


Figure 4.4.1: Schematic illustrations of retreat of the Gergeti (a) and Adishi (b) glaciers

Table 4.4.4 shows the SRS-based data on Gergeti Glacier's retreat characteristics by dates. Figure 4.4.2 (a) shows the Gergeti Glacier retreat diagram. The start point on the x-axis corresponds to the year 1977. The y-axis shows glacier retreat distances. In order to better demonstrate the climate change impact on the Gergeti Glacier, the observation period (1977-2015) has been divided into two sub-periods: 1977-2001 and 2001-2015. Figure 2(b) shows the corresponding trends.

Table 4.4.4: Gergeti Glacier terminus retreat location and distances

No	Date	The retreat from the previous benchmark, m	The total retreat, m
1	8/25/1977	0	0
2	9/26/1984	106	106
3	8/31/1989	111	217
4	8/3/1999	122	339
5	9/1/2001	40.6	379.6
6	8/30/2006	152	531.6
7	9/18/2007	25.4	557
8	8/30/2009	38.2	595.2
9	9/21/2011	94.9	690.1
10	8/28/2014	31.7	721.8
11	8/15/2015	34.4	756.2

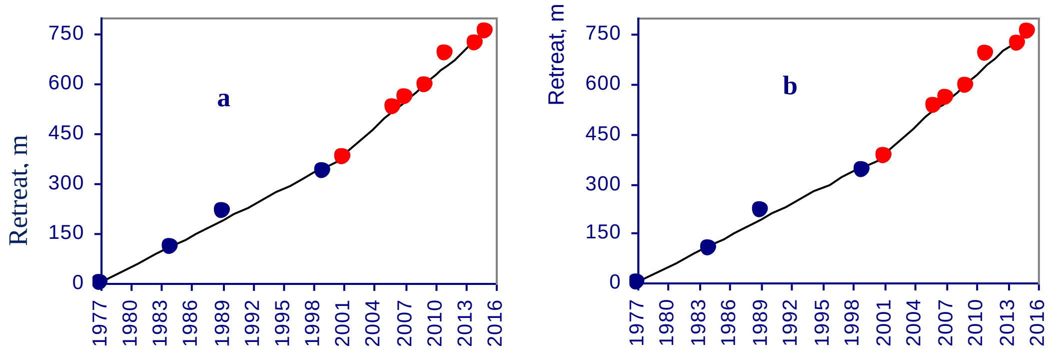


Figure 4.4.2: Gergeti Glacier retreat dynamics according to the SRS data

Data analysis shows that the retreat rate of the Gergeti Glacier during the entire period was 19.7 m/year, during the first sub-period – 15.1 m/year, and during the second sub-period – 26.7 m/year. The data for the two sub-periods show that the glacier retreat in general is of a nonlinear nature and that in the second sub-period the retreat rate significantly exceeded the trend typical for the entire period, which points to an increased impact of the regional climate change on the glacier.

Data received during ground observations of the Gergeti Glacier retreat (Table 4.4.5) are used for assuring the quality of the SRS-based retreat data.

Table 4.4.5: Gergeti Glacier terminus retreat based on field data

No	Date	Retreat from the previous benchmark, m	Total retreat, m
1	1978	0	0
2	1990	79	79
3	2000	174	253
4	2011	400	653
5	2013	65	718

The data have been used for establishing the Gergeti Glacier retreat dynamics. The observation period of 1978-2013 has been again divided into two sub-periods: 1978-2000 and 2000-2013 to make the data more informative.

Data analysis shows that Gergeti Glacier retreat rate during the entire period was approximately 21.4 m/year according to the ground observations; retreat rate in the first sub-period was 11.3 m/year, while in the second period – 35.9 m/year.

The difference between the field data and the SRS data for the entire period is approximately 1.7 m/year, for the first sub-period - 3.8 m/year, and for the second sub-period - 9.2 m/year. This shows that the SRS and field data comply with each other, and the slight divergence between the results can be explained with the difference in the benchmark calculations and observation periods.

The Stepantsminda Weather Station is located at the height of 1750 m close to the Gergeti Glacier. Table 4.4.6 shows average summer temperature values (Tmean) for two sub-periods based on the station data and difference between the two sub-periods (ΔTmean). In all three months, an increase in temperature is evident, with average summer increase being 1.1^{0}C.

These data prove that the rapid degradation of the Gergeti Glacier is caused by the modern climate change. The glacier retreat data *per se* are effective indicators of the climate change and its acceleration in the course of time.

Table 4.4.6: Average air temperature values according to the Stepantsminda Weather Station

Period	June	July	August	Summer
Tmean1977–2000, ^{0}C	11.9	14.7	14.3	13.6
Tmean 2001–2015, ^{0}C	13.1	15.2	15.7	14.7
ΔTmean, ^{0}C	1.2	0.5	1.4	1.1

These data prove that the rapid degradation of the Gergeti Glacier is caused by the modern climate change. The glacier retreat data *per se* are effective indicators of climate change and its acceleration in the course of time.

The satellite images of the Adishi Glacier dated by 1987-2016 (Fig. 4.4.1b) helped to determine the glacier terminus locations, draw its retreat chart for the entire 30-year period and two sub-periods (1987-2001 and 2001-2016) for detailed analysis of the climate change impact.

Analysis of these data shows that the Adishi Glacier retreat rate during the entire period was approximately 16.1 m/year; during the first sub-period - 7.5 m/year, and during the second sub-period - 18.9 m/year. The data for the two sub-periods show that the glacier retreat in general is of a nonlinear nature and that in the second sub-period the retreat rate significantly exceeded the trend typical for the entire period.

Data received during ground observations of the Adishi Glacier retreat in 1985-2012 were used for assuring the quality of SRS-based retreat data. The data helped to determine the glacier retreat dynamics, while the 28-year period of field observations has been divided into two sub-periods (1985-20001 and 2001-2012) to make the data more informative.

Analysis of these data shows that the Adishi Glacier retreat rate during the entire period was approximately 12.6 m/year, during the first sub-period - 11.6 m/year, during the second period - 15.6 m/year.

The difference between the field and SRS data for the entire period is approximately 2.5 m/year, for the first sub-period - 4.1 m/year, and for the second sub-period - 3.3 m/year. This shows that the SRS and field data comply with each other, and the slight divergence between the results can be explained with the difference in the benchmark calculations and observation periods.

The Mestia Weather Station is located at the height of 1500 m close to the Adishi Glacier. Table 4.4.7 shows average summer temperature values for the two sub-periods and the difference between the two sub-periods based on the station data. In all three months, an increase in temperature is evident, with average summer temperature increase being 0.6^{0}C. These data prove the assumption that the rapid degradation of the Adishi Glacier is caused by the modern climate change. The glacier retreat data *per se* are effective indicators of the climate change and its acceleration in the course of time.

Table 4.4.7: Average air temperature values according to the Mestia Weather Station

Period	June	July	August	Summer
Tmean1987–2001, ^{0}C	13.7	17.5	16.7	16.0
Tmean 2001–2016, ^{0}C	14.5	17.6	17.5	16.6
ΔTmean, ^{0}C	0.8	0.1	0.8	0.6

The research additionally studied two glaciers in Western Georgia – Kvishi (Enguri basin) and Boko (Rioni basin). Table 4.4.8 shows their characteristics based on the SRS and catalogue data.

Table 4.4.8: Characteristics of the Boko and Kvishi Glaciers

Glacier	Characteristics											
	Length (km)		Area		Height						Ablation area (km^2)	
					Minimum		Maximum		Firn line			
	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.	SRS	Cat.
Kvishi	5.8	6.1	7.2	8.4	2,862	2,460	4,395	4,090	3,441	3,240	3.3	2.7
Boko	4.2	4.5	3.7	4.6	2,616	2,450	3,996	3,900	3,463	3,380	0.8	1.6

The maximum length of the Kvishi Glacier is 5.8 km according to the SRS data and 6.1 km based on the catalogue, meaning that over the last 50 years the glacier has shrunk by 300 m or 6 m per year. Average annual retreat of the Boko Glacier, calculated in a similar way, is also 6 m.

Figure 4.4.3 features SRS-based schematic illustration of the retreat of the Kvishi (1987-2016) and Boko (1977-2015) Glaciers. Glacier locations in various years are contoured in different colors. Similarly to the Gergeti and Adishi Glaciers, retreat distances of the Boko and Kvishi Glaciers have been calculated by drawing a white curve across their contours against the satellite images dated September 7, 2015 and September 9, 2016 respectively.

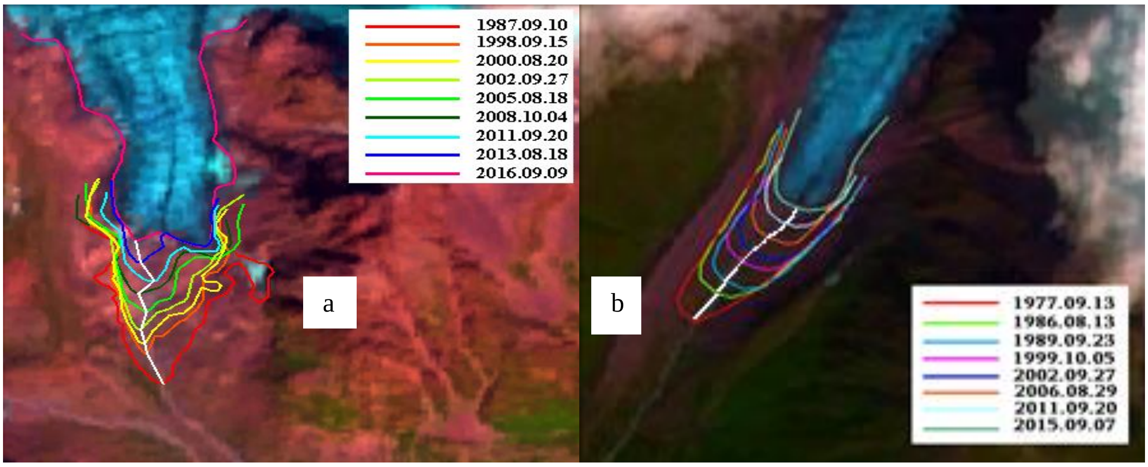


Figure 4.4.3: Schematic illustration of the retreat of the Kvishi (a) and Boko (b) Glaciers

Retreat diagrams have been drawn: for the Kvishi Glacier - for the entire period of 1987-2016 and two sub-periods of 1987-2000 and 2000-2016 to provide detailed description of the climate change impact; and for the Boko Glacier - for the entire period of 1977-2015 and two sub-periods of 1987-2001 and 2001-2015 to provide detailed description of climate change impact.

The Kvishi glacier data analysis shows that its retreat rate during the entire period was approximately 22.1 m/year, during the first sub-period - 13.5 m/year, and during the second sub-period - 28.3 m/year. The Boko data analysis shows that its retreat rate during the entire period was approximately 15.5 m/year, during the first period - 13.6 m/year, and during the second period - 18.8 m/year.

The retreat of the two glaciers is nonlinear and in the second sub-period its rate significantly exceeds the trend typical for the entire period.

The above findings show that the retreat of large glaciers has accelerated during the second period in both Western and Eastern Georgia. However, glacier degradation process is more intensive in Eastern Georgia, which is due to the climatic difference between the two parts of the country.

Possible Impact of Anticipated Climate Change on Ultimate Melting of Glaciers in Georgia

The retreat of large glaciers in Georgia is of a nonlinear nature. Data analysis shows that the retreat of such glaciers can be with high precision described using a second-degree curve (parable). By extrapolating the curve, i.e. by assuming that the melting rate remains unchanged, it is possible to establish the date by which a glacier will ultimately melt.

Table 4.4.9 shows indices for determining possible ultimate melting of glaciers.

According to the given assumptions, the Gergeti Glacier will disappear in 2140, Adishi in 2146, Kvishi in 2094 and Boko in 2175.

Table 4.4.9: Indices of possible ultimate melting of large glaciers

Glacier	Observation start year	Ultimate melting length, m	Last year of SRS observations	Length in the last year, m	Ultimate melting year
Gergeti	1977	7,856	2015	7,100	2140
Adishi	1987	7,537	2016	7,100	2146
Kvishi	1987	6,439	2016	5,800	2094
Boko	1977	4,839	2015	4,200	2175

It is quite natural that small and medium-sized glaciers will not exist by the time large glaciers become extinct.

Conclusions

A number of conclusions can be drawn regarding the climate change impact on the glaciers of Georgia, in particular:

1. The comparison of the SRS data with the topographic maps dated 1960-1970 shows that over the last 50 years the area of all glaciers in Georgia has shrunk;
2. The 50-year time difference between the SRS and catalogue data allows to assess changes in glacial basins and small glacier melting;
3. Calculations conducted for the glacial basins show that the area and number of glaciers have decreased and that this process is more intensive in eastern regions than in Western Georgia;
4. Small glacier melting analysis shows that melting goes intensively under the impact of the climate change and that in Eastern Georgia this process is more intensive than in the western regions;
5. The retreat dynamics and trends of large glaciers have been quantitatively analyzed for the period of 40-50 years. The detailed analysis shows that all large glaciers are retreating in both Eastern and Western Georgia;
6. Analysis of glacier retreat trends based on the SRS and field data shows data compliance, therefore we can make reasonable assumptions that SRS-based quantitative characteristics of the retreat of large glaciers are valid and reliable;
7. The analysis of the two observation sub-periods shows that during the second sub-period the retreat of large glaciers has accelerated in both Eastern and Western Georgia, while degradation of large glaciers is more active in Eastern Georgia compared to the western part of the country;
8. Glacier degradation process in Eastern Georgia is more intensive than in Western Georgia, which is true both for glacial basins as well as for large and small glaciers. This can be explained by the climatic differences - the continental climate in Eastern Georgia and marine humid climate in Western Georgia;

9. One of the climate change scenarios determines tentative dates for possible ultimate melting of large glaciers.

4.5 Water resources

Georgia is rich in water resources, including rivers, lakes, reservoirs, glaciers and groundwater. Rivers are the most numerous water bodies: there are 26,060 rivers with the total length of 60,000 km of which 99.4% (25,075 rivers) are less than 25 km in length and their total length is about 55,000 km. The average annual runoff of Georgian rivers is about 61.45 km^3, including local runoff of 52.77 km^3 and transit runoff (originating in Turkey and Armenia) of 8.68 km^3.

Georgian rivers feed on rainwater, groundwater, snow and glacier meltwater, and originate in wetlands, marshlands, glaciers and perennial snows. According to types of inflow, the country is divided into four major hydrological districts: I. the upper reaches of the Kodori-Enguri with glacial inflow and spring runoff making 25% of the annual runoff; II. the Black Sea and Alazani districts with mixed (glacial and snowmelt) inflow and spring runoff making 26-50% of the annual runoff; III. the Mtkvari-Iori district with mixed inflow and spring runoff making 51-75% of the annual runoff; and IV. the underground and lake inflow district (rivers feed on snow and groundwater), where 26-50% of the annual runoff falls on spring. Groundwater contributes to river forming in all the districts.

Georgia's river network comprises the Black Sea and the Caspian Sea basins with 18,109 (70%) and 7,951 (30%) rivers in each. The Black Sea Basin is much richer in water resources than the Caspian one, producing approximately 75% of the total inland renewable surface water in Georgia, which is 42.5 km^3/year, with the Caspian Sea Basin producing 14.4 km^3/year. Likhi and Meskheti (Adjara-Imereti) ridges are the watershed of the basin. The mountainous terrain and abundancy of precipitation, especially in the western part of the country, determine the density of the river network. Due to the dry climate and low terrain in the eastern part of the country, the river network is relatively sparse, while to the west of the Likhi Ridge its density increases dramatically and reaches 3.0-3.5 km/km^2 in the northwest and southwest parts of the Black Sea coast. River lengths and catchment areas also vary. Thus, in the northwest part of the Greater Caucasus (Abkhazia) rivers do not exceed 100 km in length. The Black Sea Basin rivers, originating on the Meskheti Ridge to the south of the Rioni are also rather small of size. .. In the central part of the Greater Caucasus Mountains, located far from the sea coast, catchment areas increase and river lengths exceed 300 km (Bzipi, Kodori, Enguri, Rioni).

The Kolkheti Lowland in Western Georgia is rich in small strongly meandering slow moving rivers originating in the foothills. They cross the lowland and flow into the Black Sea. The most abundant rivers in Western Georgia are Bzipi, Kodori, Enguri, Tskhenistskali and Rioni that feed from perennial snow and glaciers of the Greater Caucasus. Some of them are transboundary like the Chorokhi that originates in Turkey; the Psou originates on the Georgian-Russian border.

The Kura (Mtkvari) is the largest river in the South Caucasus that originates in Turkey, crosses Eastern Georgia to Azerbaijan and flows into the Caspian Sea. The total length of the river is 1384 km of which 351 km goes through the territory of Georgia. Other important rivers to the east of the Likhi Ridge are: Didi Liakhvi, Aragvi, Iori, Alazani, Paravani, Ktsia-Khrami, and Debeda.

The main rivers of Georgia are listed in Table 4.5.1. The figures in brackets show lengths and catchment areas of the rivers on the territory of Georgia.

Table 4.5.1: Main rivers of Georgia

Western Georgia			Eastern Georgia		
River	Length km	Catchment area, km^2	River	Length Km	Catchment area, km^2
Psou	53	426	Tergi	623 (71)	43,200 (778)
Bzipi	115	1,502	Mtkvari	1,515 (351)	188,000 (19,050)
Enguri	221	4,062	Didi Liakhvi	115	2,311
Tskhenistskali	183	2,122	Ksani	91	885
Rioni	327	13,418	Aragvi	112	2,724
Kodori	84	2,030	Ktsia-Khrami	201	8,340 (4,600)
Ajaristskali	90	1,540	Iori	320 (183)	4,650 (4,190)
Chorokhi	438 (26)	22,132 (1,600)	Alazani	390 (385)	10,800 (5,943)

There are 541 glaciers in Georgia with the total area of 543km^2; they contain ice with the volume of about 30 billion m^3, of which 1.5 billion m^3 or 5% participate in the annual water circulation, while the rest are constantly changing centuries-old ice reserves. Glaciers are mainly accumulated in Western Georgia (67.3% of total number and 81.2% of total area).

Most glaciers are small, each less than 1 km^2. The nine glaciers larger than 10 km^2 are: Chalaati (12.1 km^2), Lekhziri (35.0 km^2), Tviberi (24.7 km^2), Kvitlodi (12.1 km^2), Tsaneri (28.9 km^2), Khalde (10.5 km^2), Adishi (10.2 km^2), Kvishi (19.3 km^2) and Suatisi (11.1 km^2). Characteristics of glaciers by river basins are given in Table 4.5.2.

Table 4.5.2: Characteristics of glaciers by river basins

River	Number	Area, km^2	Firn edge, m		Ice volume, km^3
			Lower	Upper	
Bzipi	13	7.1	2,600	3,030	0.185
Kelasuri	3	1.5	2,737	3,043	0.030
Kodori	120	68.5	2,760	3,160	1.554
Enguri	194	305.2	2,980	3,420	22.462
Khobi	3	0.4	2,435	3,030	0.037
Rioni	76	73.4	2,970	3,500	2.161
Didi Liakhvi	22	6.6	3,030	3,270	0.128
Aragvi	5	1.6	3,195	3,420	0.028
Tergi	68	67.5	3,346	3,834	3.336
Asa	3	1.4	3,212	3,212	0.073
Arguni	6	1.0	3,595	3,676	0.016
Pirikita Alazani	28	8.8	3,339	3,658	0.115

Glacier ice reserves partially melt in summer, forming the river runoff. Table 4.5.3 shows data on glacier basin runoff during the ice melting period (June-November), obtained by means of empirical formulas considering the glacier area, average air temperature at the height of the firn line, and the correlation between the terminus area and total area of the glacier.

Table 4.5.3: Glacier runoff from the main glacial basins of Georgia

River	Area, km^2	Firn line height, m	Air temperature at the firn line height, m		Glacier runoff, km^3	
					m^3/s	km^3
Bzipi	7.1	2790	2,600	3,030	3.47	0.036
Kelasuri	1.5	2800	2,737	3,043	0.63	0.007
Kodori	68.5	2930	2,760	3,160	23.0	0.242
Enguri	305.2	3240	2,980	3,420	81.5	0.856

River	Area, km^2	Firn line height, m	Air temperature at the firn line height, m		Glacier runoff, km^3	
					m^3/s	km^3
Khobi	0.4	2550	2,435	3,030	0.77	0.008
Rioni	73.4	3270	2,970	3,500	17.5	0.184
Didi Liakhvi	6.6	3270	3,030	3,270	17.6	0.019
Aragvi	1.6	3420	3,195	3,420	0.35	0.004
Tergi	67.5	3415	3,346	3,834	10.7	0,113
Asa	1.4	3490	3,212	3,212	7.1	0.007
Arguni	1.0	3570	3,595	3,676	3.3	0.004
Pirikita Alazani	8.8	3562	3,339	3,658	11.6	0.019
Total	511.12				42.6	1.498

There are about 860 lakes in Georgia, most of them smaller than 0.1 km^2. The total area of all lakes is approximately 170 km^2. Most of them are freshwater. The main lakes of Georgia (by water reserves) are listed in Table 4.5.4. Tabatskuri, Paravani, Kartsakhi and Keli are groundwater inflow lakes. Ritsa, Khanchali, Sagamo and Madatapa are river inflow lakes, while Paliastomi is fed by precipitation and wetlands. Lake Bazaleti is a closed basin with no inflowing rivers, so it is only fed by precipitation and groundwater. The lake water is suitable for drinking, its mineralization not exceeding 500-700 mg/l in all seasons. Exceptions are the lakes in the Mtkvari-Alazani Basin, where mineralization reaches 2000-2500 mg/l in several seasons.

Table 4.5.4: Main lakes of Georgia

Lake	Meters above sea level	Area, km^2	Basin area, km^2	Maximum depth, m	Average depth, m	Volume, mln m^3
Tabatskuri	1991	14.2	83.1	40.2	15.5	220.1
Ritsa	884	1.49	155	101	63.1	94.0
Paravani	2073	37.5	234	3.3	2.42	90.8
Paliastomi	-0.3	18.2	547	3.2	2.6	47.3
Keli	2914	1.28	7.56	63	27.8	35.6
Kartsakhi	1799	26.3	158	1	0.73	19.2
Amtkeli	512	0.58	153	65	29.6	17.2
Sagamo	1996	4.81	528	2.3	1.6	7.7
Khanchali	1928	13.3	176	0.8	0.48	6.4
Bazaleti	878	1.22	14.4	7	4.5	5.5

There are **43 artificial water reservoirs** in Georgia, of which 35 with a total volume of 1,700 million m^3 are located in the Caspian Sea Basin, while 8 with a total volume of 1,470 million m^3 are in the Black Sea Basin. The total volume of the reservoirs makes 5.1% of the annual river runoff in Georgia.

Twelve large reservoirs with a total volume of 2.4 km^3 and total surface area of 107 km^2 are used for power generation. The Jvari Reservoir with a total volume of 1.092 km^3 and surface area of 13.5 km^2 is the largest reservoir in Georgia. Thirty reservoirs in Eastern Georgia with a total volume of 1 km^3 are used for irrigation purposes. The main reservoirs of Western and Eastern Georgia are listed in Tables 4.5.5 and 4.5.6, respectively.

Table 4.5.5: Main reservoirs of Western Georgia

Reservoir	River	Volume, mln m3		S, surface area, km^2	Depth, m		Function
		T, total	P, power storage		T / S	P / S	
Jvari	Enguri	1,092	662	13.5	80.9	49	Power generation
Shaori	Shaora	71	68	13.2	5.4	5.2	

Reservoir	River	Volume, mln m3		S, surface area, km^2	Depth, m		Function
		T, total	P, power storage		T / S	P / S	
Tkibuli	Tkibuli	84	62	11.5	7.3	5.4	
Gali	Eristskali	145	26	8	18.1	3.3	
Lajanuri	Lajanuri, Tskhenistskali	12	16	1.6	7.5	10	
Gumati	Rioni	39	13	2.4	16.3	5.4	
Vartsikhe	Rioni, Kvirila	14.6	2.4	5.1	2.9	0.5	

Table 4.5.6: Main reservoirs of Eastern Georgia

Reservoir	River	Volume, mln m3		S, surface area, km^2	Depth, m		Function
		T, total	P, power storage		T / S	P / S	
Zhinvali	Aragvi	520	370	11.5	45.2	32.2	
Sioni	Iori	325	300	14.4	22.6	20.8	
Tsalka	Ktsia-Khrami	312	292	34	9.2	8.6	Multipurpose
Tbilisi	Iori	308	155	11.8	26.1	13.1	
Dalismta	Iori	140	120				
Algeti	Algeti	65	60	2.3	28.3	26.1	
Zonkari	Patara Liakhvi	40	39	1.4	28.6	27.9	
Jandari	Mtkvari	52	23	12.5	4.2	1.8	
Nadarbazevi	Didi Liakhvi	8.2	7.2	2	4.1	3.6	
Narekvavi	Narekvavi	6.8	5.6	0.56	12.1	10	Irrigation
Pantiani	Mashavera	5.4	5.3	0.6	8.6	8.5	
Kumisi	Mtkvari	11	4	5.4	2	0.7	
Kudigori	Duruji	3.5	3.5	3	1.2	1.2	
Zahesi	Mtkvari	12	3	2	6	1.5	Power generation

Most of the **marshes and wetlands** are located in the Kolkheti Lowland. Small marshes are also common in the volcanic mountains of Javakheti and other regions of Georgia. The wetlands of Kolkheti cover 627 km^2. In the recent past, wetland area was much larger, but shrank drastically over years as a result of intensive reclamation. Certain characteristics of the main marshes and wetlands of the Kolkheti Lowland are given in Table 4.5.7.

Table 4.5.7: Main marshes and wetlands of the Kolkheti Lowland

Name	Location	Meters above sea level	Area, km^2	Average depth, m
Pichori-Paliastomi	Pichori River floodplain	0.5-1.8	191	8
Chaladidi-Poti	Between the Rioni and Khobi rivers	12.5	144	1.5
Eristskali II	Between the Okumi and Gagida rivers	0.5-1.8	117	1
Churia	Between the Enguri and Khobi rivers	3	90	0.8
Nakargali	At the confluence of the Enguri	4	21	1.5
Ispani I and Ispani II	The Chorokhi and Ochkhamuri river basin	1.5	19	2
Eristskali I	Between the river bank and the dunes	1.5	15	1
Natanebi-Supsa	Between the Natanebi and Supsa rivers	0.5-1.5	15	7
Pichori-Kvishona	Between the Isareta and Gagida rivers	4	13.2	2
Torsa	River floodplain	80.5	9	1

Water Use

At present, there are no risk for potential conflicts caused by water deficit between water consuming sectors thanks to the abundance of surface water resources in Georgia. However, pressure on water resources will increase, and meeting water demand may become problematic in the context of the expected climate change, considering the economic development, improvement of water supply systems and planned expansion of the irrigation and hydropower sectors.

The hydropower sector is the biggest water consumer in Georgia (92%). Although water used by HPPs returns to the rivers, in the case of diversion HPPs some river sections may experience water shortage, which means that in certain cases environmental costs should still be considered. In Georgia, drinking water supply is a priority and a large portion of the population has access to high-quality drinking water, however, some areas, especially rural settlements , still have no steady supply of safe drinking water. Tbilisi population consumes about 71% of drinking water. The share of surface water used in water supply system is about 0.6%; average water losses make up 66% of the total volume of supplied water. The irrigation sector consumes 5.7% of the total amount of consumed water, but the consumption is expected to increase after the planned rehabilitation of the irrigation system. The industrial sector consumes less water than the irrigation sector.

Tables 4.5.8 and 4.5.9 show water use indicators by sectors of economy and by basins in 2017.

Table 4.5.8: Water use indicators by economy branches in 2017

Water use sector	Extracted from natural water bodies, million m^3		Fresh water consumption, mln m^3					
			Total	Including				
	Total	Including groundwater		Drinking	Industry	Irrigation	HPP	Fishery
Total	**31,485**	**489**	**30,731**	**312**	**247**	**473.7**	**29,681**	**18**
Agriculture/irrigation	1,798	0.2	1,380			473	902	5
Fishery	13		13					13
Industry	32	6.1	31	2	29	0.3		
Food industry	6	4	6	1	5			
Oil processing	0.1	0.1	0.1	0.03	0.1			
Chemical industry	5	0.01	5	0.02	5			
Construction	9	1	9	0.2	8	0.3		
Metallurgy	10	1	10	0.2	10			
Other industries	1	0.2	1	0.2	0.6			
Hydro power	28,956	0.3	28,954	0.3	175		28,778	
Water supply	681	481	348	310	38			
Other	6	2	5	0.03	5			

Table 4.5.9: Water use indicators by basins in 2017

Water use sector	Extracted from natural water bodies, mln m^3		Fresh water consumption, mln m^3					
			Total	Including				
	Total	Including groundwater		Drinking	Industry	Irrigation	HPPs	Fishery
Total	**31,485**	**489**	**30,749**	**247**	**312**	**474**	**29,681**	**18**
Black Sea Basin	19,064	106	18,994	91	33	2	18,863	6
Caspian Sea Basin	12,421	383	11,755	156	279	472	10,818	12

Assessment of the impact of the current and expected climate change on surface runoff has been carried out for the Rioni Basin as it feeds on rain, snow and glacier meltwater, which are in turn vulnerable to the climate change. **The Rioni** is the largest river in Western Georgia. It originates on the southern slopes of the Caucasus Mountains, at the foot of Pasi Mountain at 2620 m above the sea level and flows into the Black

Sea near Poti. The length of the river is 327 km, the average inclination is 7.2 ‰, the catchment area is 13,400 km², and the average elevation is 1084 m. According to the glacier catalogue, the Rioni River is fed by meltwater from 76 glaciers with a total area of 73.4 km². The Rioni has a well-developed hydrologic network, especially on its right bank. It has 7 tributaries with lengths ranging within 50-140 km; 8 tributaries with lengths ranging between 25 and 50 km, and 14 tributaries with lengths ranging within 10-25 km. Other 355 tributaries are shorter than 10 km, their total length being 720 km. The river network density is 0.99 km/km^2. The main tributaries of the Rioni are listed in Table 4.5.10.

Table 4.5.10: Main tributaries of the Rioni River

No	Main right tributaries		Main left tributaries	
	River	Length, km	River	Length, km
1	Sakaura	30	Chanchakhi	22
2	Lukhuni	39	Garula	27
3	Lajanuri	32	Jejora	50
4	Gubistskali	36	Lekhidari	22
5	Ritseula	24	Kvirila	140
6	Tskhenistskali	176	Khanistskali	57
7	Nogela	59	Sulori	33
8	Tekhuri	101	Kumuri	28
9	Tsivi	60	Khevistskali	32

In order to assess the impact of the current and expected climate change, analysis has been carried out for Rioni Alpana and Rioni Chaladidi stations of the Rioni River Basin. Long-term hydrological characteristics of these stations are listed in Table 4.5.11.

Table 4.5.11: Characteristics of Rioni Alpana and Rioni Chaladidi hydrologic stations

Hydrologic station	Characteristics					
	Latitude/longitude	Meters above sea level	Basin area, km^2	Mean basin height, m	Normal annual runoff, m^3/s	Maximal annual runoff, m^3/s
Rioni Alpana	42º 33'; 42º 51'	406	2,830	1,810	102	850
Rioni Chaladidi	42° 12'; 41° 57'	7	11,300	-	406	1,600

The Rioni Basin is divided into four main topographic zones:

The upper (first) zone of the Rioni Basin is located above 3000 m and includes the southern branch of the Caucasian Ridge. The zone has both modern and ancient mountain glacier terrain, a trough valley formed by glacial retreat, moraine debris, a cirque and other glacial formations.

The second zone is a mountain system at the height of 3000-1000 m, including the eastern part of the Samegrelo Ridge, the southern slope of the Svaneti and Lechkhumi ridges, the northern part of the Racha Ridge and the northern part of the Surami Ridge. The Racha-Lechkhumi depression has smooth hilly terrain with numerous sinkholes and fissures. At present, the natural sinkholes are used as water reservoirs Shaori and Tkibuli. In the east this zone borders with the northwestern slope of the Surami Ridge to the middle reaches of the Dzirula River. Here the terrain takes shape of is plateau with deep ravines and canyons.

The third foothill zone is located at the height of 1000-250 m and descends on the Kolkheti Lowland. This zone has undulating topography. Most river valleys are located at the height of 200-300 m, while close to the lowland – at 50-150 m. The zone is characterized by wide river terraces that form flat surfaces along the large rivers.

The fourth zone of the Rioni River Basin is located in the Kolkheti Lowland at the height of 0-250 m above sea level. This zone is the base level of the main rivers of Western Georgia. The western part of the lowland is relatively low and swampy. It extends from the lower reaches of the Tekhura River to the Black Sea. The river bed here rises over the swampy riverine forest. The swamps occupy about 350-400 km^2. The rivers in the lowland and at the confluence often are meandering and bifurcating – branching (Tskhenistskali, Nogela).

The terrain features and the elevations provide for the diversity of soil types in the Rioni Basin. Below the mountainous zones, glaciers and perennial snows, there are mountain-meadow boggy soils (10–15 cm) underlain by brown podzolic soils (50–70 cm), mainly occurring in hilly woodland and cavern limestone zone. The foothills and hillsides are covered with red (80-100 cm), yellow and yellow podzolic (100-120 cm) soils. In the Kolkheti Lowland there are silt marshy soils (120-150-200 cm) and boggy soils (120-150-200 cm). Based on the above data, hydrologic soil groups, reflecting permeability of soils, have been identified in the Rioni Basin. Table 4.5.12 gives rainfall infiltration rate and relative potential runoff characteristics by hydrologic soil groups.

Table 4.5.12: Characteristics of hydrologic soil groups

No	Hydrologic soil groups	Infiltration rate (cm/hr.)	Relative potential runoff
1	A	>0.75	Low
2	B	0.35-0.75	Medium
3	C	0.15-0.35	High
4	D	0-0.15	Very high

About 50% of lands in Rioni River Basin are covered by forests, 40% are farmlands, while the rest 1.6% are glaciers, lakes, reservoirs and river beds.

Figures 4.5.1 and 4.5.2 show the dynamics of river runoff (Qmean) and precipitation (Pr) in the upper reaches (Shovi, Ambrolauri, Alpana) and lower reaches (Kutaisi, Poti, Chaladidi) of the River Rioni in 1956-2015.

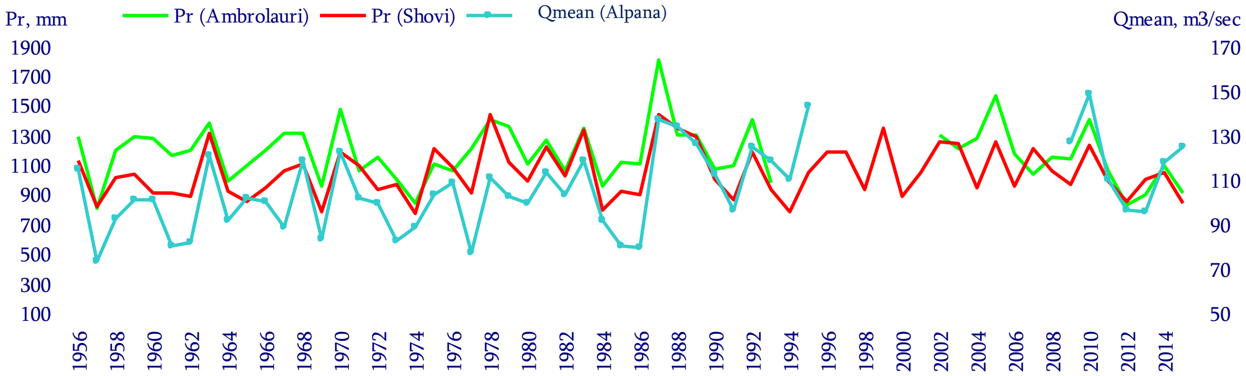


Figure 4.5.1: Dynamics of river runoff and precipitation in the upper reaches of the Rioni River in 1956-2015

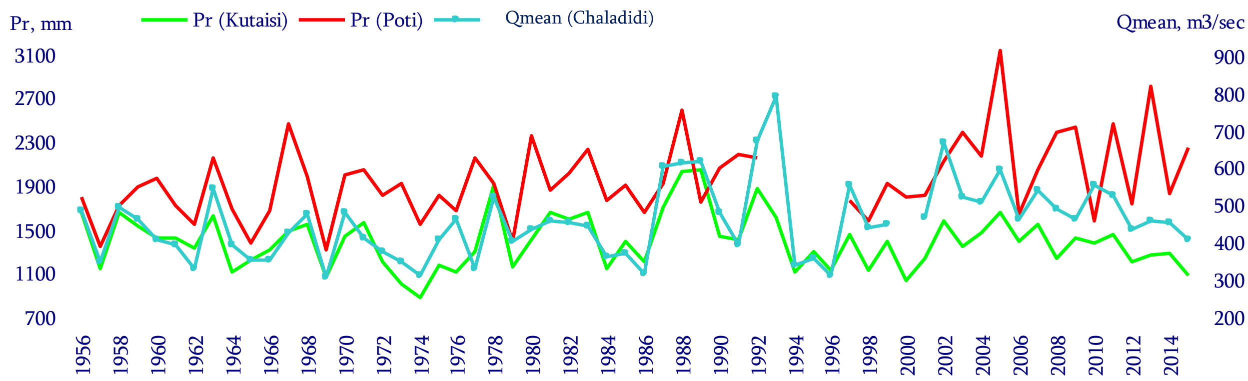


Figure 4.5.2: Dynamics of river runoff and precipitation in the lower reaches of the Rioni River in 1956-2015

Rioni runoff forecast using HBV-IHMS model

The Rioni runoff forecast has been carried out for the two forecast periods (2041–2070 and 2071–2100) under the RCP4.5 scenario of the regional climate model. The integrated hydrological modeling system developed by the Swedish Meteorological and Hydrological Institute (HBV-IHMS) was used for hydrological forecasting. Model calculations of the Rioni River discharge and surface runoff volumes were conducted using historical data on meteorological parameters (precipitation and air temperature) and soil hydrologic parameters.

Soil types and land use characteristics were identified in two sections of the Rioni River - Rioni Alpana and Rioni Chaladidi – using digital elevation model (DEM) of the Rioni River Basin (Figures 4.5.1 and 4.5.2). Forecast volumes of the Rioni discharge and surface runoff for 2041-2070 and 2071-2100 were calculated based on the hydrological model and analysed as compared with the climatic and hydrologic data for the base period of 1971-2000. Calculation results are given in Table 4.5.14.

Table 4.5.13: Precipitation (Pr) in the forecast periods and change (ΔPr) in respect to the base period

Climatic parameters	Station			
	Shovi	Ambrolauri	Kutaisi	Poti
Pr (1971-2000); mm	1,187	1 072	1,408	1,887
Pr (2041-2070); mm	1,103	955	1,197	2,120
Pr (2071-2100); mm	1,130	923	1,213	1,905
ΔPr (2041-2070; 1971-2000), mm	-84	-117	-212	234
ΔPr (2041-2070; 1971-2000), %	–7.6	–12.3	–17.6	11
ΔPr (2071-2100; 1971-2000), mm	-57	-149.4	-195.6	17.9
ΔPr (2071-2100; 1971-2000), %	–5.1	–16.1	–6.1	0.9

Table 4.5.14: Discharges (Qmean) and runoff volumes (Wmean) of the Rioni River in the forecast periods and their change in respect to the base period in Rioni Alpana and Rioni Chaladidi sections

Hydrologic parameters	Rioni Alpana	Giorgi Chaladidi
Discharge, Q_{mean} (1971-2000), m^3/s	107	454
Runoff volume, w_{mean} (1971-2000), km^3	3.4	14.4
Discharge, Q_{mean} (2041-2070); m^3/s	98.5	413
Runoff volume, w_{mean} (2041-2070), km^3	3.1	13.1
Discharge, Q_{mean} (2071-2100); m^3/s	102	439
Runoff volume, w_{mean} (2071-2100), km^3	3.2	13.9
ΔQ_{mean} (2041-2070; 1971-2000); m^3/s	-8.5	-41
ΔQ_{mean} (2041-2070; 1971-2000); %	-7.9	-9.0
ΔW_{mean} (2041-2070; 1971-2000); km^3	-0.3	-1.3

Hydrologic parameters	Rioni Alpana	Giorgi Chaladidi
ΔW_{mean} (2041-2070; 1971-2000); %	-8.8	-9.0
ΔQ_{mean} (2071-2100; 1971-2000); m^3/s	-5	-15
ΔQ_{mean} (2071-2100; 1971-2000); %	-4.7	-3.3
ΔW_{mean} (2071-2100; 1971-2000); km^3	-0.2	-0.5
ΔW_{mean} (2071-2100; 1971-2000); %	-5.9	-3.5

The findings show that compared to 2071-2100, annual mean discharge (Q_{mean}) in the Rioni Alpana section decreases by 8% in 2041-2070 and by 5% in 2071-2100, while in the Rioni Chaladidi section it decreases by 9% in 2041-2070 and by 3% in 2041-2070. The downward trend in the annual mean discharge (Q_{mean}) in 2041-2070 and 2071-2100 in the light of decreasing rainfall can also be explained by glacier melting dynamics. In order to determine the impact of the current climate change it is reasonable to use the established dynamics of glaciers' area in the Rioni Basin and the corresponding forecasts developed with the help of high resolution satellite images. According to the calculations, the glaciers' area in the Rioni Basin, which was 73.4 km^2 according to the 1977 catalogue data, will decrease by 38% to 45.4 km^2 by 2070 and by 45% to 40.1 km^2 by 2100. The forecast degradation of the glaciers correlates to the forecast downward trend in river discharges.

4.6 Groundwater Resources

Protection and sustainable use of fresh drinking groundwater is a priority for any country in the context of climate change. In a number of declarations, made over the last decade, the United Nations Organization (UNO) and the world Health Organization (WHO) mentioned accessibility of safe drinking water as one of the most burning issue. Given the increased worldwide demand for this ecologically clean product, groundwater research and investigation are the issues of national importance for all countries. In its December 2016 resolution, the UN General Assembly (UNGA) declared 2018-2028 as the International Decade for Action "Water for Sustainable Development". According this resolution, the UNGA noted that groundwater resources can provide sufficient adaptation opportunities in conditions of drought and climate change.

The physiographic conditions, geological structure and hydrogeological features condition of Georgia is influencing on the formation and distribution of different types of groundwater resources (fresh, mineral, thermal, medicinal, industrial) on our territory. The country has a long history of research and use of groundwater resources for different purposes with a particular focus on surveying fresh drinking groundwater sources. For many years, field surveys have been carried out in different regions of Georgia to this effect. Detailed hydrogeological surveys show that Georgia's natural fresh groundwater resources amount to 573 m^3/sec and that water has the highest quality. The resources have rather uneven geographical and administrative distribution. Table 4.6.1 shows quantitative and percentage distribution of fresh drinking groundwater among regions of Georgia. It is obvious that 63% (363 m^3/sec) of all groundwater resources are found in Western Georgia, 24% (137 m^3/sec) – in Eastern Georgia and 13 % (73 m^3/sec) – in Southern Georgia.

Table 4.6.1: Distribution of Fresh drinking Groundwater Resources in Georgia

Region	Groundwater resources	
	m^3/sec	%
Abkhazia	106	18.5
Ajara	30	5.2
Samegrelo-Zemo Svaneti	109	19.0
Racha-Lechkhumi and Kvemo Svaneti	24	4.2
Guria-Imereti	94	16.4
Shida Kartli	37	6.5

Region	Groundwater resources	
	m³/sec	%
Mtatusheti-Kakheti	100	17.5
Samtskhe-Javakheti	59	10.3
Kvemo Kartli	14	2.4
Total	573	100

Even before climate change trends became obvious, Georgia paid significant attention to groundwater research. Before early 1990s, continuous hydrogeological monitoring had been carried out on 500 water points – artesian wells, springs and household wells in order to protect groundwater resources. Since then, for more than two decades, no centralized hydrogeological monitoring and groundwater cadaster have been carried out. Meanwhile, demand for drinking water has been steadily increasing, and uncontrolled drilling operations have and are being conducted for groundwater extraction.

While analyzing fresh groundwater resources, it is important to consider their use for different purposes (drinking, agricultural, industrial, etc.). According to LEPL National Agency of Mines under the Ministry of Economy and Sustainable Development of Georgia, 99% of holders of fresh groundwater production licenses produce water for drinking and agricultural purposes and only few bottle it commercially. According to the key water consumption indicators, offered by the Ministry of Environmental Protection and Agriculture of Georgia, as of January 1, 2018, responsible water consumers extracted 489 mln m^3/year of water from natural water sources. While considering fresh groundwater issues it is important to remind that in some populated areas, people extract water for drinking and household purposes from household well, springs or artesian wells without using any centralized water supply systems. Hence, the official data on water consumption are not quite precise. On the one hand, this circumstance gives hope that groundwater resources still are sufficient to meet population's demand for drinking, household and irrigation water. On the other hand, the decentralized and uncontrolled extraction of fresh drinking groundwater makes it impossible to evaluate the current state of fresh groundwater resources. The issue is of a particular national standing against the background of climate change and integrated management of water resources (including transboundary).

Effective functioning of a state monitoring system is essential for assessing ecological state of groundwater resources amid changing climatic conditions. After a long break, Georgia has been taking significant efforts since 2013 to restore the national network for fresh groundwater monitoring. LEPL National Environmental Agency (NEA), at the initiative of the Geology Department and with support from the Czech Development Agency (CzDA), has installed moder hydrogeological monitoring equipment on two wells in the Alazani artesian basin. The measure has been followed by gradual connection of water points to the monitoring network, and currently the monitoring covers 55 water points – 49 wells and 6 natural springs – in Kakheti, Mtskheta-Mtianeti, Shida Kartli, Kvemo Kartli, Guria and Samegrelo-Zemo Svaneti. The installed equipment performs continuous automatic monitoring of main quantitative and qualitative parameters of groundwater regimes (water level and discharge, temperature, pH, electric conductivity, general mineralization). Instrumental monitoring of the springs began in 2016 in Adjara within the framework of EU's „Environmental Protection of International River Basins (EPIRB)". Twice a year, the NEA conducts chemical and bacteriological analysis of water samples from the water points entering the monitoring network. Newsletters are prepared twice a year based on hydrogeological monitoring results. From the date of monitoring resumption up to the present, eight newsletters for corresponding periods have been prepared and published. Monitoring results also have significance for integrated management of water resources and statusing water bodies according to EU's Water Framework Directive (WFD). It should be noted that vulnerability assessment of one of the groundwater types - fresh drinking artesian water – to climate change impacts is based on actual data of the state hydrogeological monitoring. Thus, the interconnection between the key groundwater regime parameters and main climate changes has been established considering the longest series of hydrogeological observations and geographical coverage of weather stations.

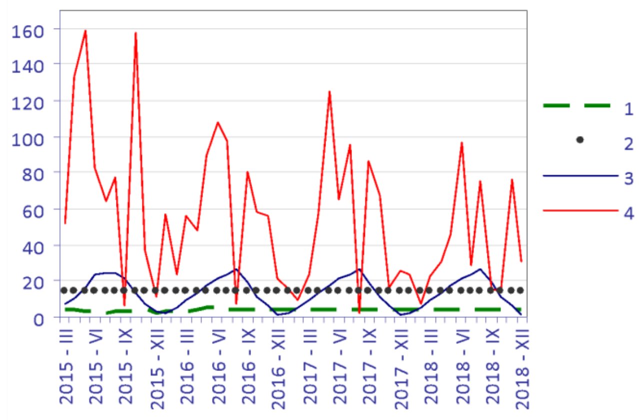


Figure 4.6.1: 1-Average monthly water discharge; 2-Average monthly water temperature; 3-Average monthly air temperature; 4-Average monthly atmospheric precipitation

Figure 4.6.1 shows the dynamics of water temperature (Tw, ^{0}C) and discharge (l/sec) in one of the wells, as well as atmospheric air temperature (Ta,^{0}C) and precipitation (mm) dynamics in 2015-2018. Despite the significant change in climatic parameters (including seasonal), their influence on the key water regime parameters is not observed in the given period that has objective reasons. In particular, water samples were extracted from deep-circulation aquifers comparatively protected from environmental factors. The well is located in Gremi Village, Kvareli Municipality, Kakheti. Based on archive materials, its depth is 110 m and water is replenished from three aquifers located at the depth of 55-51m, 66-71m and 104-109 m. Apart from quantitative and physical characteristics, chemical composition and microbiological characteristics of the artesian well were also stable in the given period. The 4-year series of observations enables only short-term forecasting of changes in hydrogeological parameters. If the current exploitation patterns remain unchanged and the aquifers remain protected from significant technogenic pollution, quantitative and qualitative parameters of the well are unlikely to be impacted by climate change in the coming 5 years. Similar results related to interconnection between the key groundwater regime parameters and main climate changes have been received for other artesian wells covered by the monitoring network in Western and Eastern Georgia.

Unlike artisan wells, natural groundwater outcrops – springs – are more vulnerable to climate change impacts. Spring discharges have declined significantly, especially in Eastern Georgia, while in Adjara springs covered by the monitoring network have seasonal regimes (discharge and temperature).

Generally, forming, feeding and regime of groundwater resources alongside with geological and hydrogeological conditions of an area mainly depend on atmospheric precipitation, namely, on its amount, intensity and type. It is also important to bear in mind that rainwater flow velocity, high on the earth surface, declines gradually after it penetrates the earth, depending on depth. Therefore, climate change impacts on quantitative and qualitative characteristics were estimated for different groundwater types considering their depth. Soil waters (zone of aeration), formed by precipitation and snow melting, are considered to be the most vulnerable to climate change among all groundwater types. These waters are directly connected to the climatic factors. Thus, groundwater in the zone of aeration evaporate partially or completely in dry period, causing soil crusting, significant intensification of wind erosion, shrinking vegetation cover and pasture areas. The vegetation cover, including forested areas, plays an important role in replenishment of groundwater reserves. The vegetation retains precipitation water, causing it to infiltrate soil. In forested areas, where soils are relatively loose, infiltration rate is one and a half times higher than in fields and meadows. Forest also slows snow melting, sometimes for 20-30 days, causing groundwater level to increase high enough to feed groundwater sources in forest-adjacent areas for a long time.

Another groundwater category vulnerable to climate change is subsoil water extracted by population countrywide through wells and used for drinking and domestic purposes. Due to relative shallowness and the lack of impermeable „cover", such water directly depends on climatic factors and is fed mainly by atmospheric precipitation. During intensive rain, subsoil water level rises, its chemical composition often changes and general mineralization declines. Subsoil water reserves replenish rather quickly.

As mentioned above, artesian fresh water is better protected from different climatic factors and extreme weather events (high air temperature, heavy rainfall, hail, etc.). In case of deep or even relatively shallow circulation, the impermeable layer ensures stability of quantitative and qualitative characteristics of artesian waters. The above classification should be kept in mind while assessing groundwater vulnerability to climate change. Long-term forecasting of fresh drinking groundwater resources should be considered that all types of groundwater form a single interrelated dynamic system, and change in any type can potentially impact other types of groundwater resources.

Future climate change impacts on fresh groundwater resources can be assessed using RCP4.5 climate change scenarios for mid- and late-21st century: 2041-2070 and 2071-2100. Atmospheric precipitation and air temperature projections were converted to the reference period of 1971-2000. Based on the scenarios, in 2041-2070 annual atmospheric precipitation will decrease by 9% and 10% in Eastern and Western Georgia respectively, while in 2071-2100 the same parameter will change insignificantly. During the first projected period, average annual air temperature will increase by 1.6-3.1^{0}C throughout the country, while during the second period it will rise by 0.4-1.7^{0}C.

The decrease in atmospheric precipitation and the rise in air temperature in both projected periods will have a certain negative impact on the regimes of subsoil water (household wells) and spring water. Western Georgia, Samtskhe-Javakheti and Imereti regions will be particularly vulnerable to climate change impacts in this sense. The towns of Zugdidi and Poti, Samegrelo, make an exception, as no climatic factors except for seasonal are likely to influence subsoil water levels or spring flow rates there. As regards fresh groundwater sources of a comparatively deep circulation, their hydrogeological parameters are likely to change according to time-space distribution of climatic changes. Substantiation of this concept requires a special comprehensive research. It is quite likely that during seasonal shortage of drinking and domestic water, demand for artesian fresh water will increase again and assessment of aquifer exploitation intensity will become even more crucial.

According to the above scenarios, no evident changes can be observed in the monthly maximum 1-day and 5-day precipitation (Rx1day, Rx5day) in Georgia, but it is important to consider these indices in terms of safe operation of water-related infrastructures. Despite the rehabilitation and construction works of the past decade, some communities in Georgia still experience severe shortage of drinking and irrigation water. Mudflows and flash floods, caused by extreme weather events, cause a serious damage to water supply infrastructure. The situation is particularly difficult at high temperatures in summer.

Climate change will continue to have a negative impact on natural conditions, safe operation of infrastructure facilities and fertility of agricultural lands in Georgia. The growing man-made load and demand for water resources invite the following question: are the available reserves of high quality water sufficient to meet the population's demand for drinking and domestic water on the long run in the context of global climate change? While selecting water points for monitoring in 2013, specialists from the Geological Department of the National Environmental Agency purposefully focused on points of fresh drinking artesian water. Assessment of quantitative and qualitative characteristics of fresh groundwater resources more or less protected from environmental factors is a matter of national importance for Georgia in the context of climate change. In this sense, hydrogeological monitoring enables evidence-based discussion of challenges related to the assessment, forecasting and sustainable use of fresh groundwater resources. The following recommendations proceed from the current state of management of fresh drinking groundwater resources in Georgia.

Adaptation Measures/Recommendations

Given the many years of uncontrolled exploitation of groundwater aquifers and unsustainable use of fresh water resources in Georgia, it is important to create a state control authority for groundwater water well drilling and recording, which will entail certain legislative amendments;

In order to appropriately assess and forecast qualitative and quantitative characteristics of groundwater aquifers in Georgia, it is necessary to expand the state hydrogeological monitoring network. This, in turn, is related to building the capacities of the Geological Department of the National Environmental Agency;

For the purpose of climate change adaptation and defining fresh groundwater use prospects it is necessary to conduct corresponding geological and hydrogeological surveys and implement various strategic objectives at local/community level. The measures to be taken include: state inventory of water points in all municipalities; technical fitout of artesian wells; creation and update of databases; preparation of thematic hydrogeological maps; assessment of geological (landslide, mudflow, etc.) and hydrological processes (flood, flash flood, etc.) caused by extreme weather events on the premises of water intake facilities; identification of communities particularly vulnerable to such events; estimation of future needs for drinking and domestic water; search for alternative/additional water supply sources; when appropriate, development of integrated groundwater and surface water use schemes; community awareness raising and involvement at the corresponding stage of the surveys;

It would be important to perform digital modelling of fresh drinking groundwater resources drawing on findings of national hydrogeological monitoring, updated databases and archive materials and records. Realistic digital models can be used for long-term forecast of climate change impacts and sustainable use of fresh drinking groundwater resources.

4.7 Coastal Zone

The **Georgian coastal zone** is located on the east coast of the Black Sea. Low topography, range of mountains bounded from three sides, and synoptic-scale feature processes make the subtropical climate humid in the Black Sea. It is noteworthy that this region is the humid subtropic located in the extreme north of the Earth. Various physical and geographical conditions of the coastal area have determined the development of various specific infrastructure - transport-harbor, recreation-resort, nature conservation, etc.

Three factors directly influence the formation of the eastern shores of the Black Sea: planetary and regional climate (mainly wind, tide, river runoff, sea level variability), tectonics (differentiated vertical movement of riverbanks) and anthropogenic factors. Where from the longest-term processes are the movement of structural blocks and sea level variability. The fastest impact on the study environment is the anthropogenic factor. It is also associated with the accumulation of excess CO2 in the atmosphere and the creation of a greenhouse effect.

The main determinants of development of natural factors are cyclic processes in the sun. Humanity has been observing the periodicity of sunspots over the last 400 years. The relation between the number of spots and the activity of the sun has been confirmed, the cycles of different duration have been identified: 11, 22, 75-100, 200, 2300 years, etc. The most well studied cycle is early periodic 11-year change in the Sun's activity. Since the instrumental observations began, almost 24 solar cycles have passed. The 24th cycle, which is characterized by low solar activity, should be completed in 2019. It is assumed that the 25th cycle will be even lower. It is compared to the cycle of the Maunder Minimum (also known as the "prolonged sunspot minimum"), which coincided with a Litlle Ice Age in Europe in the XVII-XIX centuries. In the first decades after the 25th cycle, the average annual temperature may drop by several tenths of a degree, but then it will be offset by the greenhouse effect.

In the Holocene, the Black Sea is connected to the World Ocean by the Strait of Bosporus and the Dardanelles. In the Black and Mediterranean Seas, with no inflows and outflows, it is easy to determine changes in seas and world ocean levels, especially at high elevations. This is based on the forecast of the recent marine transgression peak.

Transgression prediction of sea-level/ocean water level in the last century was as follows by2050: minimum +0.5 meters, maximum +3 meters. The prediction was based on well-studied Nymphaea and New Black Sea phase transgression levels, (+2)–(+3) meters. Other divergent data for sea level change forecasts are not available today unless we consider the change in CO2 concentration. There are many scenarios for the development of events, including the following: the 25th and subsequent cycles of solar activity may become the beginning of a stronger and long-term cooling; warming may last longer than it normally should, which is clearly expected given anthropogenic activities; Mankind may find a way to neutralize the effect of the greenhouse gasses it provokes; natural processes may also override and events maybe developed in a Nymphaea or New Black Sea phase scenario.

Georgia's Black Sea coast, even in the best of the scenarios discussed above, faces difficult problems to solve, and global warming only exacerbates them. The problems are mainly caused by excessive and irrational farming activities. In order to predict the development of the coast of Georgia, it is necessary to consider the morphodynamic development of the coast in natural conditions, its actual state and the possibilities for its development.

Coast development in the natural environment

The eastern coastal line of the Black Sea has the north, the central and the south areas. Their base directions or azimuths are as follows: north area 105^0, central area 170^0, and south area 235^0. The most frequent and strongest west rhumbs are in the almost straightforward direction of the central area. These rhumbs will actively move beach material from the northwest and southwest to the center of the arc.

It is known in paleogeography that the relief and the climate approaching the present day were formed 6-5,000 years ago, when the Black Sea level was only a few meters below its present level. Since then there have been several fluctuations in water levels: the highest level was about 2–3 meters above 4000 years ago (New Black Sea phase transgression); the lowest level is Phanagorian regression 2500 years ago, and some scientists say it was about 10 meters, others only 1-2 meters; Approximately actual level, 0 meters, is marked 1500 years ago during Nymphaea transgression. During the same period, two short water levels of 2–3 meters were recorded. The last of these dates to about XVIII century (the so-called "Little Ice Age").

Vertical movement of structural blocks of the beach. Where the mountains lie directly above the sea, the structural blocks are overwhelmed and so-called Abrasive shores ("cliffs") arise. The structural blocks within the Kolkheti lowland are subducted by 1 or 2 mm per year. As a result, reservoirs on the confluence of large rivers develop. An exception is the structural block on which Poti City is located. Here the sinking speed is 6 mm per year. This is most likely caused by overcrowding of the city with heavy buildings and intensive drilling of the city area for the purpose of obtaining drinking water over the last century, which has damaged the integrity of the groundwater pressure horizons. Structural block movement is also affected by sea level fluctuations - a rise or fall of several tens of meters in thickness may slow or accelerate block movement, or even change one direction of movement to another.

Lithodynamics. In the lithodynamic system the main source of energy is the long river. In many cases, the system is named by the feeding river. During the flood, the river will divert waste material from the catchment to the sea at the confluence of the river. The accumulated sediment will be transported by waves to transit areas along the coast and nourish the beaches located there. The length of a coastal system fed by a nutrient source-a long river is considered to be the length of a dynamic system. Currently, the lithodynamic systems of the historically established the Chorokhi River and Poti (the Rioni River) are divided into several subsystems with or without their own power supply.

Chorokhi River Lithodynamic System. Chorokhi lithodynamic system is formed by abrasive and sand-pebbly banks. Abrasive: Rocky sections of Sarpi-Kalenderi, Makhinjauri, Green and Tsikhisdziri Capes. Accumulated: sections of Kvariati-Batumi cape and Bobokvati-Natanebi. The underwater slope is of complex formation. Chorokhi and Batumi canyons cut and prenetrate into the submarine platform and Kobuleti submarine pit.

Naturally, beaches of the Chorokhi River at the confluence of the marine created a sedimentary stream flowing to the north by the prevailing, westward storm surges and reaching the confluence of the Natanebi River. In the cartographic materials of 1832 the river Chorokhi flowed into the sea in two branches: south - actual confluence and north - at the confluence of the Mejini River. On the map of 1890, the northern branch is abandoned (the confluence of the Mejini River). Thus, the united confluence of the river appeared to be at the source of the Chorokhi underwater canyon. This has led to the loss of about 90% of the material deposited in the rivers at great depths. In natural conditions, the river Chorokhi was carrying annually approximately 5 million m3 alluvial sediments to the sea, including a 2.5 million m3 beach-forming fraction, from which pebble amounted approximately to 0.4-0.5 million m3. Thus, the concentration of the entire flow of the river Chorokhi in the southern tributary changed the processes underlying the lithodynamic system, and a sharp shortage of sediments on the Adlia-Batumi coast.

The construction of Batumi Port in 1878 had a radical impact on the development of the Adjara coast. A 170 m long dam was built to protect the water area of the Port against the storm and precipitating sand, which led to a sharp increase in the cape of Batumi - about 4 meters a year and blocking the beach-forming material to the north. After the construction of the Batumi Port, erosive processes developed north of the Batumi Cape, on the Makhinjauri-Kobuleti section. Solid sediments from the rivers - Korolistskali, Chakvistskali, Dekhva, Kintrishi and Achkva could not stop washing processes due to their small size and thickness.

Table 4.7.1 gives the characteristics of the Adjara rivers before their natural conditions are violated. Specifically, the granulometry of the data of the seventies of the 20th century is given, at a time when the natural regime was maintained in the Chorokhi River. After construction of dams in Turkey, the flood peaks on the Chorokhi River were removed and the river almost no longer carries solid runoff of large fraction into the sea.

Small river data, unlike the Chorokhi River, have not undergone any significant changes in the last 30 years. It is noteworthy that in the past, when the shoreline flow at the mouth of the Chorokhi River flowed smoothly towards the Natanebi River confluence, the coastline along the Batumi-Kobuleti section was at least 50-70 meters ahead of its contemporaries. As the beaches narrowed, dense rocks of Green and Tsikhisdziri Capes began to play the role of grass covers. As a result of the blockage of the coastal flows, the dynamic system became even more fragmented.

Table 4.7.1: Adjara Rivers Beach-Forming Drift

River	Cobblestones		Coarse sand		Sand		Annual total, m3
	m^3	%	m^3	%	m^3	%	
Achkva	50	4	600	4	800	55	1,450
Kintrishi	4,100	6	250	4	2,500	36	6,850
Dekhva	500	2	1,400	5	600	24	2,500
Cahkvistskali	4,700	5	900	1	2,900	34	8,500
Korolistskali	1,700	4	600	1	1,200	34	3,500
Bartskhana	200	8	1,100	4	1,200	48	2,500
Chorokhi	310,000	1	140,000	6	2,050,000	82	2,500,000

The construction of the Batumi port caused the division of the Chorokhi dynamic system into three, more or less independent subsystems:

1. Village Kvariati-Cape of Batumi;
2. Batumi Port - Tsikhisdziri Cape;
3. Tsikhisdziri Cape - Natanebi River.

Significant morphometric changes did not affect the Sarpi coastline, which is not included in the Chorokhi dynamic system and exists as a separate autonomous site.

Sea Storm Activity

Table 4.7.2 presents the long-term observations of the Adjara Hydro-meteorological Observatory on the wave characteristics on the Georgian coast.

Table 4.7.2: Wave characteristics on the Georgian coast

Wave force	Average wave parameters			Repeatability of waves of different wave force (rhumb), on daily basis				
	h	τ	λ	southwest	west	northwest	norh	northeast
0	0	0	0	Calm sea is repeated during 91 days				
1	0.06	1.4	3.0	5.1	23.8	16.7	17.2	3.7
2	0.23	1.8	5.0	8.5	50.0	27.0	18.0	5.6
3	0.46	2.6	10.8	6.35	32.4	11.2	6.95	1.28
4	0.74	4.0	25.5	2.42	16.6	4.8	1.78	0.15
5	1.25	5.6	50.0	1.3	9.6	1.27	0.73	0.11
6	2.15	6.8	75.0	0.22	1.9	0.22	0.36	–
7	3.3	8.5	115.0	0.07	0.4	0.07	–	–
8	4.45	9.8	155.0	0.04	0.04	0.04	–	–

Table 4.7.3 shows the number of storms recorded by Poti Hydrometeorological Station and the Maritime Transport Agency's Hydrometeorological Department in different periods from 1961 to 2009.

Table 4.7.3: Number of storms recorded in different periods during the period 1961–2019

Poti Hydrometeorological Station	Storm Force					Total	Average, annual
	4	5	6	7	8		
1961-1971	325	77	6			408	37
1978-1988	713	112	2			827	75
1997-2007	254	210	23	3		490	45
2007-2010	37	13	3			53	13
2010-2017	247	79	6			332	42
Maritime Transport Agency's hydrometeorological department		5-6 force	6 force	6-7 force	7-8 force		
2012-2019 (August)		97	6	12	1		

There is no regularity in the annual distribution of storms in 1961-2007. However, there is an increase in the frequency of strong storms (5 force or more). From 1961 to 1971, strong storms accounted for 19% of total storms, 26% in 1978-1988, and 54% in 1997-2007. The above percentages confirm the increase in storm energy. Three storms with force 7 are recorded. During the 40 years of observation, the period 1997-2007 was the most active, with 236 cases of strong storms. Of these, only in 2007 - 52 strong storms were recorded - 34 storms of force 5 and 15 cases of force 6. During the 4 months, November 2007 - February 2008, two storms of force 6 and three storms with force 7 were recorded. Such storm activity is abnormal in the light of previous observations.

Maritime Transport Agency's Hydrometeorological Department carries out continuous recording of waves using automatic recorders. Recording in Poti Hydrometeorological Station was conducted 3 or 4 times during a day. Continuous recording of waves gives more opportunity for analysis. For example, on December 9, 2013, during the night, ordinary winter 6-degree storm increased by force 8 from by 12 a.m. within a period of 2 hours, and decreased to force 6-7 in 40 minutes, and again reached force 6 in 4 hours. On the Georgian shores, a rapidly developing and weakening storm could not have had a particular impact, except for the deep-water Kalenderi shore. The longer the wave development phase, the deeper the accumulated submarine slope. The maximum wave hits the shore closer and transmits more energy. Whereas earlier in the winter, the waves were monitored three times in 24 hours (precise night observation was not possible), the duration of the recorded (40-minute) surge of the sea with force 7-8 degree; In the submitted reports, it may be increased for several hours or not recorded at all. Thus, the methods of processing old and new records are different and they are difficult to compare.

The number of strong storms in 2007 far exceeds that of other years in 60 years. There is an impression that temperature rise and storm surge are occurring in parallel, but in subsequent years, especially due to warming in 2016, 2017, 2018 and current 2019, the temperature difference between the cold and warm air masses in the atmosphere decreases and therefore their energy dissipates. Not only does the frequency of strong waves decrease, but also their duration. Precipitation may increase due to evaporation as the result of warming, but reduce runoff from spring floods, especially on glacier-fed rivers.

Particularly strong and long-term waves occur at a distance of 400 to 800 km from the coast of Georgia across the Crimea, the Azov Sea or further west. Large waves occur in these areas as the result of stable and strong winds blowing only when many climatic factors combine. This wave reaches our shores mainly as sea swell, rarely accompanied by wind and rain.

Actual state of the seaside on the Sarpi-Batumi Section

Sarpi. Earlier, Sarpi Beach was fed by a small border river (small ravine). 700 m of the 1000 meter-beach is in Georgia and 300 m - in Turkey. The beach is surrounded by capes on both sides. Because of this, the waves do not carry beach material out of the area, only its depreciation is carried out. In 2016-2017, the beach was rehabilitated by artificial insertion of material from the Chorokhi riverbed. Today Sarpi Beach is stable.

Kvariati. The coastal zone of Kvariati is stable, fed by the material from Gonio. In most cases, the active beach area has temporary buildings (open-air cafes, bungalows) and permanent structures (hotels, cottages). The beach's natural profile is disturbed, which damages buildings and the nearby beach during storms.

Gonio. The Gonio coast was characterized by a full-profile beach embankment, the width of which is within 50-75 meters between 2000 and 2009. In 2018, in some areas the beach width has been reduced by approximately 10 m. The reason for this is the construction of a motorway on the beach embankment. On the southern fragment the beach is more spacious and stable, in 2000 – 2018 it was washed 1 meter per year. The average annual rate of washing at the mouth of the Chorokhi River is about 4 meters.

The **confluence of the Chorokhi River** is actively being washed out, since after the construction of dams on the river and its tributaries, no solid sediment can be brought into the confluence. The washing process will be irreversible and will continue until the shore receives the azimuth of the Kvariati-Gonio coastline.

Adlia coastal zone. By 2018 south of the treatment plant the beach's width was 35m, in 2009 it was 45m. It is protected by a deformable stone gabion from the shoreline treatment plant to the airport.

Batumi beach. The south coast of Batumi is devoid of the old shoreline embankments. This indicates that the Chorokhi Delta coast was characterized by high dynamics, oscillations of the seabed, the amplitude of which was estimated to be within the first hundred meters.

By 2018, in the extreme south of Batumi, beach width averaged 25-30 meters, compared to 45 meters in 2009. Further north, in the new settlement area of the city, the coastline is relatively stable and the beach is approximately 60-65 m wide. Currently, large-scale coastal protection works are being carried out by a foreign company on the coast of Adlia and Batumi.

The Cape of Batumi. The Cape of Batumi is an active lithodynamic site, which is due to the underwater canyon. After filling the stone shaft on the Batumi Cap, the accumulated volume reached its maximum growth and approached the Batumi submarine canyon. Sediment caused by storm surges began to disappear in the canyon. Loss of large material amounted to about 80-100 thousand m3 per year.

By 2018 the width of the Cape beach is an average of 95 meters and has increased from 6 to 14 meters compared to 2009. The distal part of the cape, between the old and the new ones, is an exception. Here the increase was 27 m.

Loss of sediment along the coast occurs at great depths during stormy periods. On January 14, 1999, to the east of the stone shaft a 200m long beach with a total area of about 11,000m2 was pulled away from the shore and sinked in the sea. Similar processes have happened before and are expected in the future. That is why it is inadmissible to build heavy buildings on the Cape. It is noteworthy that the shortest distance from the Alphabet tower to the sea is currently 180m, and after the avalanche in 1999, it was only 110m. In 20 years, the surplus totaled 70m.

Makhinjauri-Tsikhisdziri. The upper part of the mid-mountain laterite clay and loamy crust, by the action of exogenous factors, has been transformed into an unstructured brownish-reddish loamy mass, indicating a more humid and high-temperature climate in this area in the past (Tertiary period). The coast to the north of the Cape of Batumi is fed only by the sediments of local, medium and small rivers.

The width of beaches in Makhinjauri in 2009 was 35-45 m, almost the same in 2018. However, at present, supplies of material on the underwater slope are already depleted and the stability of the shores depends solely on artificial feeding.

Chakvi beaches are fed by the Chakvistskali River runoff. From 2009 to 2018, the condition of the seabed has almost not changed. The maximum width of the beach is over 60 m at the Chakvistskali River. In the southern section, a berm with boulders was built a few years ago to protect the railway. The northern part of berm emerged a 10-15 m wide beach.

Across this section, the underwater slope is monotonous and the mean inclination is 0.013. The surface is about 1.5-2.0 meters deep covered with gravel-pebbles, from 1.5-2.0 meters to 10-12 meters deep with sand, with silt at a greater depth.

Current status of the coastal zone on Tsikhisdziri-Natanebi section. In the lower central part of the Kobuleti seaside plain, three mature and deep peatlands have developed in the past, "Ispani-1", "Ispani-2" and "Ispani-3". The nature of "Ispani-2" is well preserved and has been declined.

The northern part of the Kobuleti coast is a relatively stable area. The beaches are 50-55 m wide on average, 80 m in the pine forest (the same parameters were in 2006). In the central and southern part, along the stepped wall the beach width is 20-55 and 20-30 meters, respectively. Periodically, material from the Kintrishi River sand-gravel quarry is brought to the beach, which has a positive effect on its parameters.

Natanebi - Supsa coastal zone. This section is particularly interesting. It was never completely washed and always managed to regenerate through the Natanebi River and the Supsa River.

Ureki coast from the Supsa River to the Natanebi River is represented by various degrees of enriched titanium and ferromagnetic fine-grained sand, the origin of which is related to the effusive rocks in the Guria Mountains. Positive effects of this sand on the human body, in particular the cardiovascular and central nervous system, as well as the locomotorium have been established. Ureki curative agents (magnetic sand) are used successfully in the treatment of both children and adults.

Poti dynamic system. As a result of the construction of HPPs on the Rioni River, the average annual volume of solid material decreased from 8 million m^3 to 4.4 million m^3, including beach-forming material - from 2.1 million m^3 to 1.3 million m^3. This has not led to any adverse effects on coastal formation, since the coastline currently fed by the Rioni River is so small (14 km) that the accumulation process (the terrestrial uplift in the Delta region is still 10-12 m) continues today.

Nabada - Actual state of the Sufi River section. From the southern branch of the Rioni River to the north verdure (green grass) of Poti Port (length 2.6 km), the beach width ranges from 50 to 100 meters depending on the observation time. To ensure navigation at this site, excess ballast is routinely removed from the port access channel.

Actual condition of Poti Port-Supsa River section. There are no beaches on the Poti Port-city section (“Huge” Island). It is completely fortified with rock.

Maltakva, Grigoleti. The width of the beach is 20-30 meters from the city channel to Maltakva. 50-70 meters from Maltakva to Grigoleti. This area feeds mainly on city channel output, depending on the trouble-free operation of the water distribution point. The point is currently being rehabilitated. On the Grigoleti section, resort buildings are located directly on the beach and the stone gabion, causing their damage, washing the beach and washing the roots of the pine grove. This site periodically requires locally-sourced material to be artificially introduced to the beaches. In order to prevent loss of coastal sediment in the Supsa River Canyon, it is necessary to build a sediment trap / stone gabion to the north of the Supsa confluence, which will lead to sediment accumulation and long-term stabilization of the shore.

Actual state of Nabada-Khobistskali Section. The pebbles are no longer found on the beaches of this area, as the verdure (green grass) of the Port of the Mokvi River in Abkhazia and the nature of Ochamchire completely cut off the possibility of pebbles to move south. The remnants of the old pebble beaches are partially washed, partially covered by Rioni sand. Along with the Nabada Delta, this area is the only one on the eastern shore of the entire Black Sea that is constantly on the rise.

The problem of stabilization of the Kolkheti lowland coastal zone is almost entirely related to the anthropogenic factor. Anthropogenic impacts have resulted in a reduction in the amount of material released by the rivers (construction of power plants on the Rioni, Supsa and Natanebi rivers), as well as disruption of the natural process of sedimentary shore movement (construction of Poti Port, the Rioni River dumping, etc.). All this has led to both a shortage of sediment in some areas of the coastline and its unnatural redistribution throughout the dynamic system.

Actual situation of the Ganmukhuri-Enguri-Anaklia-Khobistskali River Section. Prior to the construction of the Enguri HPP, the Enguri River produced 1.5 mln m^3 of beach-forming sand sediment in the sea. Much of the material was lost in the underwater canyon at the confluence, some moving through the Anaklia beaches to the Khobistskali River.

The construction of the protective walls, the verdure (green grass) of the Port of the Mokvi River and the nature of Ochamchire completely blocked off the beach material moving south; the retreat of the Enguri River estuary began and the surrounding areas were washed away. To the present day, the retreat (backing out) of the shore in Ganmukhuri and Anaklia totaled at least 200 m.

Shore protection measures are to be taken to protect the Churia Protected Area. Infiltration of seawater into the Churia swamp will inevitably result in the destruction of rare fauna and flora.

Problems on the Black Sea coast of Georgia and the Effects of Global Warming

From the 1960s onwards there are predictions based on paleogeographic studies and directly related to the paleoclimate. In this respect the Holocene is well studied, especially the Upper Holocene (5-6 thousand years), where instrumental research has added historical written sites. Surveys have used unmistakable indicators such as high-ocean markers in the form of transgressive zones, which are easily dated by mollusk waste. Forecasts suggest that modern, transgressive sea-level rise (directly linked to warming and melting ice) should have been completed by 2050, with an accuracy of about 20 or 30 years. Then the regression level would start, i.e. cooling. In the Upper Holocene, the periodicity of large transgressions is 2000 years, and the periodicity of small transgressions is 400-450 years. Forecast of sea-level rise - minimum 0.5 m, maximum 3 m.

The main pillar of modern solar cycle prediction is the frequency of sunspots that have an average 11-year cycle. In addition, different cycles and events of different periods on the surface of the sun are separated. For example, it is not yet known how to link climate change to the sharp decrease in plasma velocity in both hemispheres of up to 30 cm/s, while the velocity has been steadily 1 m/s for several decades. Forecasting for 11-year cycles often fails - for example, the 24th cycle should have been very quiet. In some studies, the 24th and the next 25th cycles compared the very quiet cycle of the Maunder Minimum (when there was a Little Ice Age in Europe). There were really ***no sunspots*** and the solar cycle lasted 10.5 years. Only 130 spots have appeared in recent months, while the norm is the range of 140-200 spots. Usually, the timing and character of the current cycle cannot be precisely determined. The 23rd cycle should have been higher than the 22nd, but it didn't. In addition, the 22nd, 23rd and 24th cycles were characterized with reduced activity. At this time the temperature on earth was constantly increasing. The question is, what is the relation between temperature and the solar activity? This science is still young and it is not possible to make accurate predictions on short observations. This does not mean that no predictions are made. On the contrary, many scenarios need to be developed to counteract the negative effects of climate change.

As for the lithological, morphological and hydrological (including waves) characteristics of the seashore, climate change is definitely affected by them, although these impacts are difficult to assess and, in the short term, impossible given the high anthropogenic secondary landscape. In our case, there are no natural features left on the east coast of the Black Sea that are not distorted by anthropogenic impacts.

Paleogeographically, the peak of the last "Little Ice Age" coincided with the beginning of the 19th century. The sea level may have been 1.5 or 2 meters lower than in modern times. Since that time, sea-level rise has been steadily increasing, i.e. warming - melting of polar ice and other glaciers. The impact of this process on the environment has only been known since the 1960s. This process was recorded on the east coast of the Black Sea, in the name of the transitional regression of the banks in the dynamic system of the Bzipi River. At that time, only on the beaches of the Bzipi River system were there active resort and urban construction works.

The shoreline was washed out entirely on the seashore, but there's a rationale to that - to extract construction ballast directly from beaches and rivers, to place buildings directly on beaches or shorelines, etc. Roots of all pine trees were washed away in the pine forest along the Bzipi-Bichvinti section, though the trees continued to live their normal lives. The grove of relic pines was guarded by a wide beach, with no waves, but there were clearly signs of washout in the past. Studies have revealed the cause of the washout - the confluence of the Bzipi River is displaced to the north, where the shore has started to accumulate and retreat (backing out). Subsequently, the shore stabilized. Later analysis of maps of 1840-1880 and 1951-year aerial photos and geophysical surveys revealed the relationship of river confluence with sea level variability.

The impact of climate change on humanity has been profound and many historical accounts have been preserved, but it is unlikely that these changes would be devastating to human existence, except in some cases where bad crop has caused hunger and death. For the same reason, in the jungle of Asia and in the hills of the American continent we find abandoned cities with no signs of destruction or visible natural disasters.. Acceleration of this process is almost always due to climatic factors.

Whatever the scenario of the sea-level rise due to global warming, it will still be devastating for the Georgian coast, as the processes on the seashore, including the balance of sand-pebble material, are irreversibly disturbed. From these processes, due to the construction of HPPs, the sand-pebble material deposited by the two largest rivers is completely removed --the solid runoff of the Chorokhi River averaged 5,335,000 m^3 per year, of which 2,500,000 m^3 is beach-forming (more than 0.4 million m^3 of pebble stone) and 1,500,000 m^3 -the solid runoff of the Enguri River, of which about 0.5 million m^3 is beach-forming. Material for construction continues to be obtained from other much smaller but important rivers (e.g. Kintrishi, Natanebi and Supsa Rivers). Material extracted from the terraces of such rivers should only be used for reinforcement. This inexpensive material (at a modern pace) is exhausting and in the near future the country will have to develop mining quarries to rehabilitate the beaches, which will cost the state budget far more expensive.

It should be noted that the Soviet-era policy of restoring and protecting the Black Sea coast can no longer respond to the present-day natural and economic conditions of the country. In particular, the Black Sea coast, as has been repeatedly stated, is an accumulative genesis and is built up by the steady flow of rivers into the sea. In recent decades, HPP cascades of dams have been built (at Enguri in the 70s) on the large "coast feeding" rivers (Chorokhi, Enguri and, partly, Supsa), thus, blocking the entry of solid sediment needed to stabilize the beaches into the sea. Until 2014, in the lower reaches of these rivers, unlimited extraction of sand and gravel for the construction of roads and other facilities was carried out. From this period, the prohibition of inert material extraction in the floodplains of the Black Sea rivers within a 20 km radius created the prospect of future improvement. It takes some years to rehabilitate the deepened and deformed beds. Currently, in the riverbeds of the main rivers, there are practically no quarry sites for rehabilitating the coasts..

Thus, in conditions of inert material deficiency, it is advisable to build a berm with boulders to protect the banks of non-recreational use.

The construction of boulevards in Batumi and Anaklia resulted in major material damage in 2008-2011. Improper planning and design destroyed a significant section of the boulevard which is newly constructed, firnhished and equipped with the relevant infrastructure and is worth several mln GEL.

A few years ago, a large part of Adlia settlement was washed away and it became necessary to relocate homeless people to other areas.

Residents of the resort town located on the Grigoleti coast have been heavily damaged due to inadequate construction of shore protection structures for several times. Other areas of the coast are also in trouble.

The principal negative effect of global warming for the coast is the sea-level rise that will cause flooding and loss of territories. This is a long process. As noted above, the anthropogenic factor is much faster and more likely to cause flooding and loss of area - mostly it defines the vulnerability of the coastal zone.

4.8 Extreme Hydrometeorological Events

The complex terrain often contributes to intensification of atmospheric circulation processes and the formation of various types of extreme hydrometeorological events (flood, flashflood, avalanche, strong wind, drought, etc.) in Georgia. Such events have become increasingly frequent and intensive in the context of climate change (Figure 4.8.1), causing significant economic damage and often human casualties.

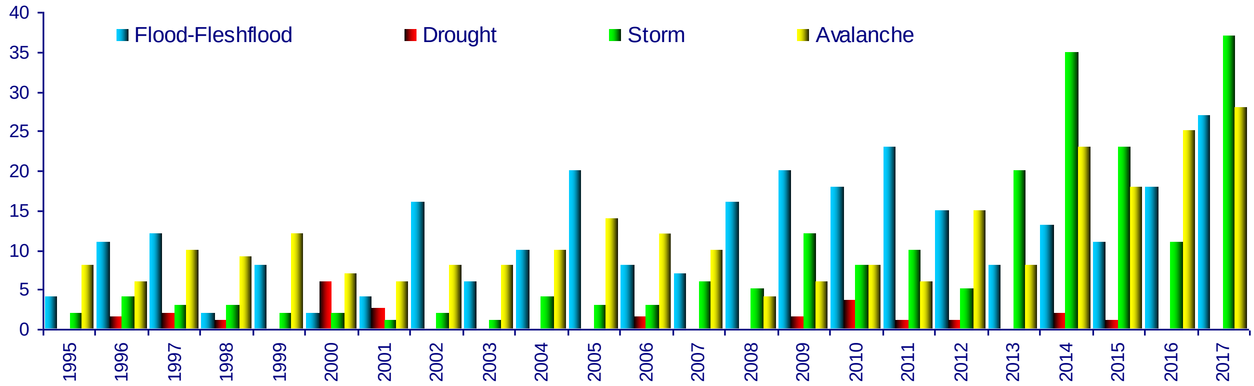


Figure 4.8.1: Extreme events on the territory of Georgia in 1995-2017

Floods and Flashfloods

The main climatic factors causing floods and flashfloods in Georgia are: 1. intense and incessant rains; 2. sharp increase in air temperature resulting in snow melting accompanied by heavy rains; and 3. intense melting of snow glaciers. It should be noted that 34% of the recorded flashfloods are of mixed origin (snow and rain) and 66% are caused by intense and incessant rains.

Floods and flashfloods occur on all rivers several times a year, while catastrophic floods - once in 5-6 years. Special mention should be made of catastrophic floods /flashfloods that took place in 1968, 1987, 1996, 2005 and 2014–2019. In 1987 alone, floods destroyed more than 4,400 homes, 16 km of railroads, more than 1,800 km of roads, more than 1,300 km of other infrastructure facilities, 80,000 ha of agricultural lands, and more than 1,500 agricultural buildings. Dozens of people were killed or went missing. The total damage was estimated at $ 300 million.

In terms of seasonality, on the southern slopes of the Caucasus Mountains floods and flashfloods occur in summer, in Meskheti and Likhi they mainly take place in spring and summer, in the Kolkheti lowland floods and flashfloods occur throughout the year, while in the lowlands of Eastern Georgia and highlands of

Southern Georgia they are frequent in spring and summer. As regards flood risk level, it is very high (22%) in the Kolkheti lowland, high (16-22%) in the belt between 300m and 2000 m above sea level, medium (10-16%) in the Mtkvari basin, low (4-10%) in Javakheti and very low (less than 4%) in Iori.

Table 4.8.1: Average annual number of floods / flashfloods in the regions of Georgia

No	Region	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual	Event per 1000 km^2
1	Abkhazia	0.4	0.2	-	1.1	1.7	4.2	2.8	4.8	1.8	2.0	2.4	0.2	21.6	2.5
2	Samegrelo-Zemo Svaneti	0.5	0.6	0.3	1.5	2.4	5.1	6.5	5.6	0.2	0.8	1.3	1.4	26.2	3.5
3	Racha-Lechkhumi and Kvemo Svaneti	-	0.3	-	2.0	5.9	6.8	4.5	4.0	-	2.2	1.1	-	26.8	10.9
4	Imereti	0.4	0.5	2.1	2.7	1.6	1.8	1.4	0.7	-	1.6	1.6	1.8	16.2	2.5
5	Guria	-	-	-	1.5	-	0.7	1.8	4.0	3.3	2.9	1.8	1.5	17.5	8.6
6	Ajara	-	-	0.6	3.9	3.3	0.4	0.6	2.2	1.6	1.2	0.6	1.2	15.6	5.4
7	Samtskhe-Javakheti	-	-	0.3	6.5	4.6	1.8	0.4	-	-	0.3	0.8	-	14.7	2.3
8	Shida Kartli	-	0.2	0.8	7.5	3.4	3.6	0.9	0.6	0.2	0.2	-	-	17.4	5.1
9	Kvemo Kartli	-	-	0.2	20	3.7	2.4	1.2	0.2	-	-	-	-	27.7	4.1
10	Tbilisi	-	-	-	1.7	2.2	1.7	1.1	-	-	-	-	-	6.7	18.6
11	Mtskheta-Mtianeti	-	-	-	0.6	3.2	3.4	2.3	2.5	0.2	-	-	-	12.2	1.8
12	Kakheti	-	-	-	0.4	2.2	3.4	3.1	0.5	1.1	0.7	-	-	11.4	0.9

Statistical analysis shows that amounts of flood-forming precipitation vary by region. For example: in the coastal areas of Guria and Adjara, flashfloods are formed by rainfall ranging between 90 and 120 mm, at the rest of the Black Sea coast rainfall should be within 80-100 mm, while in the Kolkheti lowland it should be within 50-80 mm to form a flashflood. Due to the steepness of slopes, 30-50 mm rainfall can cause flashfloods in the mountain belts in western and eastern regions of Georgia, and 30-40 mm rainfall can cause flashfloods in mudflow zones. A comparison of dates of flashfloods and intense rainfall shows that on small rivers flashfloods are formed in almost all cases on the day of intense rainfall, and on big rivers they are formed 12 or 24 hours after the rainfall.

Extreme precipitation indices reflecting intensity, amount and duration of precipitation (Rx1day, Rx3day, Rx5day, R30, R50, R80, R90, CWD and PRCPTOT) have been selected to identify climatic factors causing floods and flashfloods.

Rx1day	Monthly or annual maximum 1-day precipitation
Rx3day	Monthly or annual maximum 3-day precipitation
Rx5day	Monthly or annual maximum 5-day precipitation
R30mm	Number of heavy precipitation days, number of days when PR≥30 mm
R50mm	Number of heavy precipitation days, number of days when PR≥50 mm
R80mm	Number of heavy precipitation days, number of days when PR≥80 mm
R90mm	Number of heavy precipitation days, number of days when PR≥90 mm
CWD	Annual maximum number of consecutive days with PR≥1 mm
PRCPTOT	Sum of monthly or annual total daily precipitation when PR≥0.1 mm.

Precipitation showed an upward trend in Western Georgia in 1986-2015 as compared with 1956-1985. All the weather stations at the Black Sea coast (Batumi, Kobuleti, Poti, Zugdidi) reported an increase in maximum 1-day precipitation (Rx1day), especially in autumn. Since one-day heavy rainfall is sufficient for flashflood forming in this region, the increased precipitation has resulted in higher flood risk and increased frequency of floods over the recent decades. An increase in maximum 3-day and 5-day precipitation (Rx3day and Rx5day) is observed in the upper reaches of the Rioni River (Ambrolauri, Shovi) and its tributaries -

Kvirila (Sachkhere) and Tskhenistskali (Lentekhi). In both cases the increase occurs in spring, and since spring and summer floods in the Rioni basin are caused by snow melting and rainfall, the region's susceptibility to flood has become significantly higher.

According to the climate scenario, Rx1day is expected to increase only in Zugdidi and Kobuleti in the two 30-year forecast periods (2041-2070 and 2071-2100) compared to the 30-year base period (1971-2000). An increase in Rx3day and Rx5day is forecast in the Rioni Basin and its tributaries.

The number of flood-forming wet days (R30mm, R50mm) increased at almost all stations in the Rioni River basin (Ambrolauri, Shovi, Lentekhi, Sachkhere). In Western Georgia, there is also a significant increase in the number of consecutive wet days), which contributes to flood risks. There is no evident increase in these indices during the forecast periods, so, no increase in flood risk should be expected.

The number of heavy precipitation days (R90mm) has increased significantly in the coastal regions of Adjara (Batumi, Kobuleti); an upward trend has also been observed in Poti (R80mm). In both forecast periods, both indices show a downward trend everywhere except Kobuleti.

Sum of annual total precipitation (PRCPTOT) has increased in most eastern regions of Georgia, especially in autumn. The upward trend in Rx3day and Rx5day on the Alazani tributaries indicates at increased flood risk. The Lagodekhi and Telavi weather stations report an increase in the number of heavy precipitation days (R30mm, R50mm), especially in autumn, in the Alazani River Basin. It should be noted that, unlike Western Georgia, there is no obvious upward trend in CWD in the eastern regions.

According to the climate change scenario, a significant increase in the number of heavy precipitation days (R30mm) is expected at Telavi, Stepantsminda and Tianeti stations in Eastern Georgia, and R50mm at Telavi and Kvareli stations. No significant increase in CWD is expected in Eastern Georgia.

Droughts

Droughts are observed almost throughout Georgia and are particularly severe in Kakheti, Shida Kartli, Kvemo Kartli and Zemo Imereti. If earlier droughts recurred with the interval of 15-20 years, lately they occur every 6-7 years. In 1995-2008, damage caused by droughts to agriculture alone amounted to GEL 400 million.

Georgia is a diverse region in terms of precipitation. Thus, in the Greater Caucasus, Guria-Adjara and Kolkheti plains annual precipitation exceeds 1000 mm, while in the rest of the country it is less than 300-750 mm. This is why desertification, which is mainly caused by drought, is an urgent problem for Georgia, especially for its eastern regions.

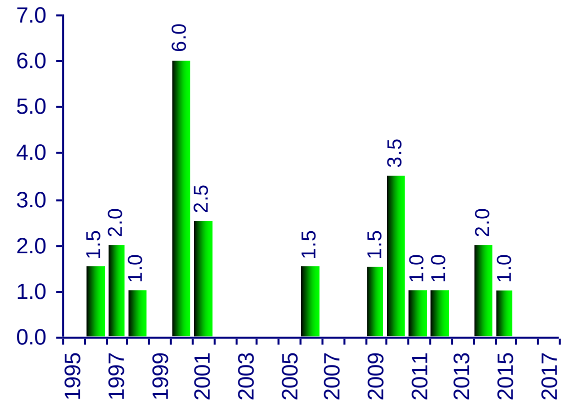


Figure 4.8.2: Drought duration in months in 1995–2017

This was well illustrated by drought that hit Georgia in 1998-2000 and strongly affected the national economy. In 2000 drought lasted for more than 7 months. If global climate warming continues, desertification may affect arid and semi-arid landscapes and foothills in Eastern Georgia, as well as sub-alpine and alpine zones in the mountainous regions. In the absence of preventive measures, the process can become irreversible, especially in Kvemo Kartli region and Dedoplistskaro district.

Strong Winds

In Georgia strong winds are caused by different types of synoptic processes and in each individual case are conditioned by magnitude and direction of the pressure gradient and physiogeographic conditions of the region. Strong west and east winds prevail throughout the year on the territory of the country, which is conditioned by the terrain and the direction of the mountain ridges. Wind direction varies seasonally, thus, in Western Georgia, east winds prevail in winter, and west winds - in summer, and in Eastern Georgia, west winds prevail over east winds.

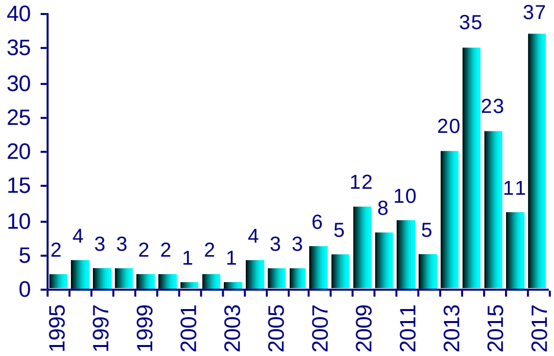


Figure 4.8.3: Strong wind events in 1995–2017

East and west winds prevail in the Kolkheti lowland. The prevalence of north winds in Abkhazia is caused by proximity of the Caucasus Range. In Adjara and Guria, west sea winds prevail most time with east winds gaining momentum in winter. In the Kolkheti lowland, sea winds prevail in summer and continental winds – in winter. Local winds gain/in importance in the eastern part of the Kolkheti lowland, in the vicinity of the Likhi ridge, giving strength to east winds.

Strong winds are particularly damaging to agriculture and various infrastructure facilities. In 1996-1998 alone wind damage exceeded GEL 80 million; 10 people were killed.

Snow Avalanches

On the territory of Georgia snow avalanches are particularly intense in mid-mountain and high-mountain zones of the Caucasus, Lesser Caucasus and Guria-Adjara region. There are about 5,000 avalanche hotspots in the country, of which more than 1,100 pose threat to highways, populated areas and communication infrastructures. Of particular note in this respect are the years 1970-1971, 1975-1976, 1986-1987, 1996-1997, and 2004-2005 when heavy snowfall caused catastrophic avalanches that killed 176 people and caused damage exceeding $ 750 million.

Table 4.8.2: Recurrence of avalanches (%) by months and altitudes

Altitudinal belts, m	Number	X	XI	XII	I	II	III	IV	V	VI	VII	Total, %
1000	25				1.2	1.6	1.6					4.4
1000-1500	78			0.7	2.0	4.5	6.2	0.3				13.7
1500-2000	158		0.5	3.3	5.0	6.3	11.5	1.2				27.8
2000-4000	310	0.3	2.5	5.2	6.3	10.5	17.8	10.0	1.0	0.2	0.3	54.1
Total	571	0.3	3.0	9.2	14.5	22.9	37.1	11.5	1.0	0.2	0.3	100

Mountain weather stations have been selected to assess the upward trend in avalanche hazard in the context of climate change.

Table 4.8.3: Weather stations in the mountainous regions

Station	Region	Altitude m
Goderdzi Pass	Ajara	2030
Khulo	Ajara	1338
Bakhmaro	Guria	1926
Mta-Sabueti	Imereti	1248
Gudauri	Mtskheta-Mtianeti	2194

Station	Region	Altitude m
Ambrolauri	Racha-Lechkhumi and Kvemo Svaneti	731
Lentekhi		1508
Shovi		1549
Mestia	Samegrelo –Zemo Svaneti	1448
Bakuriani	Samtskhe-Javakheti	1665

Station	Region	Altitude m	Station	Region	Altitude m
Stepantsminda		1080			
Pasanauri		1809			

The precipitation indices (Rx1day, Rx3day, Rx5day, R30mm, R50mm, CWD and PRCPTOT) have been considered for November-May, which is the avalanche-prone period in Georgia.

Intensity and duration of solid precipitation is one of the avalanche-forming factors. Analysis of data provided by the selected stations shows an increase in Rx1day in winter at almost all the stations except Bakhmaro. A significant increase in Rx3day and Rx5day is observed in Racha-Lechkhumi and Kvemo Svaneti. In the same regions, as well as in high mountainous Adjara, the number of heavy precipitation days (R30mm, R50mm) has slightly increased. A significant increase in CWD is observed at Ambrolauri and Lentekhi stations. A significant increase in Rx3day in cold season has been forecast for both 30-year periods (2041-2070 and 2071-2100) in Bakhmaro. Rx3day shows the upward trend at almost all stations, especially in Mestia, Ambrolauri and Goderdzi Pass, while Rx5day increases at Bakhmaro, Ambrolauri, Bakuriani and Shovi stations. No significant increase in CWD is observed.

Case Study

On July 2018, water in the Nenskra River reached a critical point as a result of heavy precipitation and intensive glacial melting. Extreme flood and mudflow processes developed due to high temperatures that prevailed at that time and heavy precipitation in the Nenskra Gorge. The river overflowed its banks, flooding and destroying buildings, roads and bridges that connected villages in the Chuberi community.

Mitigation measures taken in 2014-2018 included:

- Acquisition of up-to-date information from weather radars owned by Delta Enterprise, Sakaeronavigatsia and Turkish Meteorological Service with the purpose of forecasting heavy precipitation and floods/flashfloods on the territory of Georgia;
- Installation of 35 fixed automatic devices for measurement of hydro-meteorological parameters acquired within the framework of the Adaptation Fund-supported project and introduction of flood/flashflood early warning system Delft-FEWS;
- Flood, mudflows, landslides, rockslides and snow avalanches maps were developed for six community (Mestia, Mulakhi, Lenjeri, Becho, Nakra, Chuberi) of Mestia Municipality and preparation recommendations on preventive measures.

Monitoring, Prevention, Forecasting and Early Warning of Extreme Hydrometeorological Events

Monitoring and recording of extreme hydrometeorological events has a long history in Georgia with observation data counting more than 100 years. Threats assessment and multi-annual statistical analysis are mainly conducted using empirical methods that only allow for background mapping. In order to develop large-scale practical maps to prohibit settlement and all types of agricultural activities in hazardous areas, it is necessary to conduct geodetic and hydrometric surveys across the country that will include hydraulic, hydrological and geophysical modeling.

At present, Georgia has background maps of extreme hydrometeorological hazards (1:2,000,000 scale) based on multi-year observations of extreme events. The National Environmental Agency has implemented a number of small-scale projects to assess natural hazards, mainly floods and flashfloods. Special mention in this regard should be made of the project titled "*Developing Climate Resilient Flood* and Flash*flood Management Practices to Protect Vulnerable* Communities of *Georgia". The project funded by* the

Adaptation Fund under the Kyoto Protocol of the UN Framework Convention on Climate Change has identified vulnerable areas, assessed, modelled and mapped hazards in the Rioni Basin.

Territorial Zoning by Extreme Hydrometeorological Events

Registration of extreme events started in Georgia in the 1960s. Different sources contain earlier fragmentary data (from the 12th century on). In 2009-2011, historical data for 1121-2010 were collected within the framework of "I*nstitutional Capacity Building* in *Natural Disaster Risk Reduction"* project funded by the Government of the Netherlands. This helped to identify geographical coordinates of potential disaster sites and crate spatial databases that contain information about all kinds of natural disasters, including hydrometeorological events (floods, flashfloods, snow avalanches, hail, drought, strong winds). The statistical analysis of the data also revealed the regions most vulnerable to extreme hydrometeorological events and most sensitive to various threats.

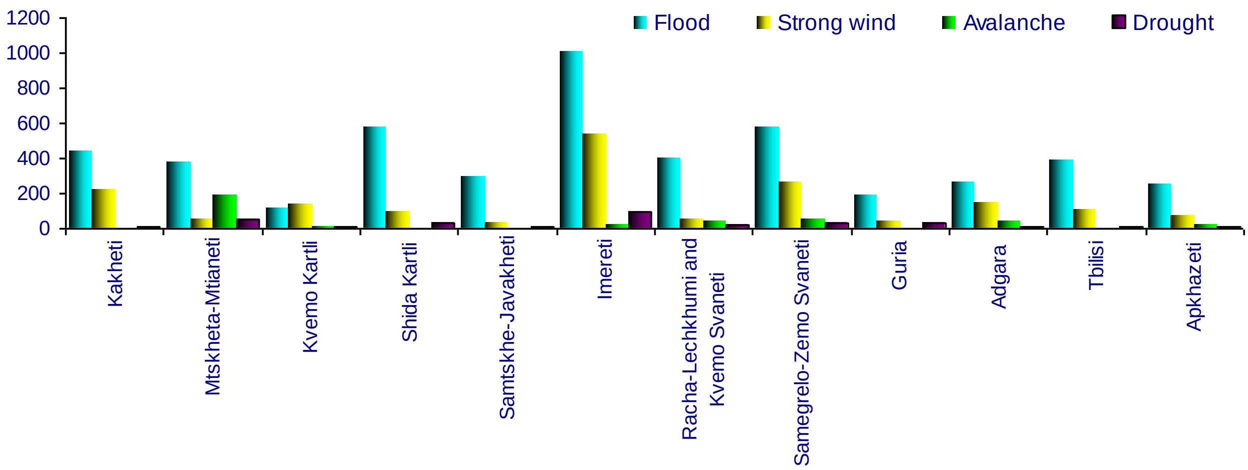


Figure 4.8.4: Number of extreme hydrometeorological events in 1121-2010 by regions

The statistical analysis also showed that floods and flashfloods are the most frequent hydrometeorological events in Georgia and that 21% of them occur in Imereti. The region is also frequently affected by droughts and strong winds (28% of droughts and 30% of strong winds). Snow avalanches are particularly problematic for Mtskheta-Mtianeti region, with almost 50% of all avalanches occurring there.

According to the percentage distribution, there are twice as much extreme hydrometeorological events in Tbilisi as in Abkhazia. However, the hydrographic network of Abkhazia is much larger with strongly segregated geomorphology and what is most important, Abkhazia has large amounts of annual precipitation, ranging from 2000 mm to 3000 mm in the mountainous areas, consequently, the data on Abkhazia appear to be unreliable.

Table 4.8.4: Distribution of extreme hydrometeorological events by region

Region	%
Tbilisi	7
Abkhazia	4
Kakheti	17
Mtskheta-Mtianeti	9
Kvemo Kartli	5
Shida Kartli	11

Region	%
Samtskhe-Javakheti	5
Imereti	18
Racha-Lechkhumi and Kvemo Svaneti	6
Samegrelo-Zemo Svaneti	10
Guria	3
Ajara	5

Given that the data for 1121-1960 are patchy and incomplete, it would be inappropriate to use them for statistical analysis. Therefore, the analysed data were divided into three periods: 1961-1976 (15 years), 1977-1993 (16 years) and 1994-2010 (16 years) (Figure 4.8.5). The analysis revealed that in 1995-2010 they recorded much more extreme hydrometeorological events than in 1961-1995. This may be caused either by climate change, namely increased intensity and frequency of atmospheric precipitation, or by the lack of complete information in 1961-1994.

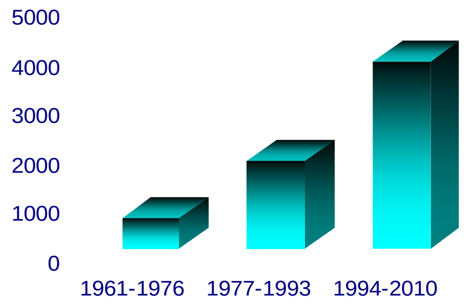


Figure 4.8.5: Extreme hydrometeorological events reported in different periods

Disaster Risk Reduction and Climate Change Adaptation Measures

Georgia has achieved a notable progress lately in reducing risks of natural disasters with the help of international donors and partners. In pursuance of the Sendai Framework for Disaster Risk Reduction 2015-2030, the State Security and Crisis Management Council, through the joint and coordinated interagency effort, developed National Disaster Risk Reduction Strategy of Georgia for 2017-2020, approved by Government Resolution No 4 of January 11, 2017.

The National Strategy, aiming to establish a unified, flexible and effective system, outlines the key preventive measures to be implemented over a four-year period and identifies responsible agencies. During the strategy development, the most hazardous areas were selected and mitigation measures were outlined, including: arrangement of an automated hydrometeorological observation network for creating an early warning system; performance of topographic and gauging stream operations and hydraulic / hydrologic modelling; arrangement of appropriate coast protection facilities, etc.

The Ministry of Environment Protection and Agriculture of Georgia prepares quadrennial National Communication on state of environment, dedicating separate chapters to natural disasters. The report overviews natural disasters that occurred in Georgia in the last 4 years, analyses their adverse effects and measures taken by Georgia for reduction/mitigation of hydrometeorological hazards.

It is noteworthy that the Government of Georgia implements “Scaling-Up Multi-Hazard Early Earning System and the Use of Climate Information in Georgia” project, aimed at developing Multi-Hazard Early Warning System (MHEWS). The seven-year project is being implemented through the United Nations Development Program (UNDP) and co-funded by Climate Fund (USD 27 million grant), by the Government of Georgia (USD 38 million) and by the Government of Switzerland (USD 5 million grant).

Eleven major river basins have been selected for identifying multi-hazards, assessing and mapping natural hazards and risks in Georgia.

The project provides for:

1. Identifying hydrometeorological and geological risks in the river basins;
2. Holding topographic and bathymetric surveys in high flood/flashflood risk areas;
3. Developing disaster risk management plans at the river basin level;
4. Mapping hazards taking into account current climate change;
5. Creating a multi-hazard early warning system;

6. Assessing socio-economic consequences, economic losses, and human casualties from hydro-meteorological and geological hazards, and vulnerability of various sectors of economy;
7. Creating a central information system and a knowledge exchange platform to inform governmental organizations and agencies about natural hazards and risks;
8. Building institutional and legislative capacities;
9. Implementing structural risk mitigation measures:
   - Installing wood or metal avalanche protection structures in avalanche-prone sites;
   - Constructing avalanche dams near settlements;
   - Carrying out high impact works to ensure road safety;
   - Carrying out hydrometric and topographic works in flood/flashflood-prone areas;
   - Developing hydraulic and hydrological modelling;
   - Installing/maintaining hydrometeorological stations for early warning;
   - Preparing relevant recommendations for coast protection measures.
10. Providing access to weather, climate and agro-meteorological information for farmers and the agricultural sector.

Furthermore, several specialized automatic agrometeorological stations and snow measurement stations, hydrometeorological stations and facilities will be commissioned and the following equipment will be purchased: a stream gauge; one short-range weather radar will be deployed in Kutaisi; two upper air sounding equipment units; two drones.

Alongside with assessing natural hazards, the project will provide recommendations on implementation of preventive measures that will require additional efforts.

4.9 Geological Hazards in Georgia

Georgia is one of the most difficult regions in the world in terms of development of disaster geological processes (landslides, debris/mudflows, rock avalanches, rockfalls, etc.), vulnerability and hazard risk: 70% of the country's territory and up to 60% of settlements are susceptible to risks of different extent. Geological hazards periodically have a serious adverse impact on thousands of settlements, agricultural lands, roads, oil and gas pipelines, high-voltage power transmission lines, hydroelectric power stations, mountain tourism facilities, etc. Negative socioeconomic, demographic and ecological impacts of landslide-gravitational, debris/mudflows and erosive events affect all areas of human life.

The National Disaster Management Strategy is based on the Hyogo Framework for Action 2005-2015 and Sendai Framework for Disaster Risk Reduction 2015-2030, as well as on principles set out in the Government of Georgia Resolution of 2017 approving the National Disaster Risk Reduction Strategy and Action Plan 2017-2020. The main purpose of the Strategy is identification, evaluation, and monitoring of geological hazards, risk identification and assessment, emergency planning, early warning system, etc., with the ultimate goal to exclude human casualties and significantly reduce economic losses.

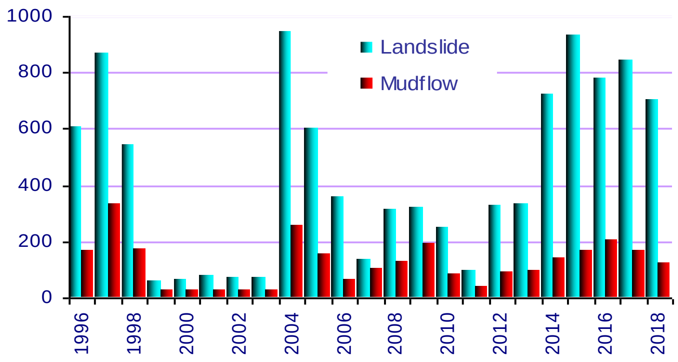


Figure 4.9.1: Landslides and mudflows, 1996-2018

According to the Department of Geology of National Environmental Agency [**74**], in recent years the quantity and magnitude of landslides and mudflow processes have increased significantly on the territory of the country (Figure 4.9.1). As of 2018, 18% (647 settlements) of Georgia's populated areas were under high risk of geological hazards (Table 4.9.1).

Table 4.9.1: Number of settlements under geological hazard risk, by region

Region	Risk			
	High	Moderate	Low	Very low
Adjara	131	128	42	28
Guria	56	61	63	13
Samegrelo – Zemo Svaneti	67	121	145	149
Imereti	73	151	152	170
Racha-Lechkhumi and Kvemo Svaneti	82	103	36	34
Samtskhe-Javakheti	17	37	35	182
Shida Kartli	7	11	32	311
Kvemo Kartli	22	39	26	277
Mtskheta-Mtianeti	171	124	49	142
Kakheti	18	74	63	187
Total	**644**	**849**	**643**	**1,493**

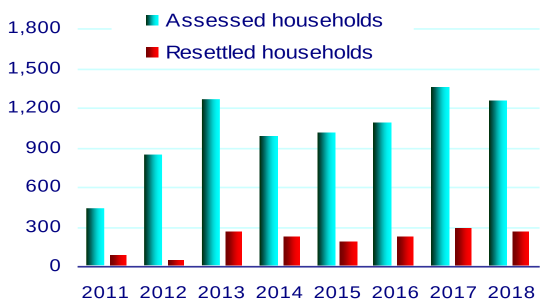


Figure 4.9.2: Households resettled in 2011–2018

Geological disasters have had a severe impact on the population of Georgia in recent years, leading to huge economic losses and killing 60 people in the 2009-2018. In 2011-2018, NEA Department of Geology assessed 8,229 households, of which 1,545 had to re-locate to the geologically sustainable area. Figure 4.9.2 shows numbers of assessed and resettled households in 2011–2018. Landslides and mudflow events are key among geological hazards in terms of their magnitude and risk, which increase year-on-year. In 2009-2018 the economic loss associated with these hazards was approximately $454 mln (Table 4.9.2).

Table 4.9.2: Landslides and mudflows and associated casualties and economic losses in 2009-2018

Year	Landslide			Debris/Mudflow			Total casualties	Total economic loss ($ mln)	Affected objects	
	Re-activated and new	Human casualties	Approx. economic loss ($ mln)	Re-activated and new	Human casualties	Approx. economic loss ($ mln)			Settlements	Houses
2009	323	1	27.6	193	3	7.2	4	34.8	285	2,696
2010	250	3	8.7	81	2	2.2	5	10.9	295	822
2011	94	3	5.6	37	8	3.9	11	9.5	309	463
2012	325	1	11.8	88	5	21.7	6	33.5	350	845
2013	336	0	19.5	93	0	20.3	0	39.8	472	1,269
2014	727	0	26.7	141	10	65.2	10	91.9	845	962
2015	936	4	29.8	167	19	108.7	23	138.5	931	1,014
2016	780	0	17.6	208	0	8.9	0	26.5	934	1,084
2017	845	0	21.3	165	0	10.6	0	31.9	1,042	1,353
2018	702	1	19.6	122	0	16.8	1	36.4	1,057	1,245
Total	**5,318**	**13**	**188.2**	**1,295**	**47**	**265.5**	**60**	**453.7**		**11,753**

All Georgian regions were divided into zones and mapped according to the risk of damage resulting from landslides. The map reflects all types of known geological hazards, starting with the simplest ones where the deformation does not exceed the aeration zone, and ending with processes as deep as dozens of meters. It also shows separate landslides (from one hectare to hundreds of hectares) and their volumes (ranging from several thousand to dozens and hundreds of thousands m^3). The territory of Georgia is divided into 7 conditional landslide risk zones:

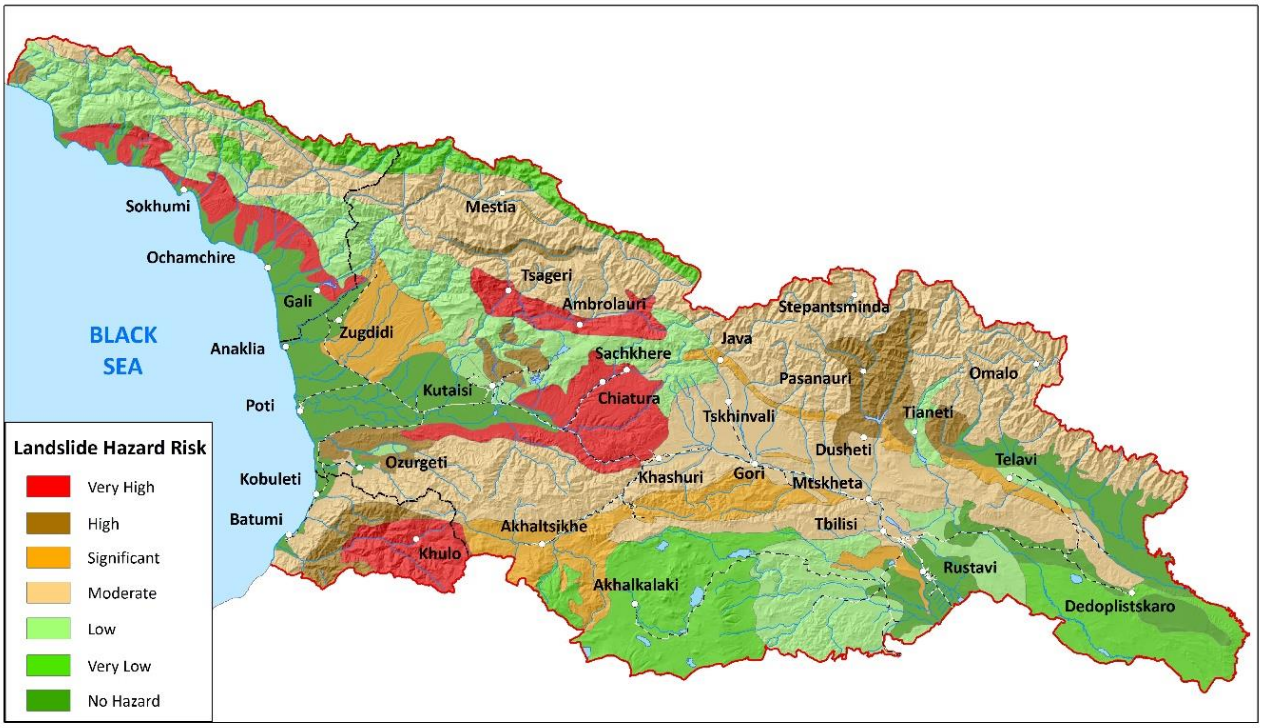
- **Very high risk zone**: severe damage and very high probability of occurrence; this zone includes mountainous Adjara, Imereti and Racha-Lechkhumi and Lower Svaneti, as well as the Black Sea coast of Apkhazeti;
- **High risk zone**: severe damage and high probability of occurrence; this zone includes: Guria foothills, Mtskheta-Mtianeti region, Okriba foothill zone and western part of Adjara;
- **Significant risk zone**: significant probability of landslides and significant damage; it includes northern slopes of the Trialeti Range with the Akhaltsikhe depression, the Samegrelo region (the hills of the Kolkheti North side) and the Tbilisi-Asureti area;
- **Medium risk zone**: significant probability of landslides; including the Trialeti ridge, eroded terrain of the medium and high mountain valleys of the Greater Caucasus, Upper Svaneti, the part of the Caucasus Range in Kakheti, the peripheries of the Shida Kartli depression, and foothills of the Tsiv- Gombori Range;

In the remaining part of Georgia, the risk of landslides is rather low. The mudflow risk zone mapping of Georgia was done in view of mudflow triggers and components of the multi-factoral geological environment of the country.

The territory of Georgia is divided into 9 conditional mudflow risk zones.

- **Very high risk zone**: severe damage and very high probability of mudflow occurrence; this zone includes Kakheti (Alazani-Iori basins), Racha-Lechkhumi and Kvemo Svaneti, Samegrelo-Zemo Svaneti and Mtskheta-Mtianeti;

– **High risk zone**: severe damage and high probability of mudflow occurrence; this zone includes Alpine zones of the medium and high mountain areas on the northern and eastern slopes of the Central and Eastern Greater Caucasus Range, as well as the high mountainous part the Smaller Caucasus in Adjara;



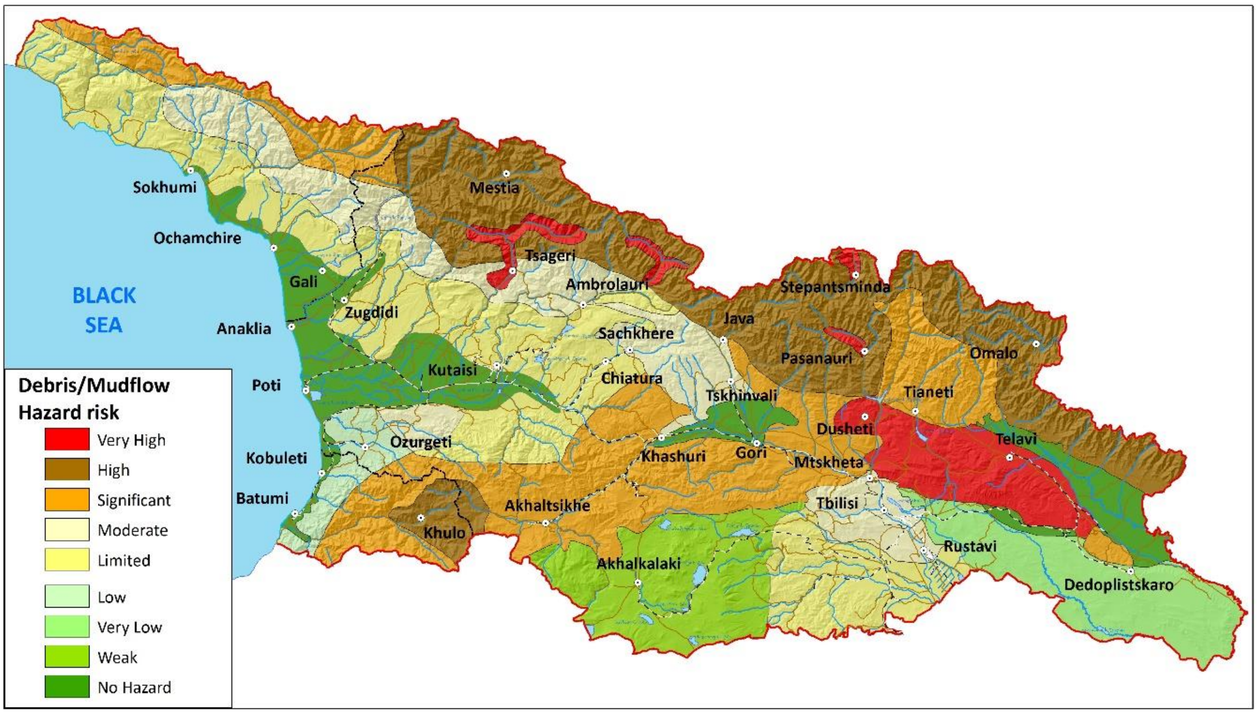
Map 4.9.1: Landslide Risk Zones Map of Georgia, by probability and damage

– **Significant risk zone**: significant probability of mudflows and significant damage; it includes the Trialeti and Meskheti ridges, medium and upper parts of the Kodori and Bzifi River basins of the Western Caucasus, and the western part of Adjara;

– **Medium risk zone**: significant probability of mudflow processes; middle reaches of the Rioni, Tskhenistskali, Enguri and Kodori river basins, headwaters of the Kvirila River basin, the low mountain and middle mountain zone of the Caucasus Range in Apkhazeti, the Algeti River basin, the Trialeti ridge in the vicinity of Tbilisi, and the low-mountain area of Adjara

– **Low risk zone**, including mountain reaches of the Dzirula, Khrami and Loki rivers, foothills of Guria and Imereti, the Psou, Sandripsha and Zhoekvara Rivers in Abkhazia.

In the remaining part of Georgia, the risk of mudflows is rather low.



Map 4.9.2: Mudflow Landslide Risk Zones Map of Georgia, by probability and damage

Causes / triggering factors of geological hazards

Multiple causes that may generate or activate geological processes include landslides, debris/mudflows, rock avalanches, rockfalls, etc. These vary in space and time depending on their main driving factors, or triggers causing destabilization. These triggers can be divided into three main groups:

- **Permanent:** geological structure (tectonics, stratigraphy, lithology) and morphological conditions;
- **Slowly changing:** tectonic movements, climatic and hydrogeological conditions, as well as changes in vegetation;
- **Rapidly changing:** meteorological, hydrological, seismic, engineering and agricultural activities, permafrost, rock strength and deformability.

The role of climatic and meteorological factors in the development of geological processes

Climate is a factor causing formation and reactivation of modern geological processes, especially such as landslides, debris/mudflows, rock avalanches and rockfalls. This factor is particularly important for regions with complex geology, relief and climate, such as Georgia, where more than 70% of landslides are directly associated with climatic conditions. As for mudflows and river erosion, these depend entirely on the climatic conditions in the area, where their meteorological triggers (atmospheric precipitation, humidity, etc.) highly vary in time and space between zones, as well as quantitatively.

The potential for the development of different natural geological processes in certain geographical environment depends on climate. Depending on the sensitivity of the particular geological environment, the intensity and activity of these processes may change under the impact of quantitative and qualitative changes in weather parameters (precipitation, air temperature, etc.) resulting from climate change. Different long-term engineering-geodynamic studies and regional geological monitoring as well as desktop analysis of long-term statistics confirm that over 70% of landslides and debris/mudflows occurring in given climatic and geological conditions as well as their dynamics are directly linked to changes in precipitation vs. annual and monthly means.

Climate-associated landslides are most common in Georgia. Their formation and dynamics of their periodic activation directly depend on precipitation, causing changes in local geology and deteriorating the shear resistance of local soils.

According to regional development and dynamic regime there are three main stages of landslide in Georgia:

- Maximum re-activation of landslide processes caused by paroxysmal extremes of precipitation (with deviation from the long-term mean values exceeding 400-600 mm);
- Moderate re-activation of landslide processes, which mainly includes intervals between periods of intensive landslide activation;
- Baseline period, when the number of landslides significantly exceeds the number of landslides that occurs during active landslide periods. In the baseline period, landslides either normally upgrade to stress activation condition or temporarily stabilize, depending on the amount of precipitation and the “moisture effect” of the slopes.

It is noteworthy that the amount and timing of annual precipitation changes are often the same in separate locations. Yet landslide processes activate in different years in these areas, which is potentially due to the geographical location of the site, vertical zoning of the terrain, and local orography.

Unlike “climate-associated” landslide processes, more than 70% of mudflows depend on the amount and intensity of rainfalls that occur during the day.

In general, the mudflow-triggering potential of precipitation depends on its intensity and duration. However, depending on engineering-geological conditions and morphology in potential mudflow-risk areas of river basins, the same amount of precipitation may differently affect the development of mudflow processes. Similar rainfalls may cause either a flashflood or a typical mudflow, depending on the specifics of local geological environment and sensitivity of local mudflow-prone areas.

In the geological environment of Georgia, the lower limit of daily precipitation that could potentially trigger debris/mudflows in the warmer period of the year (from April to October) is the 30-50 mm per day. Precipitation ranging between 50-80 mm per day would cause mudflows in all geologically "sensitive" catchments. Precipitation of 80-100 mm or more per day causes extreme mudflows in all mountain river catchments, provided there is sufficient volume of loose geological material easily erodible geological formations to form the mudflow.

Thus, calculations have been made to define by how much annual precipitation should exceed the average long-term value in order to trigger landslides in the local geological environment, or how much rainfall during the day could produce mudflows.

Figure 4.9.3 shows the relationship between increased annual precipitation and activated / new geological processes in Khulo and Dusheti municipalities, 2006-2015.

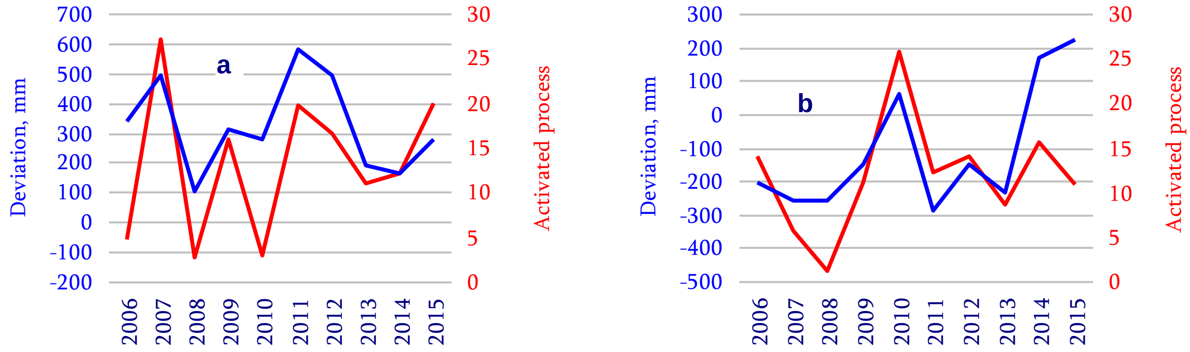
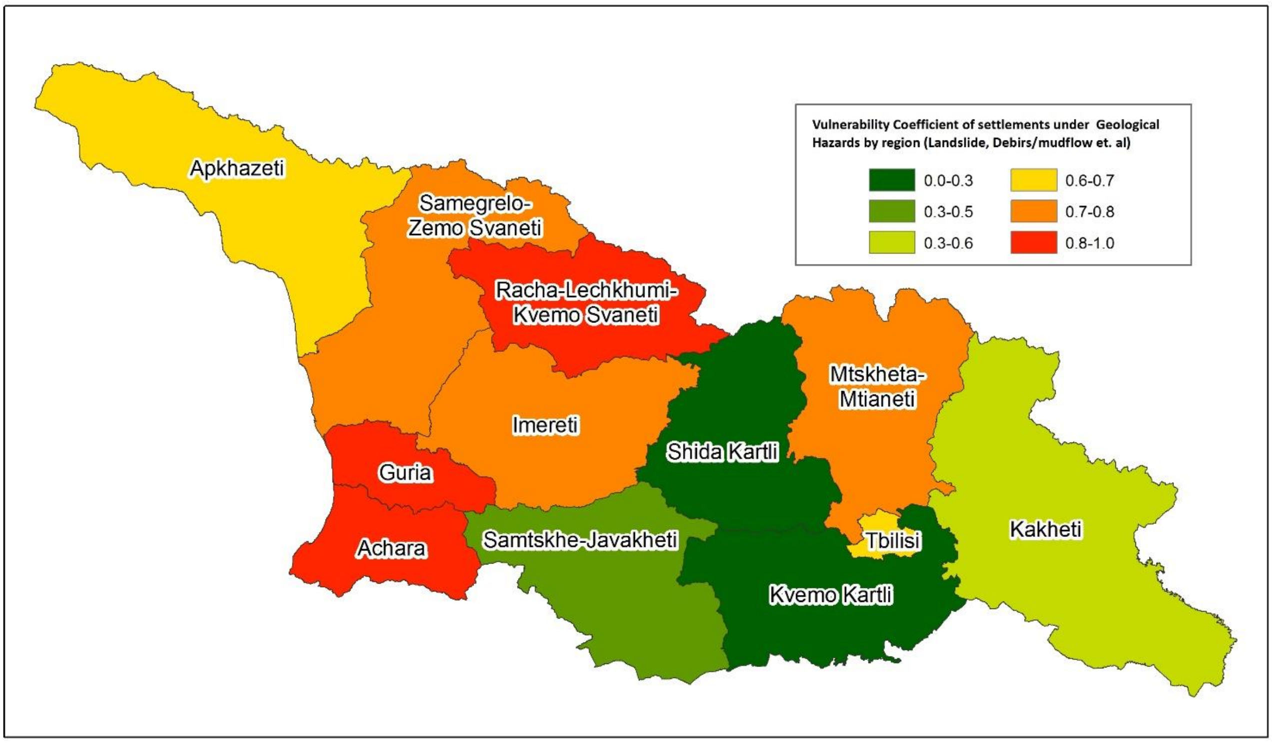


Figure 4.9.3: Relationship between increased annual precipitation and activated / new geological processes in Khulo (a) and Dusheti (b) municipalities, 2006-2015

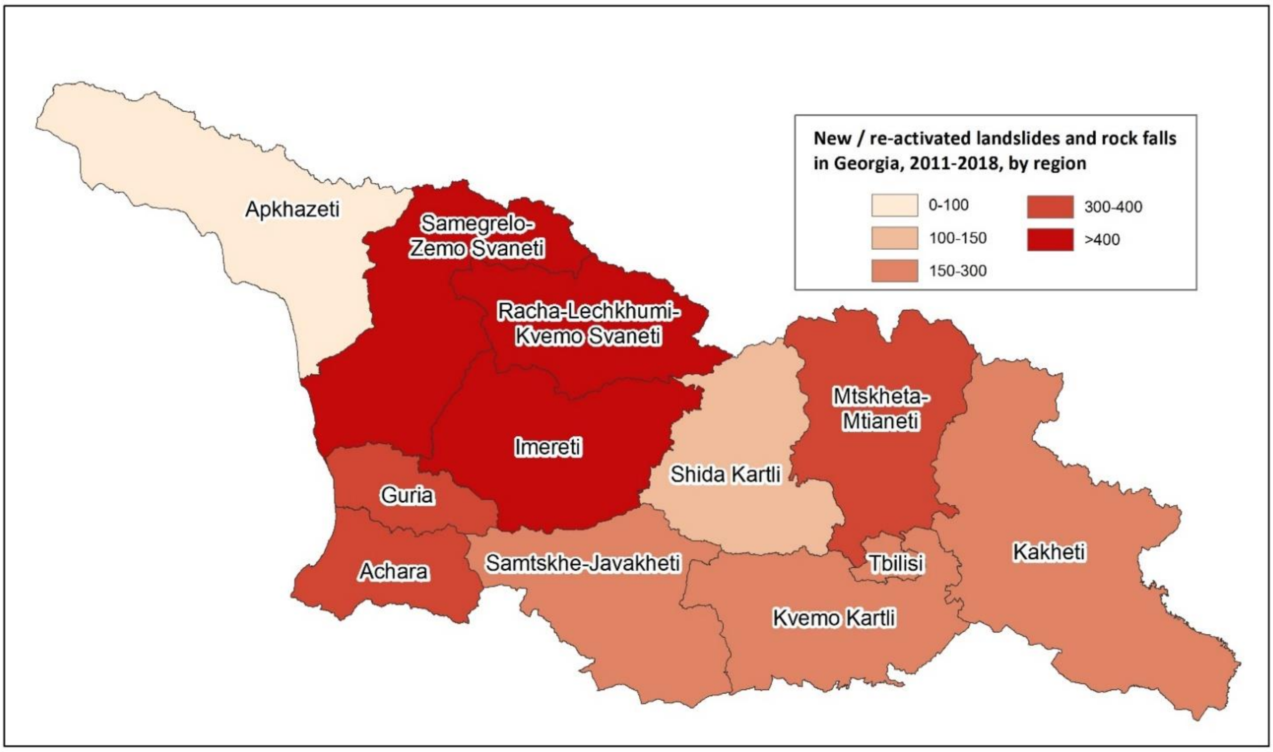
Prediction of geological hazards in space and time, including occurrence of landslides and mudflows, and assessment of associated risks remain a challenge, as there is no commonly accepted methodology. In addition, long-term forecasting requires acquisition, analysis, generalization of data and creation of an digital geodatabase reflecting multifaceted process determinants and hazard-triggering abiotic and biotic agents. It should be noted that previously generation occurrence and activation landslide processes due to local geological sensitivity occurred once in 3-5-8-11 years, yet since the beginning of the XXI century this rate has changed, and there is currently almost no the cyclicality, and every year the processes occur more frequently compared to the baseline.

On the basis of historical data (archives), geological hazard mapping was carried out by region [77]. During the mapping, a hazard category (high, medium, low, very low) was assigned to every settlement and the region's vulnerability coefficient was calculated in view of the total number of settlements in the area (see map 4.9.3). The map clearly shows that the most geologically vulnerable areas are Adjara, Guria and Racha-Lechkhumi, and Kvemo Svaneti, whereas the least vulnerable ones are Kvemo Kartli and Shida Kartli.

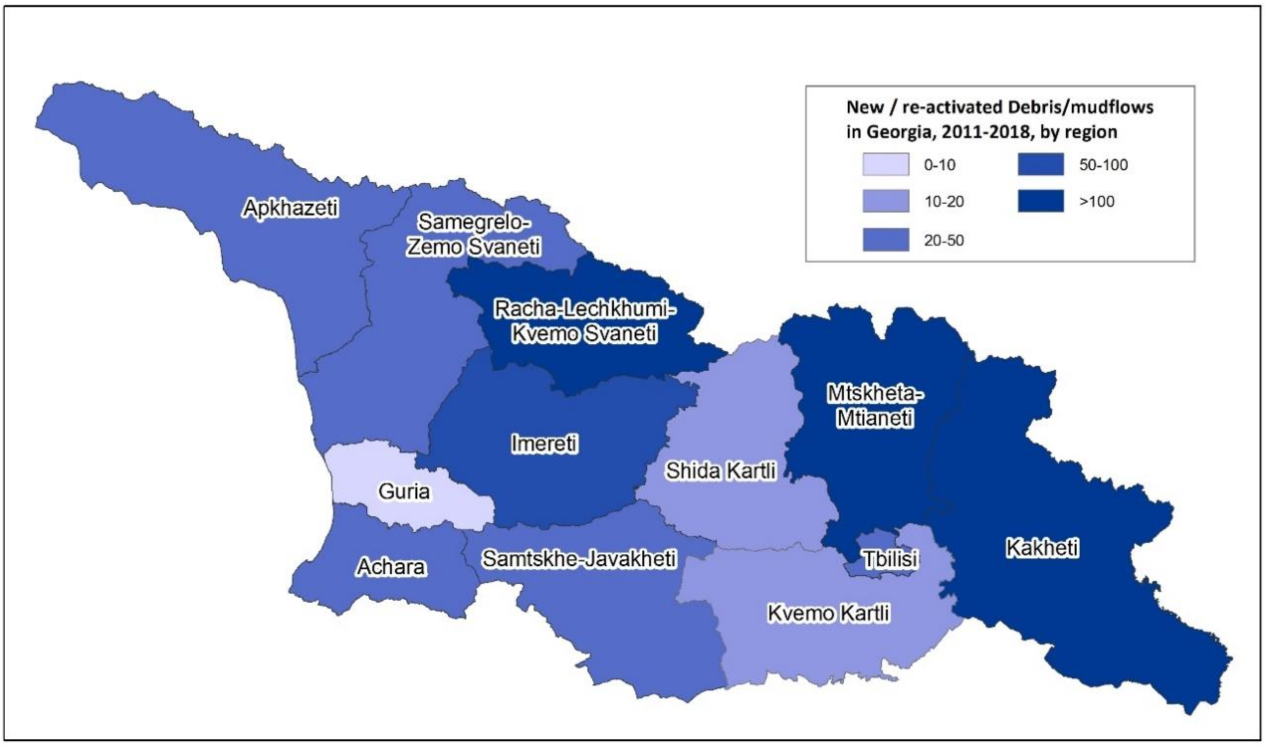


Map 4.9.3: Geological hazard Vulnerability Map of Georgia, by region

Data on new / re-activated geological processes in various parts of Georgia for 2011-2018 were processed and relevant maps prepared (Map 4.9.4 and Map 4.9.5).



Map 4.9.4: New / re-activated landslides and rock falls in Georgia, 2011-2018, by region



Map 4.9.5: New / re-activated Debris/mudflows in Georgia, 2011-2018, by region

Case study 1: Severe mudflow in the Dariali Gorge

On May 17, 2014, a catastrophic debris/mudflow event occurred at the confluence of the Tergi River and the Devdoraki-Amali River in the Dariali Gorge [75]. On May 17, a rock avalanche came down from Mt. Mkinvartsveri, bringing along five million cubic meters of rock, which was covered by ice and snow. The rock mass fell down on the Devdoraki glacier, deformed it and went on to the Devdoraki River. From the confluence with the Amali River, the flow transported the rock debris and mud downstream to the lower reaches. At the confluence of the Amali and Tergi rivers, the flow created a huge debris cone, approx. 2 mln cubic meters, that totally blocked the Dariali Gorge, erecting a 30 m high obstruction and inundated Tergi river, and took the lives of eight people.

On August 20, 2014, heavy rainfall in Devdoraki valley triggered the movement of the huge debris mass that had accumulated there on May 17, 2014, turning it into a mudflow and killing two people working at a hydroelectric power plant construction site near Tergi River.

The events of May 17 and August 20 caused major material damage to the country as a whole, disrupting the Georgian Military Highway, the North-South Gas Pipeline, cutting a high-voltage power transmission line, damaging vehicles, blocking the access to a border defense facility and customs checkpoint, the Residence of the Georgian Patriarchate, and causing huge everyday problems to people working there.

The main causes of the disaster were the geological structure of the area, local tectonics and morphology, as well as the negative impacts of climate change.

After the disaster, NEA used governmental funds to contract Swiss GEOTEST to install a modern early warning system for monitoring mudflows and critical water levels in the river, and to create a unified data exchange network to ensure proper functioning of the early warning system.

Case study 2: A disaster in the Vere River basin

On June 13-14 2015, heavy rainfalls caused a sharp rise in water levels in the Vere River and its tributaries, and triggered large-scale landslides and debris/mudflows, which resulted in the disruption of adjacent highways.

Landslides turned into muddy streams, the river waters full with the debris mass flooded some districts of the Georgian capital, Tbilisi, and washed away and / or inundated houses and infrastructure at the lower reaches of the Vere valley, killing 23 people [76].

The disaster almost destroyed the Tbilisi Zoo, many animals were killed and others were found outside the zoo, among them Big, a hippo whose photo travelled around the world after the incident.

Together with other triggers (geology, morphology, tectonics, hydrogeology), the natural disaster on the Vere river was caused by the fast increasing of the river level resulting from heavy rainfalls (about 149 mm) associated with climate change, and primarily by a landslide with an area of 32 hectares and a volume of 1 mln cubic meters that had formed between the villages of Tskneti and Akhaldaba, a significant part of which clogged into the Vere riverbed. At the same time, more than 100 landslides were activated in the valley on June 13-14.

Long-term geological observations and analyses show that debris/mudflows occur in relevant geological conditions in case of 40-50 mm rainfall per day. The stronger the rainfall, the more extreme mudflows would occur.

To protect against such events, NEA installed modern hydro-meteorological equipment in the Vere River Valley, with real-time online transfer of data on precipitation and water levels. In addition, special landslide/mudflow restriction structures were installed in two places in the valley. Geological survey of the residential area and adjacent land was carried out, and recommendations given for necessary protective measures. A report was prepared on areas at risk in Tbilisi, potential inundation areas were identified, the riverbed was straightened and widened in certain areas, etc.

Possible climate change impact on geological processes

The expected climate change is associated with changes in some baseline meteorological parameters affecting the climate over two 30-year periods (2041–2070 and 2071–2100) versus the 30-year baseline of 1971–2000.

In the first forecast period, annual precipitation would increase only in Poti, by 10% (especially in spring - by 28%), and in Zugdidi, by 8% (especially in summer - by 29%). There is a significant increase of 23% in Mount Sabueti in summer and of 6% in Shovi and Tianeti. Precipitation in Akhalkalaki would increase by 20% in autumn.

Compared to the baseline period, the annual precipitation during the second forecast period increases exclusively in Tianeti, by 1% only. Yet in some locations there is an increase in precipitation during certain seasons, mainly in the range of 3-4%. In summer, precipitation would increase by 8% in Gori and Bolnisi, by 12% in Khashuri 12% and by 14% in Tianeti.

The following climate characteristics have been used:

1. **R50mm** is frequency (number of days per month or year) of *rainfall* exceeding 50 mm/day. In the baseline period (1971–2000), R50mm was particularly high at the seaside: 10.8 days in Batumi, 6.8 days in Kobuleti and 5.8 days in Poti. According to the climate change scenario, in future R50mm decreases in all regions: by 01–0.7 days and 01–0.9 days in the first and second forecast period, respectively. Thus, in future the impact of this parameter on geological processes would not increase.
2. **Rx1day** is the annual maximum 1-day precipitation amount, i.e. the highest amount of rainfall that comes in one day in a month or year. In the baseline period, Rx1day exceeds 150 mm in five locations, and in Batumi and Zugdidi it is 200 mm. In the first forecast period, Rx1day increases in 13 out of 39 locations, including an increase by 30% in Zugdidi, 25% in Tianeti and 20% in Lagodekhi and Khashuri. In the second forecast period, Rx1day also increased in 13 locations, most in Bakhmaro by 35%, Zugdidi by 30% and Tianeti by 20%. Geological processes are likely to increase in the three areas, most significantly in Zugdidi and Tianeti that are already at high risk.
3. **R99p** is the extremely wet day rainfall, i.e. annual sum of daily *precipitation* > 99th percentile. R99p increases in six locations in the first period and in seven locations in the second period. In the first and second periods, R99p increases in two high-risk areas: in Zugdidi, by 40 mm and 48 mm, and in Tianeti by 27 mm and 24 mm, respectively.
4. **CWD**, or consecutive wet days, is the maximum number of consecutive precipitation days during the year when the amount of daily precipitation is PR ≥ 1 mm. In the first forecast period, CWD increased by 2.2 days in Kakheti and Samegrelo-Zemo Svaneti, especially in Kvareli and Khaishi by 4.6 days, in Mestia by 3.3 days and in Gurjaani by 2.5 days. In the second forecast period, CWD also increased though not so much as in the first period: 1.2 days on average in Kakheti, and 1 day in Samegrelo-Zemo Svaneti.

In both forecast periods, in the Autonomous Republic of Adjara, as well as in the regions of Guria, Racha-Lechkhumi and Kvemo Svaneti, Imereti, Samtskhe-Javakheti, Shida Kartli and Kvemo Kartli, the activity of geological processes due to climate change would be similar to the baseline, while in Samegrelo-Zemo Svaneti, Mtskheta-Mtianeti and Kakheti it is expected to increase.

In 2041-2070, the **mean annual temperature** would increase from 1.6^{0}C to 3.0^{0}C throughout the country as compared to 1971-2000. In eastern Georgia the temperature would increase by 1.8^{0}C - 3.0^{0}C, in western Georgia it is slightly lower, by 1.6^{0}C - 2.9^{0}C. In the period 2071-2100, the mean annual temperature would increase by 0.4^{0}C-1.7^{0}C. As a result, the temperature rise for this period is 2.1^{0}C-3.7^{0}C compared to the average for the period of 1971-2000.

It should be noted that in the last twenty years, the process of rock mass weathering and fracturing has intensified in the mountainous regions of Georgia, which in future together with the rise in temperatures could increase the intensity of geological processes (especially debris/mudflows) throughout Georgia.

Geological hazard management projects

In recent years, the Department of Geology has implemented several significant geological hazard management projects, supported by different donors. These include:

– 2015-2017: "Evaluation of landslide susceptibility in the mountainous parts of Georgia on the example of endangered settlements, international roads and energy conduits in Dusheti municipality", financed by the Czech Development Agency (CzDA). The project included assessment of hazardous geological processes (landslides, mudflows, rock falls, etc.) in Aragvi Gorge, Dusheti municipality; risk mapping based on modern methodology; development of recommendations for protective measures to be implemented; and installation of monitoring network at several sites;

- 2012-2017: “Developing Climate Resilient Flood and Flash Flood Management Practices to Protect Vulnerable Communities of Georgia ", funded by the Climate Adaptation Fund and UNDP. Geological hazard zoning maps and reports were prepared for the 6 municipalities in the Rioni Basin; Modern monitoring equipment was set up on 3 landslide bodies;
- 2014-2015: “Development of Hazard Mapping Methodology and Generation of a Hazard Map for the Mestia Municipality”, funded by the Swiss Agency for Development and Cooperation (SDC). It was generated geological hazards (landslides, mudslides, rocks) zoning maps and developed preventive measures;
- 2015-2016: “Strengthening Disaster Risk Reduction Capacity in Georgia - Strengthening Urban Risk Management in Tbilisi”, funded by UNDP. In the project, the Geology Department generated a geological hazard zoning map, prepared a relevant geological report for the Gldaniskhevi river basin, and generated a list of recommendations for mitigation of multi- hazard risks;
- In late 2016, a comprehensive early warning system was set up in the Amali-Devdoraki Gorge. The project was supported by the Government of Georgia and implemented with NEA participation, with the aim of safe operation of the KP132-KP135 section of the Mtskheta-Stepantsminda-Larsi section of the international highway.
- Since 2019, the NEA Green Climate Fund, UNDP and SDC been implementing a project "Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia". The project aims at geological assessment of 11 river basins (historical data processing, field geological survey, field data processing, etc.), and generation of appropriate zoning maps of geological hazards (landslides, debris, mudflows, etc.).

Climate adaptation measures to be implemented in Georgia

- Enhance geological monitoring at the regional level to identify all types of hazardous geological processes, with particular emphasis on landslides and debris/mudflows; multiple factors triggering and reactivating these processes; risk for settlements, local population as well as infrastructure;
- Create a unified database of geological processes, including the location, type, causes, risk, facilities at risk, recommended protective measures, etc.
- Develop long-term forecasts of natural geological processes and events for a period of 20-30 years, based on engineering-geological surveys, at national and local level. Together with environmental determinants, climate is one of the crucial factors in geological hazard forecasting, thus it is important to update long-term climate forecasts at least every 2-3 years;
- Engage at the national and local level, undertake commitments and create supportive environment for disaster risk reduction; raise public awareness about mitigation of geological hazards;
- Allocate resources to prepare and implement disaster risk management strategies, policies, action plans for all relevant sectors, including financial and logistical resources;
- Prepare geological hazard zoning maps for the country (1: 500,000) and separate municipalities (1: 25,000-1: 50,000), based on the analysis and extrapolation of existing regional engineering-geological

and geo-monitoring data; update the maps at least every 5 years, because geological processes are always in dynamic;

- Installation of modern geological monitoring equipment and early warning systems in geologically strained areas;
- Implement major protection measures based on relevant surveys in geologically strained areas.

4.10 Vulnerability and Adaptation of Forests

Georgia is one of the world's most forest-rich countries with more than 40% of its territory covered with forests of which 95-98% is naturally occurring forests. Rich biodiversity of Georgia's forests is conditioned by species composition, growth and development characteristics and other factors. The forests are home for 400 tree and shrub species, and abundance of endemic tree species (61 species) is a sign of rich dendroflora. More than two-thirds of Georgia's forests grow on mean and steep slopes and perform soil protection, water storage, regulation, purification, and other critical protective functions. The forests covering the Caucasus Mountains are of utmost importance on global scale as the last pristine forests in the temperate climate zone.

Diversity and distribution of forest species is conditioned by climate diversity. Alongside with forest-rich regions, there are regions with only 10% of territory covered in forest. According to 2003 Forest Fund Inventory,[92] the State Forest Fund (SFF) area was 3,005,300 ha (including the Autonomous Republics of Abkhazia and Adjara), of which forested lands were 2,772,400 ha, including 0.5 million ha pristine forests, 2.2 million ha natural forests and 0.06 million ha man-made forests.

As regards species composition of forests, dominant deciduous species are beech (42%), hornbeam (11.8%), oak (11.2%), alder (7.2%), and chestnut (3.8%), while coniferous species (fir, pine spruce) cover 17.4% of forest area.

Figure 4.10.1 shows forest areas covered by dominant species.

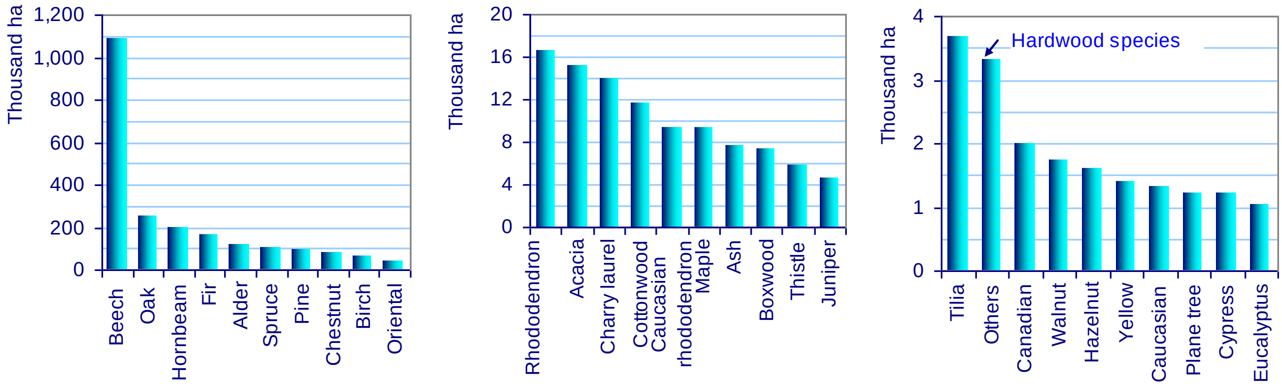


Figure 4.10.1: Forest areas covered by dominant species

The total growing stock is around 430 million m^3 and the average annual increase in growing stock is 4.0 million m^3. Figure 4.10.2 shows the total growing stock of dominant species.

[92] The document summarizing the forest inventory data was approved by the State Forestry Department in 2003 and is used as a base guiding document prior to updating relevant nationwide indicators.

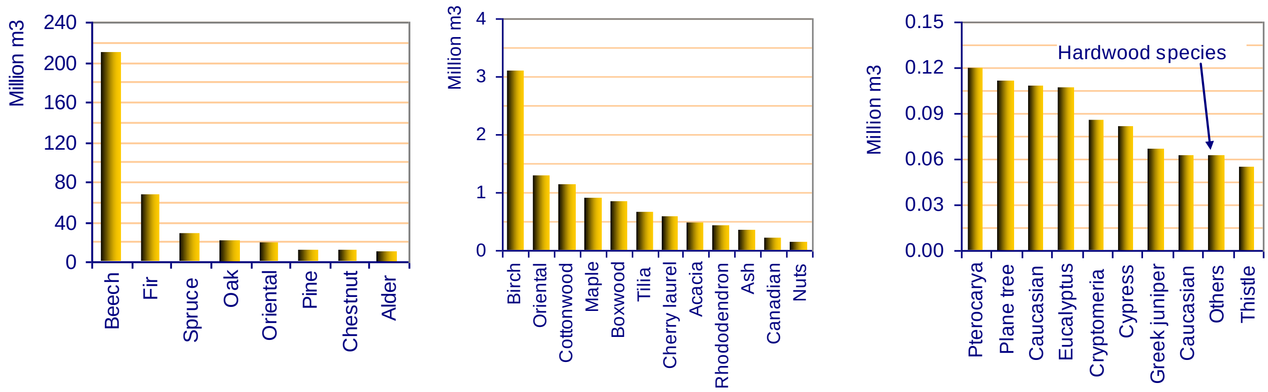


Figure 4.10.2: Total growing stock of dominant species

It should be noted that there has been no forest inventory in Georgia for decades, consequently, there is no up-to-date data on Georgian Forest Fund areas, including those covered by forests. All data in official documents and reports were based on 2003 figures. Later, they took as a basis the State Forest Fund boundaries, established by the Public Registry under Georgian Government's Resolution No 299 of August 4, 2011. However, serious mistakes in border demarcation prevent from getting accurate data on the State Forest Fund area.

According to official data, as of January 1, 2019, the total area of the State Forest Fund was 2,620,676 ha (including the protected areas and excluding the forests of the Autonomous Republic of Abkhazia).

The State Forest Fund area is managed by the following state agencies:

- National Forestry Agency - 1,996,900 ha, including 1,876,400 ha of forested land (including State Forest Fund lands (191,950 hectares) in occupied Samachablo and Kodori Gorge);
- Protected Areas Agency - 495,758 ha; including 248,790 ha of forested land;
- Forestry Agency of the Autonomous Republic of Adjara - 150,150 ha; including 141,200 ha of forested land.

In order to update the above data, it is necessary to carry out periodic forest inventory, which is one of the key and statistically reliable data sources for both sustainable forest management and full engagement of the forest sector in the climate change adaptation process. Forest inventory would improve the quality of the National Greenhouse Gas Inventory and increase the reliability of forest vulnerability assessment and adaptation measures.

The current **National Forest Inventory**, launched in 2019, offers the best way for addressing this issue, although certain progress in detailed forest inventory[93] began to show as early as in 2013. The inventory has allowed updating data on specific forest areas in Adjara, Guria, Samtskhe-Javakheti, Imereti, Kvemo Kartli and Kakheti regions.

Outdated forest data had always impeded adequate representation of the forestry sector on the National Communication on Climate Change, however, the Third National Communication managed to assess the forest areas of Adjara, Zemo Svaneti and Borjomi-Bakuriani and analyze vulnerability of local forest

[93] Management Level Inventory (MLI) is carried out at the level of forest areas (often coinciding with municipal boundaries). MLI data are used for management plan preparation.

ecosystems to the current climate change. Based on the assessment results, adaptation measures and project proposals have been prepared.

The Third National Communication also offered the following key recommendations:

- Prepare an action plan for sustainable development of the forestry sector;
- Enhance soil protective functions of forests for restoring degraded forests;
- Monitor diseases, especially climate change-driven ones, and work in close cooperation with forestry sectors of the neighbor regions and countries to prevent spreading of those diseases;
- Promote carbon storage capacity of forests by rejuvenating and increasing their density and quality;
- Explore alternative ways of forest privatization (community forests, tourism sector forests, etc.) and assess relevant risks to ensure sustainable forest management in the context of climate change.

Following preparation of the Third National Communication, Georgia has taken a number of successful steps towards implementing the above recommendations. By 2019, the Forest Code of Georgia was drafted. The key regulatory document of the forestry sector meets among other challenges recommendations of the Third National Communication. Since 2015, Georgia has seen a significant increase in forest restoration (Figure 4.10.3) and pest and disease control measures.

Despite the described achievements and a certain progress in the forestry sector, the Georgian forests still face many challenges, of which climate change impact is the most urgent. Global warming is already having an obvious impact on Georgia's climate and is likely to have a strong adverse effect on forests in the future. Lack of response or delayed response to these challenges will pose a serious risk of catastrophic degradation of large forest areas and cause a serious quantitative and qualitative decrease in forest resources and useful functions that are crucial for a large portion of the population.

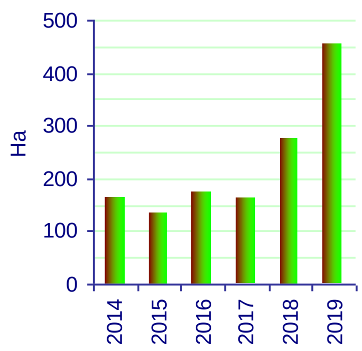


Figure 4.10.3: Restored forest areas in 2014-2019, ha

On the whole, there is a two-way relationship between forests and climate change. On the one hand, being the main terrestrial carbon sink ecosystems, forests globally play a critical role in the climate change process and mitigation of its negative impacts. On the other hand, climate change impacts composition and quality of forests, their vulnerability to pests, diseases and fires. The direct impact shows in a decrease in forest cover, sometimes in its increase (for example, the expansion of temperate-belt forests towards the poles), replacement of forest species and changes in forest distribution.

Studies conducted to this effect in different periods, show that the most reliable indicators of direct and indirect impact of climate change on forests is the distribution of temperature and precipitation in time and space that conditions distribution area, growth course and alternation of plant species, natural regeneration of forests and formation of forest types in general.

In case of Georgia, a comprehensive assessment is complicated by objective reasons, such as the lack of baseline data and information. In addition, the factual analysis is complicated by strong human impact that local forests have been experiencing for almost three decades, which has directly told on forest health and on indicators of adverse impact of climate change. For example, forest inventory update in Guria region (2017-2018) revealed a change in habitat areas of several dominant species compared to 1996 (the year of the previous inventory). In particular, a decrease in habitat areas was reported for the dominant species (beech, chestnut, oak, fir, pine, spruce) of commercial value, which was most likely caused by both legal and illegal felling over the course of many years. On the other hand, habitat areas of commercially less attractive tree species (tung tree, cryptomeria) tend to grow.

An increase in forested areas is particularly noticeable in the mountains, where farmlands have been abandoned for years due to migration of local population. Furthermore, species composition of local forests is typical of the relevant climatic belt and no significant change in species can be observed so far, which allows assuming that the changes described earlier are more likely to be caused by human impact than by climate change.

Given the above and the lack of uniform indicative data for the entire territory of Georgia, vulnerability of forest ecosystems to climate change can be assessed using the following quantitative indicators:

- Frequency of forest fires and areas affected by fires;
- Frequency of phytopathologic diseases and pests and damaged areas;
- Change in forest distribution and area.

According to the Third National Communication, the **Borjomi-Bakuriani** forests are particularly vulnerable to climate change impacts, as increased temperatures, decreased precipitation and longer droughts have contributed to higher frequency of fires and outbreaks of pests and diseases. According to forecasts, the negative impact will strengthen in the future.

During the preparation of the Fourth National Communication, climatic parameters of 2017 were analysed with respect to forest fires and forest pest and disease outbreaks that occurred in August 2017 in Borjomi municipality.

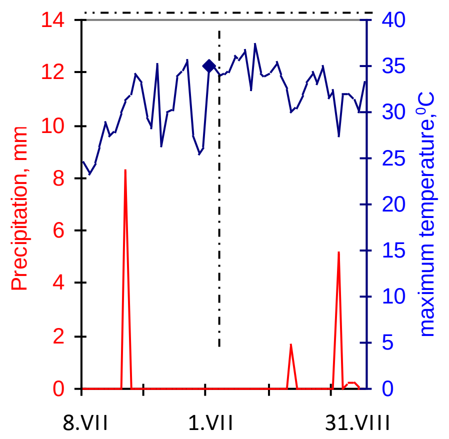


Figure 4.10.4: Precipitation and maximum temperatures, July 8-August 31, 2017

Rainless and very hot summer caused drying of the vegetation cover that resulted in rapid propagation of fire in the Borjomi Gorge in 2017 (on the area of 943 ha). According to the Borjomi weather station, in 2017, there were 236 rainy days in Borjomi. From July 8 to August 31, 2017, precipitation level was only 16 mm, including 7 mm in August (2 mm on August 17 and 5 mm on August 26). The maximum daily temperature in August exceeded 30^{0}C; the absolute maximum was 37.4^{0}C, the average maximum temperature was 33.3^{0}C. For comparison, in 1956-1985, the average August temperature in Borjomi was 26.6^{0}C (23.3^{0}C to 31.1^{0}C), and in 1986-2015, it was 28.7^{0}C (25^{0}C to 35^{0}C).

This caused the rapid propagation and complicated the suppression of the fire that started in the village of Daba, Borjomi, on August 20, 2017, causing a significant damage to the Borjomi Gorge ecosystem. Apart from the large-scale fire, two more fires were reported in Borjomi-Bakuriani region in July-September 2017 that damaged up to 15 ha.

Increased frequency of outbreaks of forest pests and diseases was also notable in Borjomi Municipality during the given period as had been forecast in the Third National Communication (TNC).

In general, populations of phytophagous insects in forest ecosystems are self-regulated under the influence of several factors, including: temperature-dependent reproduction rate, food reserves, natural enemies, etc. If these factors are within normal limits, they are not harmful and ecological balanced is maintained.

After 2015 (the period following the preparation of the TNC), spruce bark beetle (*Ips typographus*) became spread in the Borjomi-Bakuriani forests, causing serious damage to spruce groves. In 2016-2019, wilt disease was still rather intensive despite continuous pest control measures (pheromone traps, sanitation).

It is known that the beetle burrows through the weakened bark in spring, when the average air temperature is 15^{0}C and above, and such temperatures have become more frequent in recent years. Thus, in Borjomi in the first half of May 2017, the average daily air temperature exceeded 15^{0}C, and the average half-month temperature was 17.1^{0}C. Based on 2015-2019 monitoring results[94], unlike previous years, from 2015 on bark beetles managed to produce two generations annually.

As for the increased frequency of forest fires, it is largely due to human impact and cannot be taken for a direct indicator of adverse impacts of climate change. However, it is clear that climate change has both direct (high temperatures) and indirect (weakening of plants, drying of vegetation, especially of herbaceous and coniferous plants) impacts that complicate fire management.

Based on the analyzed data, it has been assumed that climate change contributed to fire risks in the Borjomi-Bakuriani forests and the expansion of areas and conditions favorable for pests. This trend is likely to be strengthened by future climate change.

As mentioned above, climate change can impact forest ecosystems both directly (changes in the course of growth of plants depending on precipitation and temperature) and indirectly (increased frequency of fires or spreading of new pest species and diseases).

These key indicators have been used for assessing climate change impacts in three regions (Kakheti, Mtskheta-Mtianeti and Guria) selected for consideration within the framework of the Fourth National Communication. The regions were selected based on several criteria, including the updated forest inventory data (2017-2018) for Guria region, which provides reliable and necessary information on changes that occurred in local forests in the period between 1980 and 2017. Abiotic and biotic disturbances have also been identified in the three regions, which are likely to be caused by changes in climatic parameters (temperature, precipitation, humidity, drought, increase in the number of frosty days, etc.) alongside with human impact.

The main indicators of forest areas in the study regions are given in Table 4.10.1.

Table 4.10.1: Forest areas and growing stock of dominant tree species in the selected regions

Region	Forest District	Forest Fund, ha	Forested Area, ha	Dominant species and stock, 1000 m^3					
				Spruce	Fir	Beech	Oak	Hornbeam	Alder
Guria	Ozurgeti-Lanchkhuti	33,646	32,178			2,426	2	175	876
	Chokhatauri	52,479	50,380	2,812	1,849	7,156		96	59
	Total	**86,125**	**82,558**	**2,812**	**1,849**	**9,582**	**2**	**271**	**935**
Mtskheta-Mtian	Mtskheta	49,492	23,270			873	455	234	
	Barisakho	67,392	65,370			4,980	1,093	665	29
	Pasanauri	50,692	49,171			3,746	822	500	22

[94] The monitoring is conducted with use of pheromone traps that are installed in the area from April to October and checked with 10-14-day intervals

Region	Forest District	Forest Fund, ha	Forested Area, ha	Dominant species and stock, 1000 m^3					
				Spruce	Fir	Beech	Oak	Hornbeam	Alder
	Tianeti	49,492	48,502			7,129	148	439	32
	Akhalgori	55,041	51,739			4,730	943	58	8
	Total	**272,109**	**238,052**			**21,458**	**3,461**	**1,896**	**91**
Kakheti	Akhmeta	64,892	61,647			8,052	243	1,024	57
	Telavi	57,124	53,125			6,985	357	1,269	32
	Kareli-Lagodekhi	71,676	67,204			8,041	1,328	565	63
	Sagarejo-Gurjaani	71,426	66,714			4,524	1,629	1,047	16
	Sighnagi-Dedoplistskaro	23,259	20,719			36	641	97	3
	Total	**288,377**	**269,409**			**27,638**	**4,198**	**4,002**	**171**
Total		**646,611**	**590,019**	**2,812**	**1,849**	**58,678**	**7,661**	**6,169**	**1,197**

Vulnerability of local forests to climate change has been assessed using a number of climate parameters (average maximum and minimum temperatures, number of hot and cold days, including days when the average temperature is above or less 10^{0}C, precipitation, growing season length, number of consecutive dry and hot days, air humidity) that influence the frequency of fires, pest and disease outbreaks, as well as replacement of forest species and changes in forest distribution.

Guria

Forests cover 48% of the territory of Guria region. The Forest Fund area is 86,125 thousand hectares, out of which 82,558 thousand hectares are covered by forest.

Beech is the dominant hardwood species in local forests, followed by hornbeam that occupies significant areas; coniferous species are mainly represented by spruce, fir and pine. Alder is the dominant soft-wooded broadleaf species. The undergrowth and shrubs are mainly represented by cherry laurel, common rhododendron and yellow azalea.

Importantly, in 2017, in parallel with forest inventory in Chokhatauri forestry district in Guria[95], climate change impacts and trends in forested areas of Chokhatauri Municipality were studied for sustainable, climate-adapted forest management planning. The inventory revealed that alongside with human impact Guria forests are affected by climate change, which mainly shows in increased spreading of forest pests and diseases. According to 2006-2014 data, 2,504 ha of forests were affected by pests and diseases (including 105 ha of boxwood groves and 2,399 ha of spruce groves, which were hit by great spruce bark beetle).

A monitoring conducted in Chokhatauri forestry district in 2017 assessed the general condition of local forests as satisfactory, in particular, it revealed a decrease in intensity of wilting caused by spruce bark beetle. Yet, new outbreaks of forest pests and diseases are possible according to future climate scenarios.

Two species - chestnut and boxwood, require special attention. From 56 to 60 percent of chestnut groves are affected by chestnut blight caused by bark-inhabiting fungus (*Cryphonectria parasitica (Murrill) Barr*), while box trees are affected by boxwood blight, caused by pathogenic fungus *Cylindrocladium buxicola* and by *Cydalima perspectalis* (Walker) or the box tree moth. It is noteworthy that the spreading and intense propagation of box tree moth can be directly linked to climate change. Although box tree moths are invasive species that are believed to have spread to Georgia from neighbor regions, their propagation and damage rates depend on climate parameters, which are expressed in Guria by rising average annual air temperatures. Thus, in 1986-2015 average annual temperature in Chokhatauri district increased by 0.4^{0}C as compared to

[95] Conducted with support of the International Union for Conservation of Nature (IUCN) and funding from Austrian Development Cooperation (ADC) within the framework of the European Neighborhood and *Partnership Instrument* (*ENPI*) *East Countries Forest* Law Enforcement and Governance (*FLEG*) *II Program.*

1956-1985 (maximum increase was in summer and autumn: 0.7^{0}C and 0.6^{0}C respectively). Considering insect biology, these conditions are favorable for production of several generations of beetles during one season. The geographic distribution of box tree moth also deserves attention. From 2014, box tree moth had been spreading intensively in Adjara, Guria, Samegrelo-Zemo Svaneti and Imereti, and in 2017 it reached Racha-Lechkhumi and Kvemo Svaneti, where temperatures are also rising, especially in spring and summer. Consequently, affected areas are likely to expand not only in Guria but also in these regions.

As regards vulnerability of Guria forests to fires, this problem is not the most urgent at the moment. On average, three small-scale wildfires are recorded annually in the region, however, according to climate change forecasts, the vulnerability to wildfires can increase both in terms of their frequency and area affected.

The forest inventory conducted in the region in 2017-2018 also revealed changes in the areas covered by the dominant species. However, the analysis shows that the changes are mainly caused by human impact rather than by climate change.

Table 4.10.2 shows changes in areas occupied by some dominant species in Chokhatauri and Lanchkhuti districts.

Table 4.10.2: Changes in areas occupied by some dominant species in Chokhatauri and Lanchkhuti districts

District	Dominant species	Occupied areas, thousand ha			Percent change
		As of 2003	As of 2017	Change	
Chokhatauri	Pine	85	29	-56	-66
	Spruce	5,230	2,318	-2,912	-56
	Fir	2,841	2,158	-683	-24
	Cedar	66	8	-58	-88
	Oak	84	5	-79	-94
	Beech	22,475	15,780	-6,695	-30
	Hornbeam	4,997	6,338	1,341	27
	Chestnut	834	2,023	1,189	143
	Tung tree		17	17	
	Ailanthus		1	1	
	Rowan		142	142	
	Yellow azalea		36	36	
Lanchkhuti	Pine	49	0	-49	
	Oak	58	0	-58	
	Beech	792	568	-224	-28
	Ashtree	113	0	-113	
	Chestnut	133	0	-133	
	Hornbeam	283	3,123	2,840	1,004
	Alder	3,746	2,373	-1,373	-37
	Tung tree	0	12	12	
	Cryptomeria	0	6	6	

As seen from Table 4.10.2, areas covered by dominating species that are more attractive from commercial viewpoint and subject to legal and illegal felling are shrinking, while areas covered by undergrowth species that replace the felled species, are expanding. The same concerns the boundaries of subalpine forests. The closer the mountain range to the sea the more humid the climate, and the upper boundary of the forest is lower than typical in continental climate regions. In Guria, the potential of vertical distribution of subalpine forests significantly exceeds its current state, which is largely influenced by human impact (overgrazing, deforestation). The climate change scenario does not forecast further lowering of the upper boundaries of the forest, and biomass growth is possible in case of appropriate forest management.

According to the climate change scenario, the average annual air temperature in Guria will rise by 2.8^{0}C in 2071-2100. The absolute minimum and maximum temperatures will increase significantly (by 5.6^{0}C) during this period. The annual precipitation will decrease by 4%. The seasonal total precipitation will decrease in all seasons. The number of hot days will increase by about 41 days, while the number of frosty days will decrease by 27 days.

Based on these forecasts, noticeable changes can be expected in Chokhatauri forests. In particular, more heat-loving and drought-resistant forest species are likely to develop, while vulnerability of forests to pests, diseases and fires will increase.

Consequently, a number of adaptation measures should be implemented to mitigate the negative impacts of climate change and to maintain and improve the quantitative and qualitative indicators of Guria forests, including:

- Restoration of degraded forests using complex methods (preference should be given to promoting natural forest regeneration and planting native species);
- Tending cutting, including thinning, to improve forests and increase the growing stock;
- Continuous pest control and monitoring activities;
- Fire prevention measures (arrangement of fire lanes and paths, cleaning forest from fallen dead wood, using early warning and detection systems);
- Energy efficient measures, including the use of dry firewood and creation of appropriate infrastructure to reduce firewood consumption and pressure on natural forests.

Mtskheta-Mtianeti

Vulnerability to climate change has also been assessed for forests of Mtskheta-Mtianeti region. Unlike Guria, Mtskheta-Mtianeti does not have any updated inventory data, but some basic information (species composition, forest cover, frequency of fires, trends in pest and disease outbreaks, etc.) is available for analysis.

Forests cover 269,409 thousand hectares or 39% of the region’s territory. Most of them grow on steep slopes and perform soil protection, water storage, regulation, purification, and other critical protective functions, as well as recreational functions. Dusheti and Tianeti municipalities are particularly rich in forest resources. Forests located in Kazbegi make part of the Kazbegi National Park, while one portion of Mtskheta forestry zone is part of the Tbilisi National Park.

Natural forests are mostly deciduous. Dominant tree species are beech, oak, hornbeam and alder.

Most forests in the region are arid light forests (400-600 m above sea level) with xerophytic vegetation. Georgian oak belt extends from 600 to 1200 m above sea level, while beech forests range from 1000 to 1600 m above sea level on northern slopes. Southern slopes are covered by oak or mixed oak forests (on shaded slopes). Deciduous forests on western, south-western and southern slopes are interspersed with pine forests. High mountain oak belt (1600 to 1900 m above sea level) is interspersed with fragments of beech and maple forests. Sub-alpine light and crooked forests (1900 to 2300 m above sea level) are represented by High Mountain oak, maple, litwinow birch, rowan, yellow azalea and other species. Above this belt begin alpine and subalpine meadows.

The forests in Mtskheta-Mtianeti region experience strong human pressure, which is mainly due to timber consumption and excessive grazing. However, the negative impact of climate change is also noticeable with respect to forest fires and pest and disease outbreaks.

In 2007-2019, up to 35 forest fires were reported in the region, with more than 75 ha of forests damaged and/or partially destroyed.

As regards the current climate change, in 1986-2015 the average annual temperature increased by 0.53^{0}C as compared to 1956-1985. The maximum increase in temperature (1.15^{0}C) occurred in August. Precipitation decreased, especially in Tianeti Municipality: a significant decrease was recorded in spring (23%) and summer (24%), and annual decrease was 18%. This has resulted in increased frequency of forest fires and spreading of new pests of deciduous trees: winter moth (*Operophtera brumata*), mottled umber (*Erannis defoliaria*) and others in 2013. Specialists ruled out invasion (i.e. spreading from other areas or neighbor regions) and explained the outbreak by climatic factors. The pests spread over 800 hectares in 2013-2014, but the populations were reduced as a result of effective control measures in 2014-2015.

According to the climate change scenario, the average annual air temperature in Mtskheta-Mtianeti region will increase by 3.3^{0}C in 2071-2100 compared to 1971-2000. The absolute minimum and maximum temperatures will rise significantly (5^{0}C), while the average annual precipitation will decrease by 5%.

Given that local forests are mainly deciduous and there is no tangible change in species composition, the expected climate change may even have a positive effect on the growing stock. The timberline is expected to move higher. However, all of the above will create favorable conditions for outbreaks pests and diseases and emergence of new pests and diseases. Fire risks will increase significantly, which in turn will worsen forest health. Consequently, it will be necessary to carry out assessment and monitoring of forest health throughout the region, implement fire prevention measures, identify degraded forest areas and intensify forest restoration activities.

Kakheti

Kakheti deserves a special consideration in terms of vulnerability to climate change, including climate change impact on local forest ecosystems.

Forests cover up to 30% (269,409 ha) of the region's territory; 98% of them are mountain forests of great environmental and economic importance.

It is also worth noting that 80% of the region's mountain forests grow on steep (more than 25^0) slopes, which increases their environmental significance. About 2% of forests are floodplain forests and 15% are protected areas. Forests are mainly composed of deciduous species with dominating beech, oak, and hornbeam. There are wingnuts (*Pterocarya*) and floodplain oaks found in the floodplain forests. Other tree species associated with oak forests are: chestnut, hornbeam, Oriental hornbeam, zelkova, lime tree, and maple. Here chestnuts often form both mixed and pure groves. The most common shrubs are: dogwood, *Swida australis*, medlar, privet, and yellow azalea.

Despite the significant decrease in precipitation and increase in temperature (average increase by season: 0.31^{0}C in spring, 0.94^{0}C in summer, 0.6^{0}C in autumn and 0.3^{0}C in winter; annual temperature increase: 0.54^{0}C), no intensive spreading or emergence of new plant pests or diseases has been recorded in the region. Yet, Kakheti forests are vulnerable to fires that have become more frequent over the years. According to data for 2012-2019, 4-5 fires are recorded annually in Kakheti and frequency of fires has increased over the last three years. The negative impacts of climate change are most obvious in Dedoplistskaro Municipality, which is one of the priority regions in terms of climate change. While preparing the Second National Communication to the UN Framework Convention on Climate Change, Georgian identified Dedoplistskaro as an area at risk of desertification, requiring effective implementation of adaptation measures. The list of adaptation measures included measures aimed at ensuring energy efficiency, such as the use of energy efficient furnaces and alternative energy sources, as well as cultivating fast growing plant species. Regarding the latter, certain progress was achieved in 2014-2018, when acacia trees, adapted to local climatic conditions, were planted on around 40 hectares in the municipality.

It is noteworthy that Dedoplistskaro is inherently poor in forests, and maintaining and improving their health is crucial for mitigating climate change impacts. Therefore, it is very important to take similar measures and plant more windbelts in the future.

Adaptation measures for forest ecosystems in Dedoplistskaro Municipality and in Kakheti in general should be planned with consideration of climate change forecasts and risks that such changes may pose. According to the climate change scenario, the number of consecutive dry days is expected to increase in 2071-2100 as compared to 1971-2000. Annual precipitation will decrease by 18%, while annual temperature will increase by 3.6^{0}C, and the downward and upward trends will respectively persist in all seasons, contributing to fire risk and emergence of new forest pests and diseases. Changes are expected in the distribution of tree species and natural regeneration abilities of forests, which will adversely affect their health. Based on the above, extensive measures should be taken across the region, including:

- Planting fast-growing species in unforested areas to reduce pressure on natural forest;
- Regeneration of degraded forests using complex methods (priority should be given to promoting natural reforestation, planting native species adapted to local climatic conditions);
- Tending cutting to improve the quality of forests;
- Continuous pest control and monitoring activities;
- Fire prevention measures (arrangement of fire lanes and paths, cleaning forest from fallen dead wood, using early warning and detection systems);
- Energy efficient measures, including the use of dry firewood and creation of appropriate infrastructure to reduce firewood consumption and pressure on natural forests.

The special adaptation measures should be reflected in regional and municipal action plans and policy papers based on the risks and climate change scenarios identified for Guria, Kakheti and Mtskheta-Mtianeti regions. It is necessary to consider climate change as one of priority challenges of the forestry sector that requires thorough analysis and assessment and to use analysis and assessment results as a basis and/or integral part of key sectoral strategies.

The measures include:

- Development of climate change adaptation strategies (including the municipal level) for Georgian forests using information from national and international sources;
- Development of climate change mitigation and adaptation guidelines for Georgian forests to serve as a basis for climate change mitigation and adaptation plans for vulnerable forests;
- Development of climate change vulnerability indicators for forest resources to collect non-climate data for analysis, including geoinformation analysis;
- Categorization of forests depending on species composition and vulnerability to climate change;
- Expansion of reforestation measures, establishment of nursery farms giving preference to species better adapted to climate change;

- Cultivation of fast-growing species to reduce pressure on natural forests;
- Enhancement of fire monitoring and prevention activities;
- Establishment of an effective pest and disease monitoring system.

4.11 Protected Areas

Brief Overview

The total area of protected areas of Georgia is 666,107 ha, which is 9.56% of the country's territory. There are 87 protected areas (PAs) in Georgia, including: 14 Strict Nature Reserves, 12 National Parks, 40 Natural Monuments, 20 Managed Reserves and 1 Protected Landscape. In addition to these, there are two Ramsar Sites and 39 Emerald Sites. Establishment of several new PAs is planned and expansion of the existing ones will increase the total PA area to 12% of the country's territory.

Protected areas play an important role in climate change mitigation and adaptation. A well-managed protected area ensures protection of existing habitats, prevention of land use changes, and restoration of degraded areas, thus promoting climate change mitigation [78]. Protected areas maintain important ecosystem services, thereby increasing the resilience and reducing vulnerability of livelihoods to climate change.

Healthy ecosystems represented in PAs act as significant carbon sinks and help reducing greenhouse gas emissions. For example, the pine forests of the Borjomi Strict Nature Reserve (6,983 ha) can accumulate 767,250 t of carbon (about 110 t/ha). These forests annually absorb 8 t/ha or 50,976 t of carbon dioxide [79]. Spruce trees occupying 85,000 ha on the territory of the Borjomi-Kharagauli National Park can accumulate 9.1 t/ha of carbon dioxide (i.e., 771,000 ton), while the 15,800 ha forest of the Mtirala National Park can accumulate about 143,000 t. The total market value of forests in the Mtirala and Borjomi-Kharagauli PAs is approximately EUR 5.3 million in terms of carbon accumulation capacity [80].

Peatlands in the Kobuleti PAs play an important role in carbon accumulation. It is estimated that natural peatlands annually reduce carbon dioxide emissions by 1.5-4 t per ha [81].

Protected areas reduce the vulnerability of livelihoods and the environment to climate change by maintaining the integrity of ecosystems. They play an important role in forming drinking water resources. For example, the Borjomi-Kharagauli PAs supply drinking water to Borjomi and surrounding villages, the Mtirala National Park supplies water to Batumi and surrounding villages. The Alazani River, originating in the Tusheti PAs, is an important source of irrigation water for farmlands of Kakheti. PAs provide timber and non-timber forest resources. Water bodies located in protected areas ensure fish stock conservation, etc. Furthermore, protected areas mitigate local climate and contribute to prevention and reduction of risks of natural disasters [80].

Climate change will have a significant impact on PAs, affecting their ability to protect target species and habitats. Therefore, it is important to have an interconnected PA network integrated into the wider landscapes to facilitate species migration and ensure plant and animal resistance to climate change.

Despite the expansion of the PA system, key biodiversity areas (KBAs), such as animal migration corridors, biological corridors, important plant areas (IPAs) and others remain beyond their boundaries. To date, neither the existing PA system nor the planned establishment of new PAs can ensure creation of a unified network - there is no connected system of protected areas integrated into a sider landscape [82].

However, some steps have been taken to this effect: priority conservation areas and corridors have been identified within the framework of Caucasus Ecoregion Conservation Plan. The first wildlife corridor has been established between the Borjomi-Kharagauli National Park and Adjara region in the western part of the Lesser Caucasus, connecting critical conservation areas of Georgia and Turkey.

It should be noted that National Protected Areas System Development Strategy and Action Plan for Georgia (2018-2030), approved in 2019, provides for considering climate change impacts while identifying shortcomings of the existing PA network and assessing the need for establishing new and expanding the existing PAs. The document highlights the need for modeling expected climate change impacts on species and habitats and developing adaptation measures. However, it does not call for mainstreaming climate change issues in management plans. At present, only a few management plans mention climate change as a direct or indirect threat to PA values and only two management plans (Javakheti and Vashlovani PAs) propose few climate change mitigation and adaptation measures (e.g. adaptation plan development, monitoring equipment, training).

Climate Change Impacts on PA Habitats and Species

Climate change will affect all PA ecosystems in Georgia to a certain degree, yet the most rapid and dramatic changes are expected in the mountains which are one of the most sensitive biomes. Environmental diversity of high mountain regions conditions diversity of local flora and fauna. High mountains are considered “hot spot” for plant diversity, as they are home for rare, relict, endemic and endangered plant species [83].

According to the climate scenario, air temperature is expected to increase throughout Georgia in the two forecast periods (2041-2070 and 2071-22100) as compared to the base period (1971-2000). As regards annual precipitation, it is likely to decrease almost on the entire territory of Georgia with few exceptions in both forecast periods.

Rising temperatures will significantly change plant diversity at high elevations. Species will migrate from low to high elevations, which will endanger cold habitat plants. The already sparse cover of relict tertiary tall grass will become depleted, some highly sensitive species (including relict, rare, endemic and endangered species) will be destroyed, and alpine species found at the snow line will become extinct. The most dramatic changes caused by glacier melting are expected in the subnival and nival zones. The described changes in air temperature and precipitation will dramatically change the vegetation and the landscape of the region by the end of the century. Vegetation is likely to resemble that found on dry rocky range of the Greater Caucasus [88].

Climate change will lead to changes in species composition and distribution of forests, invasion of more heat-loving species, and vertical elevation of the upper forest line. The arid forests in the Vashlovani PA and zelkova forests in the Babaneuri Strict Nature Reserve are likely to expand, while areas of forests composed of birch, aspen, Caucasian fir and Oriental spruce in respective PAs are expected to shrink [8]. The Bichvinta-Miussera Strict Nature Reserve may lose its significance because of the dramatic decrease in areas under Pitsundian pine.

As a result of climate change, vertical elevation of the upper forest line will narrow the already narrow sub-alpine and alpine zones and endanger habitats of local rare species (chamois, wild goat, Caucasian tur, snowcock, black grouse etc.).

Climate change may impact protected species in PAs in a way that would lead to their dispersal, movement to new habitats or local extinction. Species distribution area may extend beyond the PAs, but the species will not be able to migrate to new habitats as they may turn to be fragmented or degraded. Within an ecosystem, species may react differently to climate change. New species may replace local species in the existing ecosystems and thus trigger formation of new ecosystems [78].

Over the last 20 years, the population of river trout (*Salmo labrax fario Linnaeus*) has decreased three times in Adjara. Because of rising water temperatures in summer months, this cold water loving species have to move to upper reaches in search of colder habitats, where they face shortage of food and space, which affects younger fish and causes reduction in their numbers [86].

Climate change accounts for the emergence of Indian Crested porcupine and dipus – species characterized for hot arid regions of Iran and Pakistan - in the Vashlovani PAs. The expected habitat change endangers a number of bird species in the Chachuna Managed Reserve. This particularly concerns rock partridge, black francolin, pheasant and Eastern imperial eagle [87].

Potential impacts of climate change were assessed using the example of Caucasian salamander (*Mertensiella caucasica*). This species is endemic to the southwestern Caucasus ecoregion and is found only in Georgia and Turkey with 85% of the total population in Georgia. Caucasian salamander has been identified as one of the main natural values in the management plans of the Borjomi-Kharagauli and Kintrishi PAs. Potential effect of climate change on the distribution of Caucasian salamander was shown using future distribution modelling (average for 2041–2060 and 2061–2080) under RCP 4.5 and RCP 8.5 emission scenarios [88]. According to this model, the future distribution shows a remarkable expansion towards the northwest part of the Greater Caucasus and a regression from the west part of the Lesser Caucasus up to the Greater Caucasus. Modeling results indicated that most habitat loss seems to occur in the West Lesser Caucasus including the northeast of Turkey and the East Lesser Caucasus. In the Caucasus hotspot, the expected distribution range of Caucasian salamander will decrease with the risk of local extinction.

Pests and Diseases

Climate change causes active spreading of already known diseases and their carriers, as well as emergence and spreading of new diseases. Climate change can be attributed for the spreading of existing tree diseases (chestnut cancer, great spruce bark beetle, European spruce bark beetle, *Ips acuminatus Eichn* and wood-decay fungi) and the outbreak of relatively new diseases such as chestnut moth (*Cameraria ohridella Deschka*), oak moth (*Tischeria complanella Hb = Tischeria Ekebladellia Bjerkander*) and fungal pathogen of box tree (*Cylindrocladium buxicola*) in the Adjara's PAs [86]. Box tree fungal pathogen in combination with box tree moth (*Cydalima perspeqalis)* has had a devastating effect on box trees that could no longer be found in Mtirala, Kintrishi and Machakhela PAs, the Sataplia Managed Nature Reserve and the Tskaltsila Natural Monument by 2018. The pathogen fungus Chestnut blight (*Cryphonectria parasitica*) that has been recorded in the Adjara's PAs can destroy chestnut old groves in the next decade [89].

Brown marmorated stink bug (*Halyomorpha halys*) has already arrived in the Kintrishi PAs and further observation is necessary on its invasive potential [90]. Equally dangerous is the gypsy moth (*Lymantria dispar*), which initially spread to the pistachio trees at the edge of the Chachuna Managed Reserve and in 2019 already invaded the Reserve [89].

Another very dangerous invasive animal species is Asian long-horned beetle (*Anoplophora glabripennis*), which causes huge problems in Europe and America. The increase in its number is directly related to the increase in temperature. It seems that the pest has not yet arrived in the Adjara's PAs, but there is a threat of its invasion from Turkey, where it already appeared and spreads rapidly [90].

In recent decades, the number of pests has increased significantly in coniferous forests of Georgia's PAs. Various pests have been identified in Tusheti, Kazbegi and Tbilisi National Parks and in Mariamjvari Strict Nature Reserve, which in most cases cause drying of pine trees. In the Borjomi-Kharagauli Strict Nature Reserve and National Park, coniferous forests have been seriously damaged by European spruce bark beetle (*Ips typographus*). This pest normally produces one generation annually, but monitoring carried out in

Borjomi district showed that it already produces the second generation [89]. Modeling shows that 45% of *Picea* habitat in the Europe study area was suitable for a second *I. typographus* generation, and this was projected to increase to 69% by the end of the century [91].

Invasive Species

In many protected areas, invasive alien plant species are considered a significant threat, as they transform unique ecosystems and endanger natural and agricultural diversity [82]. Preliminary observations show that invasive alien species pose a major threat to rich plant diversity of Georgia, which is particularly crucial in light of changes in land use, habitat degradation, and current climate change [92].

*In order to assess potential invasion risks in the context of current and expected climate change the areas of high conservation value (AHCV) (*sites of exceptional botanical richness, assemblage of rare, threatened and/or endemic plant species) such as protected areas and the areas of high plant endemism. *Out of 278 plant species strictly endemic to Georgia, 114 species where used, which allowed identifying 27.8% of the territory of Georgia as AHCV. Among the 27 selected invasive alien plant species (IAPs),* most noxious ones are *Ambrosia artemisiifolia*, *Robinia pseudoacacia*, and *Ailanthus altissima [93].*

To model the future distribution of invasive alien plant species (IAPs) two different climate projection scenarios (RCP4.5 and RCP8.5) were used for 2050. The modeling showed that the AHCV that is not or only barely affected by IAPs is the PAs in the far south in the Lesser Caucasus Mountains and in the northeast in the Greater Caucasus Mountains. They showed that the actual protected areas cover only 9.4% of the areas of high plant endemism in Georgia and PAs seems to be located in areas with low suitability for IAPs. Consequently, invasion risks are higher outside the PAs and thus beyond the scope of established conservation management. .

So far, IAP occurrences in Georgia are mainly found in Adjara and Samegrelo regions and around the cities of Kutaisi and Tbilisi. All IAPs have largely not yet reached all their potential distribution in Georgia. Under future climate projections (i.e., year 2050), the suitability ranges for IAPs will shift toward higher altitudes in the higher and lesser Caucasus Mountains and toward the east of Georgia. On the other hand, a decrease in suitability to IAPs is observed at low elevation, which means that climate change will also decrease the suitability of some IAPs in the western part of Georgia.

At present, 44 alien species are found in the Kintrishi PAs, though not all of them have the potential to become invasive and cause any damage to ecosystem integrity. Most of those species are found in urban areas and are not distributed in forests or sub-alpine meadows. But with climate change, the situation is likely to change for the worse. Some of the alien species found in the Kintrishi PAs have high invasive potential. These are: *Ailanthus altissima, Robinia pseudoacacia, Ailanthus altissima, Hemarthria altissima, Paspalum dilatatum, Paspalum dilatatum, Phytolacca Americana, Robinia pseudoacacia, Spiraea japanica, Spiraea japonica*. *Ailanthus altissima* and *Robinia pseudoacacia* deserve special attention as they can become highly invasive for the Pshavi-Khevsureti PAs [90, 94].

The diseases, pests and invasive species described above will put significant pressure on ecosystems and local species in a changing climate.

Climate Change Impacts on Recreational Functions of Protected Areas

Climate change will affect not only the natural values of protected areas but also flow of visitors and corresponding economies. Climate change might couse shifts in visitation suitable places as well as changes in visitation timing [95]. The number of visitors in Georgia's PAs has a steady upward trend (the visitor data has been available to the Agency of Protected Areas since 2007). The Natural Monuments and National

Parks are of particular importance in this regard. The number of visitors has increased from 7,714 in 2007 to 1,108,503 in 2018. The upward trend still persists judging from the data for 2019 (625,695 visitors as of July) and concerns both Georgian and foreign visitors [89].

The main aim for visiting PAs is to explore and hike local wilderness /landscapes [96].

According to available data, visitation numbers increase from March to November and peak is in August. The Vashlovani and Chachuna PAs make an exception with peak visitation in May, which can be explained by peculiarities of local flora and supposedly with a pleasant climate.

To assess the relationship between climate and park visitation in the United States National Parks System (340 parks), historical monthly mean air temperature and visitation data were evaluated and potential future visitation (2041–2060) was projected based on warming-climate scenarios (RCP 4.5 and RCP 8.5). The data showed strong relationships between visitation and temperature. Visitation generally increased with increasing average monthly temperature, but decreased strongly with temperatures > 25°C. The potential visitation are projected for most months in most parks, in total annually by 8–23% as well as expansion of the visitation season at individual parks (13–31 days). Potential future visitation patterns at many high-latitude and high-elevation parks may look more like historical visitation at mid-latitude parks, and patterns at mid-latitude parks under a warmer future may look more like historical patterns at lowland parks [95].

A similar trend can be observed in the Waterton Lakes National Park in Canada, for which the model projected that annual visitation would increase between 10%-36% in the 2050s [97].

There are similar patterns in Georgia, where in most PAs visitation increases with increasing temperature and reaches its peak in August - the hottest month of the year. Similarly to the US, warming-mediated increases in potential visitation are projected for most PAs in Georgia, most of them being medium- and high-elevation parks. In the PAs, where visitation is low during hot months, further decrease should be expected during the hot period.

PA management practices need to be adjusted to the increasing visitation numbers. Some PAs already suffer from negative visitation impacts (household waste, noise, water pollution, grass cover damage, etc.), directly affecting all their functions, including the recreational one. Therefore, as visitation increases, the need for developing effective corresponding management strategies comes to the fore. Tourism development strategies have been elaborated and/or updated for some PAs, but they do not address climate change issues.

The number of visitors has not yet exceeded the daily critical number, so it is too early to speak about overtourism. But assess carrying capacity of individual PAs becomes even more important given the warming-mediated increases in potential visitation.

A general tourism development strategy for the Agency of Protected Areas exists, but it needs updating, and climate challenges needs to be addressed in it.

In view of the increasing visitor flow, PAs and adjacent local communities should develop corresponding adaptation strategies and plans to make use of the opening opportunities on the one hand and to address challenges on the other.

Protected Areas Role in Preventing and/or Reducing the Impact of Natural Disasters

Protected areas play an important role in adapting to climate change impacts, particularly in mitigating risks and impacts of natural disasters. PA ecosystem integrity contributes to local climate resilience and reduces risks of extreme natural events, including droughts, storms, landslides, avalanches, floods and others. Healthy forests and meadows in PAs regulate ground and surface water flow, prevent floods, landslides and erosion, ensure water purification, river bank stabilization, etc. Forest ecosystems accumulate water in rainy season and release it in dry season. Forest plays an important role in preventing snow avalanches in winter and slows down snow melting, thus contributing to equal generation of annual runoff and reducing high water and associated floods, landslides and soil erosion.

The role of ecosystems of several PAs in reducing the impact of natural disasters was assessed in 2011 and 2016. The study showed that the forests were protected and managed well enough in the Borjomi-Kharagauli National Park. A landslide was reported in 2011 in the support zone of the Borjomi-Kharagauli National Park. Overfelling caused soil erosion and landslide that damaged agricultural lands and 120 rural homes, forcing local farmers to move to new places offered by local authorities. Nothing of the kind was observed in the protected areas during this period [80].

The Mtirala National Park plays an important role in extending the period of snow melting. Snow melts slowly and evenly under the forest cover. Snow cover there typically is 6-8 m, sometimes reaching 12 m. Melting of this amount of snow would have very hazardous consequences in the absence of unique forest ecosystems. Forests also regulate river runoff, reducing flood risks in spring and autumn and drying risks in summer. The Mtirala National Park is located in the southwest part of Georgia, in the Autonomous Republic of Adjara. The park includes the municipalities of Kobuleti, Khelvachauri and Keda. In 2008-2010, 11 people were killed and 472 houses were damaged by landslides in these municipalities. Meanwhile, no landslides or other natural disasters occurred in the same period either in the Mtirala National Park or along the Kintrishi Gorge. Flashfloods and landslides are also rare in the villages located on the steep slopes of the Machakhela Gorge [98].

One of the priority objectives of the establishment of the Tusheti Strict Nature Reserve is prevention of soil erosion and runoff regulation. Birch and *Rhododendron caucasicum* play a special role in preventing landslides, erosion and avalanches. Forests in the Tusheti PAs slow water run-off thus preventing water level raising in rivers and reducing risk of floods in populated areas and agricultural plots located in the lower reaches [99].

Peatlands of the Kobuleti PAs and local sphagnum species can absorb and store large amounts of water. If daily precipitation exceeds 100 mm, sphagnum absorbs excess water and thus prevents floods in the surrounding areas [81].

Impact on Protected Areas

Natural disasters have intensified on the territory of Georgia, including the protected areas in recent years. Heavy rainfall in the Lagodekhi PAs caused major floods in 2011 and 2018. During the 2011 flood, rivers brought down 100-year-old trees, damaging tourist trails to waterfalls [89].

A flash flood hit the Borjomi-Kharagauli PAs in June 2015, damaging field infrastructure. In the same year, heavy rains caused a landslide in the Tusheti Protected Landscape, damaging a road connecting several villages. In October 2017, flood damaged picnic facilities in the Kintrishi PAs and an HPP in the lower reaches. The Mtirala National Park witnessed avalanches in January 2015, floods in August 2018 and minor landslides in April 2019. In 2016, a mudflow on the Migmakhevi River in the Pshav-Khevsureti Protected Areas killed one person and damaged a road and a bridge. In 2017, excess water accumulated in Guro’s Natsvetari, Guro Gorge, caused flooding on the Migmakhevi and Arghuni rivers. Floods and mudslides also occurred in the Kazbegi Protected Areas: in 2016, a mudflow changed the bed of the Tergi River, while in 2017, heavy rain caused flood on the Kurostskali River and then on the Tergi.

It is noteworthy that the increase in the monthly or annual maximum 1-day precipitation (Rx1day) in some PAs is likely to intensify geological processes. Thus, in Lagodekhi this indicator will increase by 20% and 9% in the first and second forecast periods respectively.

One of the major threats for the protected areas are fires, some of which are caused by lightning, others spread from adjacent areas (especially grassland fires in Vashlovani, Chachuna, Gardabani, Tusheti, Pshav-Khevsureti, Borjomi, Batsara-Babaneuri and other PAs) or are caused by careless handling of fire on the territory of protected areas. About 80 fires were recorded in PA forests in 2007-2018. Fire risk is particularly high in the semi-arid forest ecosystems of Vashlovani, Chachuna, Iori and Korugi PAs, boreal coniferous and mixed forests in the Borjomi-Kharagauli PA, pine forests in Tusheti and Mariamjvari PAs and mixed deciduous and coniferous forests in the Algeti National Park.

In both forecast periods, the increase in average monthly and annual temperatures and the decrease in average precipitation pose a serious fire risk for almost all protected areas. The risk will be particularly high in forests affected by pests that cause drying of trees and contribute to fast spreading of fire.

Forest management plans for a number of protected areas (Ajameti, Kolkheti, Katsoburi, Nedzvi, Machakhela) identify fire-prone areas and key prevention measures (early warning and communication, provision of fire safety and firefighting equipment, etc.). It is important to develop similar plans for all protected areas.

Natural disasters can significantly affect the habitats and migration corridors of protected species found in the PAs. This is another strong reason for holding effective adaptation measures.

Protected Areas of Samtskhe-Javakheti Region

Vulnerability to climate change was assessed for the Borjomi-Kharagauli and Javakheti PAs in Samtskhe-Javakheti region. The PAs were selected for demonstration purposes, as they include mountain biomes that are most sensitive to climate change. A significant portion of both PAs are fire-prone, however, pest outbreak in the Borjomi-Kharagauli PAs makes them even more vulnerable to climate change.

The Borjomi-Kharagauli PAs (206,523 ha), consisting of Borjomi National Park, Borjomi Strict Nature Reserve, and Nedzvi and Tabatskuri Managed Reserves, is almost entirely located on the territory of four municipalities - Adigeni, Akhaltsikhe, Aspindza and Borjomi. In 2007, the national park was recognized by the PAN Park organization and became part of its network [100].

Man-induced impact is relatively small across much of the Borjomi-Kharagauli NP. The main value of the NP is the forest, covering 75% of its territory. Local forests and mountains are rich in relict, endemic, rare and vulnerable species of flora and fauna. There are also fragments of rare relict Colchic forests there. The NP is home for a number of red-listed plant species (chestnut, hop hornbeam, Staphylea, oriental oak, and wych elm), 64 mammals, of which 11 are endemic to the Caucasus and 8 are on the Red List (red deer, chamois, lynx, Eurasian otter, brown bear, etc.), 217 bird species both migratory and nesting, of which 13 are on the Red List of Georgia (Caucasian grouse, golden eagle, scoter, etc.), and endemic reptile species (Caucasian salamander, Caucasian parsley frog, Adjarian lizard, Caucasus viper, etc.).

As noted above, forest pests pose a serious threat to the Borjomi-Kharagauli Strict Nature Reserve and National Park, of which spruce bark beetle is the dominant species, strongly damaging coniferous forests. Based on the monitoring it is supposed that the beetle has produced the second generation and its impact has intensified.

The coniferous and mixed forests in the Borjomi-Kharagauli PAs are mainly affected by wildfires, although man-caused fires are also common. The damage from pests further increases the risk of fires that annually affect or destroy migratory corridors and habitats of the red-listed species (bear, lynx, deer, chamois, otter, grouse, white-tailed eagle, Caucasus viper and Caucasian salamander).

A large portion of the Borjomi-Kharagauli PAs, located in Samtskhe-Javakheti region, are fire-prone (I and II class fires). The PA Administration has firefighting equipment and trained personnel.

According to the climate scenario for the second forecast period (2071–2100), the average annual temperature in Samtskhe-Javakheti will increase by 2.8^{0}C and the average annual precipitation will decrease by 12%, making the biodiversity of the Borjomi-Kharagauli PA more vulnerable to pests and fires. The climate change will lead to elevation of the vertical climate zones and will possibly endanger some species adapted to the current conditions. Some species will move from their current habitats to more elevated zones, while species inhabiting these zones may disappear.

The population of the areas adjusting to the Borjomi-Kharagauli PAs depend on its resources. On average 7,000 m^3 of firewood are annually issued to local people. Around 150 families use alpine meadows (about 11,000 ha) for cattle grazing. Inventory of local pastures and development of a management plan have been launched. It is also important to develop a forest management plan, considering the anticipated climate change among other factors.

The Javakheti PA is located in Ninotsminda and Akhalkalaki Municipalities. Its total area is 16,209.42 ha; absolute altitudes vary from 1,500 m to 3,300 m. It includes the Javakheti National Park, Kartsakhi and Suldi Managed Wetland Reserves, the Managed Reserves of Khanchali, Bugdasheni and Madatapi lakes and the Tetrobi Managed Reserve. The plan is to expand the Javakheti PA by adding Abuli, Sagamo and Paravani lakes (approximately 5000 ha) [101].

The Javakheti PA mainly comprises highland meadows and steppes, highland volcanic lakes and wetlands. Vegetation is represented by mountain meadows varieties, sub-alpine and alpine meadows, wetland vegetation, birch and rhododendron forests, and man-made pine forests. The PA is home for a number of Red List species, including gray hamster, Brandt’s hamster, wolf, otter and European polecat. The Javakheti PA is known for its rich bird diversity and is recognized as one of the most important hotspots for migratory birds. Most of the 140 bird species found there are related to the lakes. Local bird fauna includes the globally threatened Dalmatian pelican (*Pelecanus crispus*) found on Lake Kartsakhi, common crane, gray heron, white stork, Egyptian vulture, cinereous vulture, griffon vulture, pelican and other birds. Out of endemic fish species, only the red-listed river trout and lake trout are found in Madatapa and Khanchali lakes.

As regards the use of natural resources, the main focus here is on pastures and lake fish. Around 8,453 ha on the territory of the PA are potential pastures. At present, pastures are used by both local farmers and farmers from other regions. It is crucial to conduct pasture inventory and develop management plans.

Sulda and Kartsakhi Managed Reserves and the Natural Park are class I and class II fire-prone areas respectively. Most of them are man-caused fires spreading from the adjacent areas. As in the Borjomi-Kharagauli PAs, increasing temperatures and decreasing precipitation are likely to make the Javakheti PA more vulnerable to fires and endanger local biodiversity.

The expected impacts of climate change on Javakheti ecosystems have not been studied yet. However, the prevalence of drought-resistant species allows suggesting that the climate change will have a relatively weak impact on local grassland ecosystems. Studies show that impact of climate change-driven invasive species will be less significant in the Javakheti PA than in other PAs.

The Javakheti Protected Areas Management Plan addressed the climate change factor by highlighting the need for studying and modeling climate change impacts and developing adaptation plans, considering the transboundary context and providing training.

Apart from the PAs, there are six Emerald Sites in Samtskhe-Javakheti: Madatapa, Bugdasheni and Khanchali Lakes, two sites in the Borjomi-Kharagauli NP, and one in the Ktsia-Tabatskuri Managed Reserve. The Madatapa, Bugdasheni and Khanchali lakes are likely to be designated as Ramsar Sites.

Recommended Adaptation Measures

1. Assess expected climate change impact on important species and habitats of protected areas and develop corresponding adaptation measures and recommendations;
2. Elaborate spatial development plans for the PA considering potential impact of climate change;
3. Ensure consideration of areas of high plant endemism, animal migration corridors, biological corridors, important plant areas, etc. while altering the boundaries of the existing PAs and establishing new PAs, in light of potential impact of climate change;
4. Create a unified network of protected areas integrated into a wider landscape to maintaining ecosystem representation in the long run and facilitate species adaptation to climate change;
5. Enhance transboundary cooperation in planning/implementing climate change monitoring and adaptation activities;
6. Develop and implement National Climate Change Response Strategy for PAs;
7. Prepare management plans for each protected area considering potential climate change, in particular [102]:

   Use local and regional climate scenarios while developing the management plans;

   Consider most sensitive units to climate change while defining conservation values;

   Identify adaptation needs while developing goals and actions;

   Use the best available scientific data.
8. Develop forest management plans for relevant PAs, consideration potential impact of climate change;
9. Develop grassland managements plans the relevant PAs, consideration potential impact of climate change;
10. Ensure restoration of degraded forests and meadows within and around protected areas (in collaboration with other relevant agencies);
11. Conduct monitoring of pathogenic, harmful and invasive species, risk assessment, planning and implementation of appropriate response and prevention measures (in collaboration with other relevant agencies, e.g. the National Forestry Agency, municipalities, neighbor countries);
12. Enhance fire monitoring and implement preventive measures (in collaboration with other relevant agencies, such as the National Forestry Agency).
13. Consider potential impact of climate change on visitors flow, visitation suitable places, visitation timing and duration as well as corresponding economies in tourism development strategies for PAs;
14. Establish climate change monitoring system in protected areas (network of meteorological devices to record of, at least, key climate data: e.g. temperature, rainfall).

4.12 Human Health

Overview

According to the World Health Organization (WHO), climate change has a significant impact on human health, health care and social welfare systems [103]. The WHO reports that three climate change factors have a direct negative impact on health. These are:

- Heatwaves;
- Natural disasters; and
- Change of infection patterns.

According to WHO data, **extremely high temperatures** are one of the leading causes of death from cardiovascular and respiratory diseases, especially in the elderly. The most convincing example is the death of 70,000 people, mostly elderly inhabitants of shelters, during the 2003 heatwave in Europe.

The WHO associates extremely high temperatures with an increase in the levels of ozone and atmospheric air pollutants, which in turn causes an increase in incidence of cardiovascular and respiratory diseases. At extremely high temperatures, an increase in the level of allergens (allergy-causing particles) in the atmosphere was recorded, which may be a cause of increased incidence of asthma. 300 million people worldwide are affected by this disease, and WHO forecasts a further rise in the incidence in the context of the current climate trends.

The increased frequency of **natural disasters** following climate change has a number of negative effects on human health, including: higher rates of injuries and deaths, destruction of homes and medical facilities; high prevalence of mental disorders and other non-communicable chronic diseases among internally displaced persons, developing under the influence of general stress. Alongside with the negative health effects, IDPs also face social problems, such as loss of income, which ultimately limits their access to health services and causes health deterioration.

Another major problem associated with natural disasters is the outbreak of foodborne and waterborne infectious diseases, mostly manifesting in gastrointestinal problems, such as diarrhea, vomiting and fever. Such outbreaks are mainly caused by intoxication with contaminated drinking water and food prepared with such water, supplied by flood-damaged water supply and sewage systems.

The **change of infectious patterns** manifests itself not only in a higher incidence of foodborne and waterborne infections, but also in a higher incidence of infections transmitted by vectors (transmitting insects). Climatic conditions are critical for the existence of cold blooded insects. The risk of outbreak of vector-borne diseases is higher if climatic conditions are favorable for their life and propagation. One of the most common infections transmitted by a disease vector - anopheles mosquito - is malaria. The incidence of this infectious disease has increased significantly in many countries due to climate change.

According to WHO experts, the impact of climate change on health can be assessed only approximately. Given the current economic progress and the climate change trend, in 2030-2050 we should annually expect an additional 250,000 deaths due to climate change. Of these 38,000 deaths (mainly in the elderly population) will be associated with heatwaves, 48,000 may be caused by diarrhea, and 60,000 – by malaria, while 95,000 may be linked to a nutritional deficiency in children, which is also associated with negative impacts of climate change.

Situational Country Analysis

Prevalence of Climate-Sensitive Diseases

According to 2018 report of the National Center for Disease Control and Public Health (NCDC), in 2017 cardiovascular diseases (CVDs) remained the leading cause of deaths in Georgia; the trend was established back in 1990.

The NCDC data show that cardio-vascular diseases made 17.2% of all recorded diseases and 9.4% of new cases in 2017 in Georgia. In this group of diseases, hypertension (high blood pressure), ischemic diseases (deficient supply of blood and thus oxygen, causing, for instance, myocardial infarction) and cerebrovascular (brain blood vessels) diseases are characterized by high morbidity and mortality. In Georgia, in 2000-2017, there was a rapid increase in the incidence of cardio-vascular diseases compared to other countries; hospitalization per 100,000 people increased from 500 in 2003 to about 2,600 in 2017.

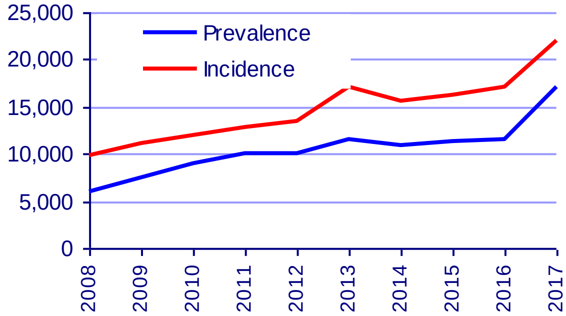


Figure 4.12.1: Trends of incidence and prevalence of CVDs in 2008-2017

A large share of CVD is accounted for hypertension (high blood pressure), which equaled 53.3% as of 2017. High blood pressure was reported in 37.7% of the population, according to a research on risk factors of non-communicable diseases. In 2010 the percentage was 33.4%. Ischemic heart disease (including myocardial infarction) accounts for 16% of CVDs, and cerebrovascular (cerebral circulatory) diseases occupy the third place in this group of diseases (NCDC, 2017). The prevalence and incidence of CVDs in Georgia are reflected in Figure 4.12.1, which clearly shows a steady upward trend.

According to data on respiratory diseases (RDs), there has been a slight decline in the number of deaths from RDs since 1990. The NCDC reports that RDs moved from the 2nd position in 2005 to the 5th position in 2017 among most common causes of death. However, it is noteworthy that a number of diseases that may be related to climate change still rank high. These include chronic obstructive pulmonary disease (COPD), associated with increased air pollution, and asthma, which is associated with increased concentration of allergens in the air.

The incidence of infectious and parasitic diseases (first reported cases per 100,000 population) decreased in 2017 compared to 2015 from 3,000 to 2,400, but still exceeded the 2008 figure of 1,200.

No new malaria cases have been recorded in Georgia since 2015 due to successful eradication efforts (in 2002 there were 0.9 cases of malaria per 100,000 population; the incidence fell dramatically to 0.3 in 2003 and subsequently decreased monotonically).

National Environment and Health Action Plan (NEHAP-2)

The National Environment and Health Action Plan (NEHAP-2) for 2018-2022, approved by Georgian Government Decree No 680 of December 29, 2018, is based on the principles of the Parma and Ostrava declarations adopted during the 2010 and 2017 ministerial meetings within the framework of the European Environment and Health Process. NEHAP-2 addresses the requirements of the Action Plan for the Implementation of the Association Agreement between Georgia and the European Union, conceptually and strategically linked to 2030 Sustainable Development Agenda (UNO) and Health 2020: The European Policy for Health and Well-Being (WHO). The National Action Plan was developed by an interagency working group, supported by experts from WHO's European Centre for Environment and Health (ECEH), located in Bonn, with participation of all stakeholders (ministries, agencies, research institutions and non-governmental organizations, international and local experts). The National Action Plan is managed, coordinated and supervised by the NEHAP Coordination Board.

NEHAP-2 strategic objectives include a climate change component, consisting in integration of health measures into climate change adaptation and mitigation policies.

It is important for Georgia to develop an action plan in accordance with the resolution of the 61st World Health Assembly 2008, urging Member States to take decisive action to address health impacts from climate change in line with the following priorities:

- Strengthen health systems' capacity for monitoring and minimizing public health impacts of climate change;
- Identify risks and health impacts from climate change for the most vulnerable population groups above all;
- Develop and implement appropriate strategies and actions;
- Develop and share knowledge and good practice.

Strategic Interventions:

MTO (Midterm Objective) 5.1 - Evaluate vulnerability to climate change, health impacts and adaptation (health care aspects), including assessment of existing and anticipated risks related to health impacts of climate change by 2022;

MTO 5.2 - Develop National Health Care Adaptation Strategy and Action Plan, among them, for medical facilities by 2021;

MTO 5.3 - Harmonize the legislation with regard to the requirements of the UNFCCC Convention and assessment of health outcomes by 2022;

MTO 5.4 - Health care facilities reduce the share of greenhouse gas emissions in national emissions, including introduction of renewable energy use in several hospitals within the framework of the pilot project by 2022;

MTO 5.5 - Education / preparation of population and preparedness for emergencies caused by natural disasters such as earthquakes, floods and other extreme weather events as well as technological disasters by 2020.

Current and completed projects

Within the framework of the first phase of the EU-funded Climate Forum East (2012-2015), climate vulnerability was assessed in six partner countries, including Georgia, where climate health impact was assessed with the main focus on heatwaves in Tbilisi. Based on the assessment results, Heatwave Action Plan for Tbilisi was developed within the framework of the first phase of "Building Safe and *Resilient Communities*" project funded by the Austrian Development Agency in cooperation with Georgia Red Cross Society. The 2nd phase of Climate Forum East involved development of Heatwave Action Plan for Batumi, analyzing climate change and health policy and providing a number of recommendations [104].

Both action plans were based on surveys carried out within the framework of various projects, which allowed assessing particular impacts of heatwaves in Tbilisi and Batumi using heat indices.

Within the framework of the USAID-funded project "Institutionalization of Climate Change Adaptation and Mitigation in Georgian Regions" (National Association of Local Authorities of Georgia), "The Georgian Road Map on Climate Change Adaptation" [105] was developed. Alongside with other sectors, the document assesses social sector's vulnerability and capacity to adapt to climate change in all municipalities of Georgia, and offers relevant recommendations.

International Approach to Building Climate Resilient Health Systems

The WHO has developed Operational Framework for Building Climate Resilient Health Systems [106]. The framework provides guidance for health systems (professionals and managers) and public health programming to increase their capacity for protecting health in an unstable and changing climate. International development agencies and other donors could use this framework to focus investments and country support for public health, health system strengthening and climate change adaptation.

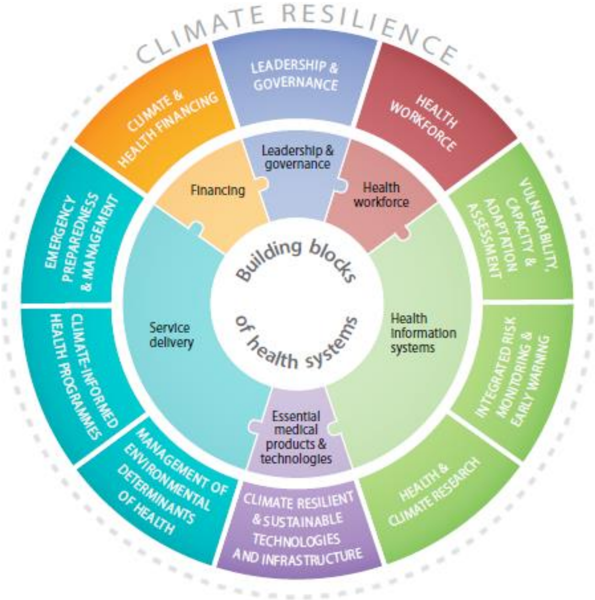


Figure 4.12.2: Ten components comprising the WHO operational framework for building climate resilient health systems, and the main connections to the building blocks of health systems

The manual will also assist international development agencies and other donors in investing wisely in the country. Lastly, this framework will be particularly useful to the countries where the health component of the national adaptation plan is being developed. The document provides a conceptual framework for building a climate resilient and sustainable health system.

The WHO recommends building climate resilient health systems with the so-called building blocks (Figure 4.12.2).

As shown in the figure, the blocks necessary for building a climate resilient system include: leadership/governance, health work-force (HR), vulnerability, capacity and adaptation assessment, integrated risk monito-ring and early warning, health and climate research, climate resilient and sustainable technologies and infrastructure, management environmental detriment of health, climate-informed health programs, emergency preparedness and management, climate and health financing

The framework elaborates on each component (block) and its relation to the health "blocks", specific purposes of each component, and examples of measurable outputs. Thus, the framework describes in detail the mechanisms for using components for building climate resilient health systems.

Assessment of Georgian Health System

The WHO also offers a survey (questionnaire) for rapid assessment of health system preparedness for climate change. The questionnaire has been filled in by experts to assess preparedness of the health system of Georgia. The survey results are presented in Table 4.12.1.

Table 4.12.1: Assessment indicators of status of health system preparedness for climate change [106]

Management and Policy	Yes/No/To some extent	Comment
Is there a contact person for local climate change issues in the Ministry of Health in your country?	Yes	
Is there a plan for health sector adaptation to climate change in your country?	Yes	It is one of the components of NEHAP-2
Does the National Communication reflect climate change mitigation effect on the health sector?	-	
Health Adaptation Issues		
Are there any ongoing projects aimed at health sector adaptation to climate change in your country?	Yes	*Supportive Risk Awareness and Communication to Reduce Impact of Cross-Border Heatwaves* (SCORCH)
Are there any activities aimed at enhancing institutional and technical capacities in the field of climate change and health care in our country?	To some extent	NEHAP
Has an assessment of health sector vulnerability and adaptation capacity been conducted at the national level?	Yes	Outlined in the 2nd and 3rd National Communications of Georgia
Is an early warning system against climate-sensitive risks part of the integrated disease monitoring and response system in your country?	To some extent	
Are there any activities in progress to establish climate-resilient health infrastructure in your country?	Yes	
Financing		
Have any funds been allocated in the national budget for a two-year program of health system resilience to climate change?	Yes	
Have any funds been allocated at the international level for a two-year program of health system resilience to climate change?	No	
Health benefits of climate change mitigation actions		
Does the National Climate Change Mitigation Strategy consider mitigation effects (benefits) on the health sector?	To some extent	
Have financial benefits of climate change mitigation for the health sector been assessed in your country?	Yes	

Heatwaves and Health

According to one definition, heatwave is a condition when air temperature exceeds a temperature threshold for three consecutive days. Heatwave is a climate change phenomenon having serious detrimental effects on human health. Exposure to extremely high temperatures over several days may deteriorate various diseases, especially cardiovascular ones, and have catastrophic effects, including death. In 2003, heatwaves killed 35,000 people (50,000-70,000 according to some estimates) in Europe, including 14,000 in France.

WHO's defines heatwaves as extreme climate events that require timely response and appropriate adaptation [107]. Given the importance of timely risk assessment at the government level and planning and implementation of effective responses, WHO developed “Heatwaves and Health: Guidance on Warning-System Development” [108] that can be adapted to the national context.

Heatwave Trends in Georgia

According to the climate scenario, in the first (2041-2070) and second (2071-2100) forecast periods the number of heatwaves on the territory of Georgia will increase by 157% and 187% respectively as compared to the base 30-year period (1971-2000). The increase will be the most significant in Zugdidi (213% and 432%), Tbilisi (180% and 307%) and Telavi (168% and 302%).

Table 4.12.2: Change in the number of heatwaves

City/Country	Number of heatwaves			Change in the number of heatwaves			
	2041-2070	2071-2100	1971-2000	I - Base		II - Base	
	I	II	Base	Days	%	Days	%
Batumi	6.5	7.1	1.8	4.7	163	5.3	197
Poti	6.1	6.5	1.9	4.2	116	4.6	137
Zugdidi	6.5	9.9	1.6	4.9	213	8.3	432
Kutaisi	4.7	5.6	1.5	3.2	113	4.1	172
Tbilisi	6.5	8.6	1.7	4.8	180	6.9	307
Telavi	6.6	9.0	1.8	4.8	169	7.2	302
Georgia	235.6	255.2	66.0	169.6	157	189.2	187

The duration of the longest heatwaves will also increase across the country on average by 340% and 510% respectively in the first and second forecast periods. The most significant increase will be in Tbilisi (188% and 656%), Poti (384% and 650%), Telavi (191% and 549%) and Batumi (358% and 506%).

Table 4.12.3: The longest heatwaves

City/Country	Heatwave duration, days			Change in heatwave duration			
	2041-2070	2071-2100	1971-2000	I - Base		II - Base	
	I	II	Base	Days	%	Days	%
Batumi	34	43	6	28	358	37	506
Poti	33	48	6	27	384	42	650
Zugdidi	29	36	7	22	236	29	342
Kutaisi	21	32	6	15	180	26	379
Tbilisi	24	53	6	18	188	47	656
Telavi	24	46	6	18	191	40	549
Georgia	32	41	6	26	340	35	507

The number of diseases that may develop or deteriorate due to heatwaves is rather high in Georgia. Large population groups (elderly and disabled persons) lacking social and economic means to cope with extremely high temperatures, are particularly vulnerable to the negative impacts of heatwaves. For example, such people cannot afford buying air conditioners.

Vulnerability and Capacity of Georgian Cities to Adapt to Heatwaves

Heatwaves are considered a serious urban problem ("urban heat island" - a rise in temperature caused by heat emitted by asphalt and buildings in urban environments), therefore a special focus was on assessing vulnerability and adaptation capacity of some large cities. In particular, vulnerability and adaptation capacity of Tbilisi, Telavi, Kutaisi, Zugdidi, Poti and Batumi was assessed using multi-criteria analysis, based on three main components: (1) capacity of human population to adapt to heatwaves; (2) heatwave impacts; and (3) sensitivity to heatwaves. The analysis drew on data from strategic documents, reports, ministry databases, and experts.

Table 4.12.4: Selected indicators by components

Component	Selected indicators
Adaptive Capacity of population	
Social resources	Recipients of Targeted Social Assistance (%), pension recipients (%)
Human resources	People with secondary education (%),qualified health workers (%)
Financial resources	Jobless people (%), average wage
Physical resources	First aid stations

Component	Selected indicators
Heatwave impact	Number of heatwaves, duration of heatwaves
Sensitivity to heatwaves	
Local communities	People older than 65 years (%), including women (%), population density
Health sector/human health	Cardiovascular diseases (%), respiratory diseases (%)

All of the listed indicators were used to assess the present situation, and the impact of heatwaves was determined by comparing the current climate data with the periods of 1956-1985 and 1986-2015. Future trends were projected by comparing two forecast periods (2041-2070 and 2071-2100) with the base period (1971-2000).

Based on the current climate data, Telavi is the most vulnerable to heatwaves its vulnerability index being 81.31, Batumi follows with 82.32 and in turn is followed by Zugdidi with 78.76. Telavi's high index is explained by limited capacity to adaptation, which in turn is accounted for a high level of poverty, low average wages, and shortage of qualified health workers. The sensitivity index is also high (second only to Kutaisi), which indicates a high prevalence of cardiovascular and respiratory diseases in Telavi. Batumi showed the lowest capacity to adaptation, though its sensitivity index is also lower than Telavi's. High sensitivity and heatwave impact indices in Zugdidi are balanced by high capacity to adapt to heatwaves, which has a good effect on overall vulnerability index, putting the city on the third place. Tbilisi shows average indices and ranks fourth out of the six cities. Poti has the highest heatwave impact index, but low sensitivity index and ranks fifth. As for Kutaisi, its adaptation capacity is so high that despite the highest sensitivity index (the highest prevalence of cardiovascular and respiratory diseases), it still ranks sixth.

Vulnerability to heatwaves in the first and second forecast periods was assessed by determining future impacts of heatwaves. It was suggested that adaptation capacities and sensitivity of cities remained unchanged, with only climate impacts (frequency and duration of heatwaves) changing.

In the first forecast period (2041-2070), vulnerability index changes depending on future change of climatic parameters: Batumi ranks first (vulnerability index 79.47), which is mainly due to significant increases in the duration of heatwaves. However, heatwave impact index is also high in Zugdidi (74.93), which is followed by Batumi, Telavi, Poti, Tbilisi and Kutaisi.

Given the climatic parameters of the second forecast period (2071-2100), Telavi ranks first (78.82) and is followed by Tbilisi (75.88) and Zugdidi (73.43). As with the first forecast period, heatwave impact is the only variable parameter, meaning that duration and number of heatwaves in the "leading" cities will increase dramatically.

Recommendations

At the national level it is recommended to:

1. Initiate inter-sectoral dialogue and discuss interrelated climate change and health issues;
2. Mainstream health issues into the national climate adaptation plan;
3. Take effective steps in line with the climate change component of the National Environment and Health Action Plan;
4. Follow WHO recommendations and adapt the assessment methods;
5. Encourage interrelated climate change and health research.

At the local level it is recommended to:

1. Plan and initiate heatwave adaptation measures by local governments, especially in vulnerable cities;

2. Develop an action plan or a roadmap on city's adaptation to heatwaves.

Non-governmental organizations are recommended to:

1. Increase community awareness of climate health impacts and involvement in decision-making;
2. Initiate small-scale adaptation measures.

4.13 Energy

Energy is a key pillar of the economy - human wellbeing depends heavily on energy. World practice shows that energy and economics are closely interconnected - economic growth is followed by energy consumption growth, in turn, energy development contributes to economic progress.

As a result of climate change, rising sea levels, rising temperatures, changes in rainfall, changes in winds and frequent extreme events can pose a serious threat to the reliable functioning of the energy sector. It is therefore essential to increase the resilience of this sector to climate change - to plan and implement adaptation measures.

Georgia consumes electricity, petroleum products, natural gas, coal and biomass, as well as small amounts of geothermal and solar energy **[109].** Georgia's energy system relies heavily on imported fossil fuels. In 2013-2017, the share of net energy imports (imports-exports) in domestic supply increased from 66% to 74%. Based on the country's energy policy, it is expected that by 2030 the share of local resources will increase.

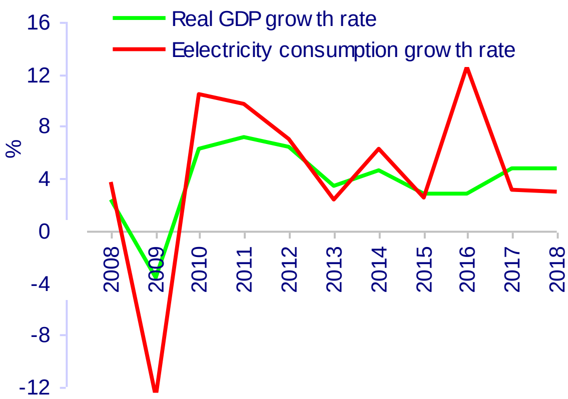
Electricity generation

Electricity generation increased by 3.85% on average in 2013-2018 years. Table 4.13.1 shows generation by sources in 2013–2018.

Table 4.13.1: Electricity generation in 2013–2018

Year	Total	HPPs								TPPs		Wind Farms	
		total		regulating		seasonal		small					
		KWh	%	KWh	%	KWh	%	KWh	%	KWh	%	KWh	%
2013	10,059	8,271	82.2	5,385	53.5	2,557	25.4	329	3.3	1,788	17.8		0.0
2014	10,370	8,334	80.4	5,159	49.8	2,683	25.9	492	4.7	2,036	19.6		0.0
2015	10,833	8,454	78.0	5,119	47.3	2,817	26.0	518	4.8	2,379	22.0		0.0
2016	11,574	9,329	80.6	5,406	46.7	3,239	28.0	684	5.9	2,236	19.3	9	0.1
2017	11,531	9,210	79.9	5,348	46.4	3,260	28.3	603	5.2	2,233	19.4	88	0.8
2018	12,149	9,949	81.9	5,801	47.8	3,456	28.4	692	5.7	2,115	17.4	84	0.7

The nature of electricity consumption and the change in GDP have been consistent for years. Exception is 2016, when the sharp increase in consumption led to large-scale cryptocurrency production. Georgia's GDP grew on average by 3.8% in 2008-2018. Electricity consumption also increased by 4.2% in 2008-2018.



Electricity demand during the autumn-winter period cannot be met by the capacity of HPPs and TPPs, which requires the import of electricity. As of May-July,excess water resources allow for electricity demand to be met and residual electricity exported.

The power transmission and distribution network is one of the most important infrastructure in the country, the development of which ensures safe, uninterrupted and reliable supply of consumers. Important amounts of electricity to neighboring countries allow for the import and export of electricity through the transboundary transmission lines in the Georgian electricity system.

One of the most important functions of transmission and distribution system operators is the loss of energy in the transmission and distribution networks and its reasonable reduction. In 2010–2018, losses in the transmission network were 1.74–2.21%. Losses in the network of the major distribution network operators (JSC Telasi and JSC Energo-Pro Georgia) are generally downward. The actual losses of electricity in Telasi and Energo-Pro Georgia network were the lowest as compared to previous years and were 4.8% and 7.9% respectively.

Hydro Power

More than 80% of electricity generated in Georgia comes from hydropower plants (HPPs) [110]. As of 2018, there are 85 HPPs operating in the country, including 7 large regulating HPPs (with installed capacity of 1993 MW), 17 seasonal power plants (with installed capacity of 1039 MW), and 61 small HPPs (with installed capacity of 1134 MW), with an annual total of 9,949 million kWh generation. The Table below shows the characteristics of the ten top power plants (by capacity).

Table 4.13.2: Characteristics of top HPPs in Georgia

HPP name	River	Basin	Reservoir	Installed Capacity, MW	Type of Regulation	Commissioning Year
Enguri HPP	Enguri	Enguri	Jvari, Gali	1,300	regulatory	1978
Vardnil HPP	Enguri	Enguri		220	regulatory	1971
Vartsikhe HHP	Rioni, Kvirila	Rioni		184	seasonal	1976-1977
Shuakhevi HPP	Ajaristskali	Ajaristskali		178.72	seasonal	2017
Zhinvali HPP	Aragvi	Aragvi	Zhinvali	130	regulatory	1984
Lajanuri HPP	Lajanuri, Tskhenistskali	Rioni	Lajanuri	113.7	seasonal	1960
Khrami 1	Khrami	Khrami	Tsalka	112.8	regulatory	1947
Khrami 2	Khrami	Khrami	Tsalka	110	regulatory	1963
Dariali	Tergi	Tergi		108	seasonal	2016
Paravani HPP	Paravani	Paravani		86.54	seasonal	2014
Dzevrula HPP	Tkibula	Rioni	Tkibuli	80	regulatory	1956
Gumati HPP	Rioni	Rioni	Gumati	66.8	seasonal	1956
Rioni HPP	Rioni	Rioni		51	seasonal	1933
Shaori HPP	Shaori	Rioni	Shaori	39.2	regulatory	1955

The impact of climate change on the HPPs, among other factors, is reflected by change in river flow. Georgia's rivers are fed by rain, snow, glacier and groundwater. The share of water received by rivers from different sources of food varies from region to region.

The main HPPs of western Georgia are located in the basins of the Enguri River and the Rioni River. There are two large hydroelectric power plants on the Enguri River in the Enguri Basin, in addition to the construction of a Khudoni HPP with 720 MW on the Enguri River, the construction of a Nenskra HPP with 280 MW of installed capacity on the Nenskra River Basin.

The Enguri River is a river with mixed nourishment sources : 68% of annual runoff in the upper reaches is snow and glacier water, 24% - ground water and 8% - rain water, in the lower reaches 43%, 34% and 23%, respectively. Table 4.13.3 presents distribution of shares of total Enguri and Nenskra rivers annual runoff components in Enguri River Basin

Table 4.13.3: Characteristics of river runoff in the Enguri Basin

River	Watershed	Height above the sea level	Area of the watershed km^2	Average height of the basin, m	%				Annual runoff, mln. m^3
					Underground	Snow	Glacier	Rain	
Enguri	Latali	1185	1000	2570	23.7	28.7	39.5	8.10	1415
	Lakhamura	963	1370	2520	23.6	24.4	33.0	16.0	1920
	Dizi	858	1620	2490	21.8	38.3	25.7	14.2	2250
	Jvari	260	3170	2220	30.0	32.0	21.0	17.0	4670
	Darcheli	7	3660	2020	34.7	25.9	16.8	22.6	5300
Nenskra	Lakhami	652	468	2270	26.2	40.2	19.3	14.3	959

As the altitude decreases, the proportion of glacial runoff decreases, and the proportion of rainwater increases. The share of groundwater is quite high. It should be noted that the formation of groundwater is affected by both rain and snowmelt.

In both forecast periods (2041–2070 and 2071–2100) under the climate scenario, rainfall in the Enguri basin is expected to decrease in the Enguri basin as compared to 1971–2000, which will affect the river runoff.

When estimating river runoff, it is important to consider glacier melting. According to the Glacier Inventory released in 1970, 194 glacier area was 305 km^2 in the Enguri glacier basin, with satellite remote sensing in 2018 revealing that there are 153 glaciers remaining with a total area of 236 km^2, ie the number is reduced by 21% and the area by 23%. For two large glaciers of the Enguri basin, changes in the area are estimated: the Boko area has been reduced by 20% and the Adishi area by 6%. The melting process of glaciers has accelerated in recent decades, but glaciers vary in melting rate. According to rough estimates, the glaciers of the Enguri Basin may disappear by the 50's of the 22nd century.

Increased melting of glaciers is expected for some time to increase river runoff, after which glacier runoff will begin to decline. The water power industry benefits from runoff growth - Generation from HPPs may increase, but increased flow may damage runoff power, which is limited by the ability to regulate it. Properly planned reservoirs are more resistant to runoff. As the runoff increases, the risk of flooding will increase and the role of the reservoirs will also play an important role. Consequently, it is necessary to consider the impact of climate change on reservoir management.

6 HPPs are in the Rioni River Basin. Rioni is a mixed feeding river, with up to 45% of annual runoff in snow and glacier, 33% in ground water, 22% in rain water, 33%, 35% and 32% in downstream respectively. Table 4.13.4 presents distribution of shares of total annual runoff components of the rivers feeding the HPPs in the Rioni Basin at different watersheds.

Table 4.13.4: Characteristics of river runoff in the Rioni Basin

River	Watershed	Height above the sea level	Area of the watershed, km²	Average height of the basin, m	% Underground	% Snow	% Glacier	% Rain	Annual runoff, mln. m³
Rioni	Glola	1112	627	2430	33.3	26.3	18.6	21.8	883
	Khidikari	582	2002	1940	33.5	28.0	8.4	30.1	2350
	Rioni HPP	148	3520	1610	34.7	28.2	4.6	32.5	3970
Tskhelistskali	Khidi	190	1940	1800	38.8	37.6		23.6	2470
Lajanuri	Alpana	367	284	1510	30.0	30.9		39.1	325
Kvirila	Chiatura	344	899	1210	27.8	31.9		40.3	659

The Rioni River is fed only by glacial water, in the lower part of the river where the power plants are located, the share of glaciers is within 5%. The share of rainwater and groundwater is high. According to the climate scenario, precipitation decreased by 12% compared to the baseline 30-year period (1971-2000), both in the first forecast period (2041-2070) and in the second forecast period (2071-2100 years). Changes in precipitation and partially melting glaciers will affect runoff. HBV-IHMS hydrological model predicts that runoff will decrease by 9% on average in the first forecast year, and by 3% in the second forecast period.

The four main hydropower plants of Eastern Georgia are fed by rivers: Aragvi, Khrami, Paravani and Tergi. The glacier runoff only contributes to the Tergi feeding. In the other three rivers, most of the groundwater is predominant, with the share of snow and rain being approximately equal. The climate scenario in eastern Georgia is expected to reduce the amount of precipitation that is likely to reduce river runoff. Table 4.13.5 presents distribution of shares of annual runoff components of the rivers feeding the HPPs of the East Georgia at different watersheds

Table 4.13.5: Characteristics of runoff of the rivers feeding the HPPs of the East Georgia

River	Watershed	Height above the sea level	Area of the watershed, km²	Average height of the basin, M	% Underground	% Snow	% Glacier	% Rain	Annual runoff, mln. m³
Aragvi	Zhinvali	740	1880	1910	47.1	27.7		25.2	1390
Ktsia-Khrami	Trialeti	1056	1146	1910	51.6	24.4		24.0	397
Paravani	Khertvisi	1120	2276	2140	63.2	23.8		12.9	587
Tergi	Kazbegi	1717	769	2820	39.6	29.1	17.9	13.4	754

The above considerations are of a benchmark nature, and thorough research is needed in this regard.

Evaporation from Reservoirs

Elevated temperatures cause water evaporation from the reservoirs to slow down, which can affect the power generation. There are 10 reservoirs of energy purpose in Georgia in total.

Table 4.13.6: Reservoirs of energy purpose in Georgia

Reservoir	HPP	River	Volume, mln m3		Surface area, km^2
			Full	Active	
Tsalka	Khrami 1 and Khrami 2	Ktsia/Khrami	312		33.7
Jvari	Enguri HPP	Enguri	1,092	662	13.5
Shaori	Shaori HPP	Shaora	71	68	13.2
Tkibuli	Dzevruli HPP	Tkibula	84	62	11.5
Zhinvali	Zhinvali HPP	Aragvi	520	370	11.5
Gali	Enguri HPP	Eristskali, Enguri	145	26	8
Lajanuri	Lajanuri HPP	Lajanuri , Tskhenistskali	12	16	1.6
Gumati	Gumati 1 and Gumati 2	Rioni	39	13	2.4
Vartsikhe	Vartsikhe HPP	Rioni , Kvirila	14.6	2.4	5.1
Zakhesi	Zakhesi HPP	Mtkvari, Aragvi	12	3	2
Total			**2,302**	**1,222**	**103**

Khudoni HPP Environmental Impact Assessment Report [111] assesses evaporation from the HPP Reservoir. Evaporation from the reservoir with a surface of 5.25 km^2 is equal to 5,572,272 m^3, which is 1.06 m^3 from 1 m^2. This significance of evaporation is consistent with the evaporation from the reservoirs of neighboring Turkey, which has similar climatic conditions [112]. The evaporative losses from 223 reservoirs' surfaces in Turkey (the total surface area - 4,026 km2) were 4.1 billion m^3. That is, about 1.02 m^3 from the surface of 1 m^2. According to rough estimates, evaporation from Georgia's existing energy reservoirs (103 km^2) is approximately 108.7 million m^3 per year.

According to the references [113], the average air temperature increase by one degree increases evaporation by an average of 5-7%. According to the climate scenario, in the reservoir locations, the mean annual temperature in 2071–2100 (over a 30-year period) increased by 3.0–3.5 degrees Celsius in 1971–2000. Accordingly, evaporation from the reservoirs is expected to increase within the range of 15–24%, i.e. within the range of 16.3–26.1 mln m^3. Evaporation will be particularly intense during May-September.

There are about 860 lakes in Georgia, most of them are small. 15 lakes are relatively large, with a total surface area of about 150 km^2. Evaporation from these lakes totals roughly 150 mln m^3. Some of the water supplies in these lakes are involved in the formation of river runoff. The increase in evaporation from the lakes will somehow affect the river runoff.

The demand for water resources in agriculture will increased under the climate change. First, there will be an increase in demand for irrigation water, which is mostly satisfied by rivers. This may reduce water resources for electric power generation. Rising temperature, precipitation changes, glacier melting and increased extreme hydro-meteorological and geological processes provoked by the climate change will have a significant impact on the country's hydropower sector. In-depth analysis of the sector's sustainability and the development of its development strategies is crucially important, taking into account the principles of sustainable development and the risks posed by the climate change.

Thermal Power Plants (TPP)

In Georgia up to 20% of electricity is generated by thermal power plants. The following thermal power plants are currently operating in Georgia:

Table 4.13.7: Georgia's Thermal Power Plants as of 2018

N	TPP	Technology and Fuel	Installed capacity, MW
1	Mtkvari Energetika	traditionally gas-fired	300
2	Tbilsresi	traditionally gas-fired	270

N	TPP	Technology and Fuel	Installed capacity, MW
3	Gardabani TPP	gas-fired combined cycle	231.2
4	GPower	air turbine gas	110
5	Tkibuli TPP	traditionally coal-fired	13.2

The thermodynamic cycle determines the efficiency of converting heat energy into electricity in a thermal power plant. The efficiency of the thermodynamic cycle is proportional to the difference between the temperatures of the "hot" source and the "cold" sink, which reduces the efficiency of the cycle and therefore the thermal power plant. The capacity of steam turbine power plants reduces by about 0.45%, and efficiency decreases by about 1.2% when the temperature of the cooling water is increased by 1 degree. Increasing the ambient temperature by one degree Celsius at power plants reduces the capacity by 0.7% and the thermal efficiency - by 0.18%, and in the case of a combined cycle, the capacity is reduced within the range of 0.45-0.6%.

According to the climate scenario, the average air temperature at the location of the thermal power plants (in the Gardabani Region) is expected to increase in future, which directly affects the efficiency of the gas turbine stations, and indirectly the efficiency of the steam turbine stations.

Table 4.13.8: Average air temperatures and change over 20 years baseline (1971-2000) forecasted in Gardabani for 2041-2070 and 2071-2100

	Month												Spr	Sum	Aut	Wint	Year
	1	2	3	4	5	6	7	8	9	10	11	12					
Tmean in 2041-2070, ^{0}C	3.5	4.9	9.8	15.8	20.5	24.9	27.9	27.5	23.0	16.9	10.2	5.4	15.4	26.8	16.7	4.6	15.8
ΔTmean, ^{0}C	2.1	2.2	2.7	2.2	2.6	2.5	2.1	2.5	2.4	2.9	2.5	2.1	2.5	2.4	2.6	2.1	2.3
Tmean in 2071-2100, ^{0}C	3.9	5.7	10.1	16.8	20.9	25.7	28.3	28.3	23.2	17.0	10.7	5.9	15.9	27.4	17.0	5.2	16.4
ΔTmean, ^{0}C	2.5	3.0	2.9	3.2	3.0	3.3	2.6	3.3	2.6	3.0	3.0	2.6	3.0	3.0	2.9	2.7	2.9

Particularly sharp increase in temperature is expected in the afternoon. Table 4.14.9 shows the highest values (TmaxMax) for the maximum monthly temperatures observed in the Gardabani Meteorological Station during the hot period of 1986–2015 (June – September). It also lists the possible upper limit of the maximum temperatures (Tmax) of the month for 2030, 2050, 2070 and 2100 at the same station (with 95% confidence). The maximum temperature of the month with a 5% reliability may exceed the upper limit. A simple linear regression model was used to estimate the relationship between the maximum temperature of the month and the year of observation.

Table 4.13.9: Highest value among the maximum during hot months in Gardabani within the period of 1986–2015 Estimated upper limit of the maximum temperature for the month 2030, 2050, 2070 and 2100 (0C)

Year	June	July	August	September
1986-2015	37.5	39.3	39.4	38.6
2030	39.1	42.3	43.8	38.8
2050	39.5	43.5	45.2	39.8
2070	40.1	44.8	46.8	40.8
2100	41.2	46.7	49.1	42.4

The table shows that every month, especially in August and July, a sharp increase in maximum temperatures is expected already since 2030. By 2100 the temperature increase will reach 9.7^{0}C in August as compared to 1986-2015 and 7.4^{0}C in July. Such an increase in the ambient temperature caused by climate change will adversely affect thermal power generation.

To address the shortage of reserve capacities, the Georgian Power System plans to build a powerful combined cycle thermal power plant and rehabilitate the existing one. Increasing water and air temperatures in the future will not cause significant problems for thermal power plants, requiring increased water supplies, increased capacity of existing reservoirs, construction of new reservoirs, creation of a large capacity water purification system and other costly measures.

Wind Farms

There is only one wind power plant in Georgia, located in the Shida Kartli Region, in Gori Municipality [114]. The 20.7 MW power plant generates an average of 84 mln kilowatt-hours of electricity annually, which is 0.7% of gross domestic product. At present, a memorandum of understanding has been signed for the construction of 21 wind farms with a total installed capacity of 1,204 MW and an annual output of 4,653 GWh. Work is underway to sign a memorandum for 3 wind farms (total capacity 150 MW, estimated annual output 554 GWh).

Analyzing two factors, wind speed and air density, is important in terms of climate change to generate electricity from a wind farm. Increasing the wind speed at certain limits has a positive effect on the amount of electricity produced by the turbines. There is a cubic dependence between the wind speed and the power generated by the station. 4 m/s is the lower limit of wind velocity at which large wind stations generate minimal energy. Georgia, with average wind speeds, is an attractive location for the development of wind stations for the period 2041-2070 and 2071-2100, including Mta Sabueti, Kutaisi, Paravani, Batumi and Goderdzi Pass, where the average wind speed is more than 4 m/s. Tab. 4.13.10 shows the projected average wind speeds in 2041–2070 and 2071–2100 and the change over 1971–2000 at planned and potential wind station development sites.

Table 4.13.10: Projected wind speeds in 2041-2070 and 2071-22100 and change according to the period of 1971-2000

Site		2041-2070					2071-2100				
		Spring	Summer	Autumn	Winter	Year	Spring	Summer	Autumn	Winter	Year
Batumi	Wind, m/s	4.0	3.7	4.9	6.0	4.6	4.0	3.7	4.9	6.0	4.6
	ΔW wind, m/s	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4
Goderdzi Paass	Wind, m/s	4.9	4.4	4.9	6.4	5.1	4.3	4.0	4.3	5.7	4.5
	ΔW wind, m/s	0.3	0.4	0.4	0.2	0.3	–0.3	–0.1	–0.3	–0.5	–0.3
Kutaisi	Wind, m/s	6.4	4.3	5.8	6.5	5.8	6.4	4.4	5.8	6.5	5.8
	ΔW wind, m/s	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Mta Sabueti	Wind, m/s	5.9	5.0	5.6	5.3	5.5	5.9	5.0	5.6	5.3	5.4
	ΔW wind, m/s	0.3	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.3
Paravani	Wind, m/s	4.2	4.1	4.2	5.1	4.4	4.2	4.1	4.3	5.1	4.4
	ΔW wind, m/s	0.3	0.3	0.5	0.4	0.4	0.3	0.3	0.5	0.4	0.4

The amount of electricity generated by the wind station also depends on the air density, which in turn depends on altitude (elevation), pressure and temperature. The dense air puts more pressure on the turbine's rotor and produces more energy. An increase in temperature reduces the density of air, which in turn causes a decrease in energy generation. According to the climate scenario, average temperatures in the planned and potential locations of wind power stations will rise within the range of 1.5–3.5^{0}C in 2041–2070 and 2071–2100.

Extreme events caused by climate change may damage the wind station infrastructure and endanger the operation of the stations. Consequently, it is important to carry out in-depth study of current and planned wind power projects in the area of current and future climate and geological changes and to take into account the initial stages of adaptation.

Solar Energy

Due to geographical location, the rate of solar radiation in Georgia is high. Some regions of the country are characterized by 250-280 sunny days annually, which is about 6,000-6,780 sunny hours per year. Solar energy potential varies from 1,250-1,800 kWh/m^2 depending on the region. In terms of solar power usage in Georgia there are mainly two technologies used for heat and electricity. The first is the solar collector, which is relatively widespread in Georgia and used for water heating. Second, solar photovoltaic generators, which are slowly being introduced in the country and used for electricity production.

As of today the Ministry of Economy and Sustainable Development of Georgia has signed 6 Memorandums of Understanding on the construction of solar farms with installed capacity of 93 MW and annual output of 132 GWh. The contract is underway for 9 solar stations with a total installed capacity of about 100 MW and an estimated annual output of 175 GWh. The project of a solar farm with installed capacity of 30 MW and annual generation output of 67 mln kWh in the process of signing a contract. On June 30, 2016, a Memorandum of Understanding was signed between the Government of Georgia and the Georgian Energy Development Fund on the construction of Udabno Solar Power Plant in Kakheti. Ipower Tbilisi project, which was signed on April 14, 2019, provides for construction of solar farms on the roofs of the state-owned buildings & premises within the administrative boundaries of Tbilisi with a total installed capacity of 50 MW and an annual generation output of 70 mln kWh. The project is in the research stage.

The following climate factors influence the efficiency of solar power generation under climate change: temperature, precipitation, cloud cover, wind speed, hail, desertification.

Great store is placed on the temperature coefficient, which greatly influences the operation of the solar panel. Under high temperatures, solar photovoltaic converters slightly increase power and significantly lower voltage, resulting in less generation. Cloud cover and desertification of the soil create a problem as well, which often results in shading or cracking of the surface of the panels, which reduces energy output.

According to the climate scenario, the average temperature in the potential development sites of solar stations (Tbilisi, Gardabani, Udabno) will rise by three degrees Celsius in all seasons of the year from 2071-2100 to 1971-2000. In the same thirty year period, the average precipitation is expected to decrease. These climatic changes should not pose serious problems for the development of solar stations in these areas, although in the early stages of project implementation, more in-depth study of both historical and forecast data on hydrometeorological and other climate factors is needed, considering the possible impacts of climate change and the principles of sustainable development.

Infrastructure of the power generating industry

Climate change has a significant negative impact on power transmission and distribution lines, as well as on substations. The problem for transmission lines is increase in temperature. As the temperature rises, the conduction impedance increases, which in turn impedes the delivery of the required power to the consumer, increasing losses and delivery costs.

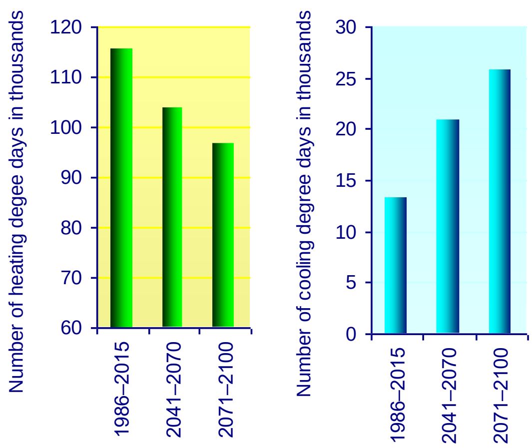
It should be noted that the impact of climate change in different geographical areas is different and therefore network losses will be different. Thus, different approaches will be needed when planning adaptation measures. In lowlands where high temperatures are already present, climate change can significantly increase losses. According to the climate change scenario, average and maximum temperatures will rise in such places. Most of the transmission and distribution lines and substations are in hilly areas. In the future, their optimal operation may be jeopardized by frequent extreme events such as floods, landslides, avalanches and other events. Especially dangerous are avalanches that can damage transmission lines and delay repair due to bad weather. At such times, the recovery of power supplies to regions is delayed and real damage is more than just damaged transmission lines - the lack of electricity can hinder the functioning of some industries or services. Problems can be solved by diversification - it means building alternative transmission lines that can deliver electricity in critical cases.

In areas at risk for desertification, planned lines need to be built to withstand arid and semi-arid microclimate. In such regions, daytime and nighttime peak temperatures are radically different, leading to frequent expansion and compression of metals, eventually leading to corrosion. Corrosion is also a major problem in transmission lines along the seashore where moisture accelerates corrosion. In this case, corrosion in the short term is less noticeable visually, as aluminum wires appear inside and damage the conductor from the inside. The problem can be solved using special aluminum cables - aluminum is used with small impurities of manganese and magnesium. It has been experimentally proven that the wires made by this method are 1.6-2 times more corrosion resistant than traditional aluminum wires, with a minimal economic cost.

Transmission System Operator of Georgia JSC Georgian State Electrosystem works to update SCADA power management and data collection system and to comply with European standard reliability requirements, on one hand, and to successfully meet existing and future challenges, on the other hand [6]. In particular, the new SCADA, along with other standard capabilities, will be able to assess the impact of system elements shutdown once every 15 minutes on power system stability; obtain information on the readiness and need for backup capacities; receive information about possible storms and critical climatic conditions in the country, which may be a signal to the stations to dispatch the transmission infrastructure.

Climate Change Impact on Energy Demand for Heating and Cooling

As the temperature changes, the behavior of individuals changes as well. Due to high temperatures during summer, the demand for electricity and cooling is increasing. Demand rises significantly in the afternoon when peak temperatures are set - cooling devices are switched on simultaneously, which increases the load on the power grid. The aforementioned danger is present in the case of non-modernized transmission lines. The largest increases in electricity consumption in Georgia in 2007-2018 were in June (87%), July (93%) and August (82%). In the same years, electricity consumption increased by 40-50% during the winter months.



Important indicators of climate change are the days of heating and cooling. Cold days are used as a reliable indicator of energy demand for heating or cooling. It is assumed that the energy demand for heating and cooling is proportional to the number of days in degrees. Degree days are the difference between the daily temperature mean (T_{mean}) and a certain temperature ($T_{threshold}$). If the difference is positive, then it belongs to the heating degree day, and if negative - to the cooling degree day. Temperature is usually set at 18^0C.

Figure 4.13.1: Number of heating degree days and cooling degree days in different 30-year periods

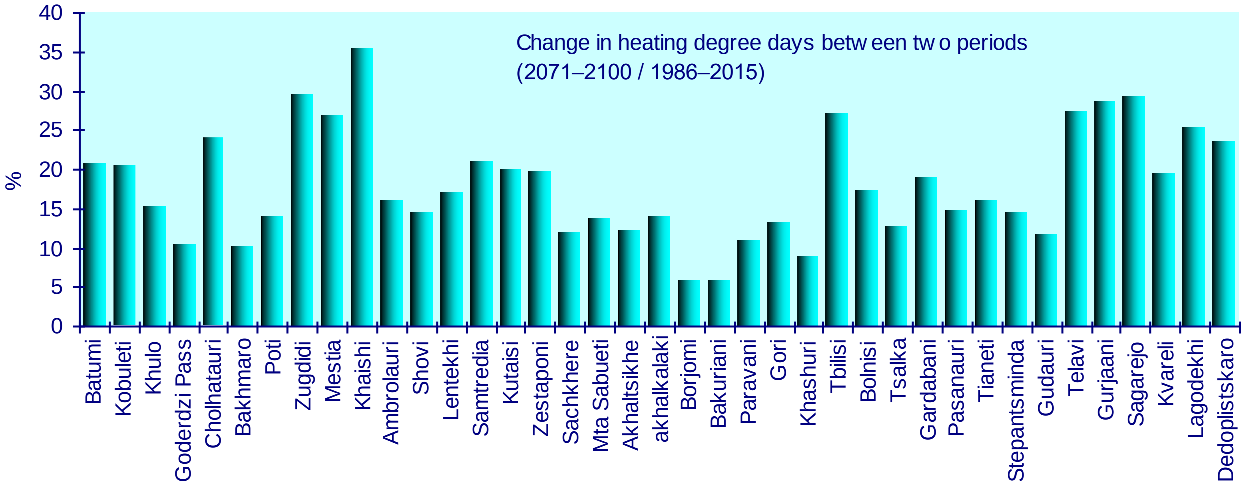
Fig. 4.13.1 shows the number of heating degree days and cooling degree days in Georgia for another 30-year period.

The number of heating degree days compared to the baseline period is reduced by 10% in the first forecast period (from 115.8 thousand to 104 thousand), and by 17% (from 115.8 thousand to 96.7 thousand) in the second forecast period.

The number of cooling degree days compared to the baseline period increased by 32% (13.2 thousand to 20.8 thousand) in the first forecast period, and by 63% (13.2 thousand to 25.8 thousand) in the second forecast period.

Climate change has a greater impact on energy demand for cooling than energy for heating, however, quantitative energy savings will be greater than an increase in energy demand for cooling. It should also be borne in mind that heating is mainly done by natural gas and firewood, while electricity generated by local hydro-resources is mainly used for cooling.

Figure 4.13.2 shows the expected change in the temperature and cooling degree days of the climate change by region. The number of cooling degree days in high mountainous areas increases sharply in percentages, but is still significantly below the levels of cooling degree days in lowlands. For example, Mestia, where there is a 589 percent increase in cooling degree days (from 65 to 449) in the second forecast period, almost 4 times the number of degree days in Tbilisi, in the context of 81 percent increase in the number of degree days (from 774 to 1,400).



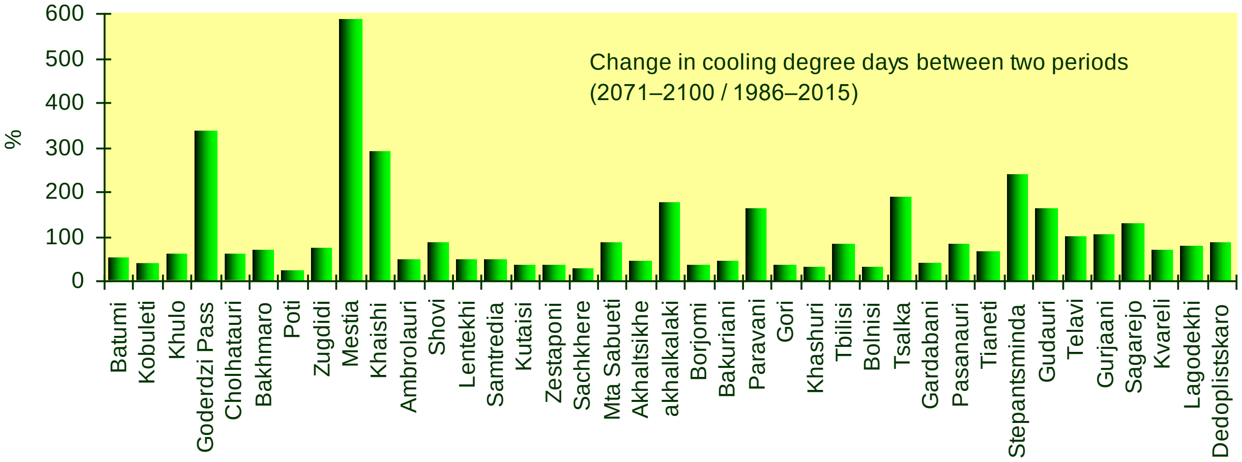


Figure 4.13.2: Changes of heating degree days and cooling degree days according to stations

There will also be increased demand for electricity from refrigerating farms. In the case of high temperatures, additional capacity will be required to maintain sufficient temperature in the refrigerators.

Impact of Geological Processes on Energy Infrastructure

Along with climate change, the incidence of natural disasters increases as a result of increased geological and hydrometeorological risks. Most of Georgia's energy facilities, especially oil and gas pipelines and high-voltage power transmission lines, are in difficult geological environment in mountainous terrain. Their normal functioning is significantly hampered by landslide-gravitational, mudflow processes. The periodic activation and dynamics of these processes is facilitated by climatic and meteorological conditions and by a critical increase in the slope tension caused by engineering activities.

The Baku-Supsa and Baku-Tbilisi-Ceyhan oil pipelines, as well as the Baku-Tbilisi-Erzurum and North-South Caucasus gas pipelines, pass through Georgia. Important sections of the pipeline are in highland, landslide and avalanche areas, causing serious damage and delays in energy supplies. The high damage category is characterized by the Mtskheta-Mtianeti, Shida Kartli and Guria regions, where a large number of oil and gas pipelines are endangered by geological processes each year. There is also a high rate in Samtskhe-Javakheti. Other oil and gas pipelines in the rest of the country are at lower risk.

In recent years, the impact of geological threats on high-voltage power transmission towers has increased significantly in the wake of climate change. Kakheti, Racha-Lechkhumi and Kvemo Svaneti, Guria and Mtskheta-Mtianeti regions, as well as the Autonomous Republic of Adjara, where a significant number of towers are under threat from geological processes, are highly damaged.

On July 25, 2015, the large-scale landslide and heavy rainfall in the Mestiachala River Basin caused the mudflow, which almost completely destroyed the infrastructure of the Mestiachala HPP under construction.

In 2014 a catastrophic mudflow occurred in the Dariali Gorge, killing two people working on a HPP near the Tergi River, disrupting a "North-South" gas pipeline, damaging a high-voltage power transmission tower.

Frequent hydro-meteorological risks (HMR) significantly affect the energy infrastructure. In case of storms, floods, landslides, transmission lines and towers are physically damaged. Similar effects can be caused by thunder and thunderstorms, which can cause the outbreak of wildfires. Small transmission lines are vulnerable to wind-damaged trees. In case of drought there is a danger of forest fires, which in turn damages any kind of infrastructure.

Adaptation-Related Recommendations

Rising temperature, precipitation changes, glacier melting and increased extreme hydro-meteorological and geological processes provoked by the climate change will have a significant impact on the country's hydropower sector. In-depth analysis of the sector’s sustainability and the development of its development strategies is crucially important, taking into account the principles of sustainable development and the risks posed by the climate change. Subject to the foregoing, it is recommended:

1. Involvement of climate change issues in energy policies, strategies and development plans;
2. Considering the problem of climate change in the long-term planning of energy demand-supply and developing appropriate adaptation measures;
3. Investigating changes in river runoff due to climate change in important river basins;
4. Implementing research and monitoring of evaporation of water in Georgia’s energy reservoirs;
5. Introducing an optimal water management system, which will enable additional energy production using surplus water resources as a result of increased runoff;

6. Increase water supplies, increase the capacity of existing reservoirs and build new ones, as well as increase the capacity of water treatment systems to prevent reduction of TPPs' efficiency due to climate change;
7. When considering the development of wind and solar power stations, considering the potential impacts of climate change and sustainable development;
8. Providing support to the public sector in building a climate-friendly energy system by creating a special fund for adaptation of the system, in partnership with the private sector in order to share risks and investments;
9. Promoting the creation of a climate-friendly energy system by the private sector (owners of energy facilities) through enhancing staff skills and assessing climate change risks;
10. Promoting climate change-related research in the energy sector at academic institutions and universities.

4.14 Transport

As a rule, the sustainable development of any country is directly linked to effective and efficient operation of the transport sector.

Georgia is located at the crossroads of Europe and Asia and its economic growth largely depends on effective use of its transit function. Since the 1990s, Georgia's role as part of the transport corridor between Europe, Caucasus and Asia has increased significantly. This reinforces the interest in sustainable development of Georgia, which primarily involves the creation of a quality transit infrastructure in the country. One of the main priorities of the Government of Georgia is modernization and construction of transport infrastructure meeting international standards and harmonization of the national legislation with the international one. In order to achieve this, the government is implementing important infrastructure projects that will help to attract additional freight flows to Georgia and increase the efficiency of its transport system.

Climate change has negative impacts on the transport sector and these impacts are likely to intensify in the future. Climate change causes an increase in costs related to the operation, maintenance, repair and rehabilitation of transport infrastructure. Upgrading the infrastructure to adapt it to climate change requires high-cost interventions, but without adaptation measures economic losses will be much more significant.

Road Network

The road network of Georgia consists of 20,000 km of roads divided into three categories: roads of international importance (1,595 km long), roads of national importance (5,372.6 km) and roads of local importance (13,774 km).

Map 4.14.1: Roads of international importance, Georgia

The number of vehicles registered in Georgia shows a steady upward trend (Figure 4.14.1), having increased by 55% in 2018 against 2007. Annual freight transport by road amounts to 25 million tons (around 59.9% of total freight traffic) and passenger traffic reaches 260 million people.

High volume of international road transport creates a high traffic load. In the period between 2011 and 2018 international transport volume ranged within 31.1 million tonnes, and had no significant changes in 2018, (Figure 4.14.2).

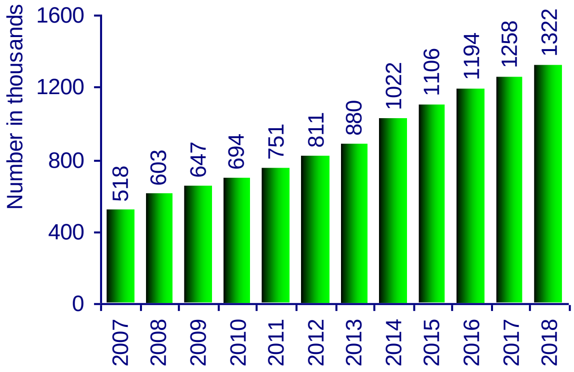


Figure 4.14.1: Number of vehicles in 2007–2018

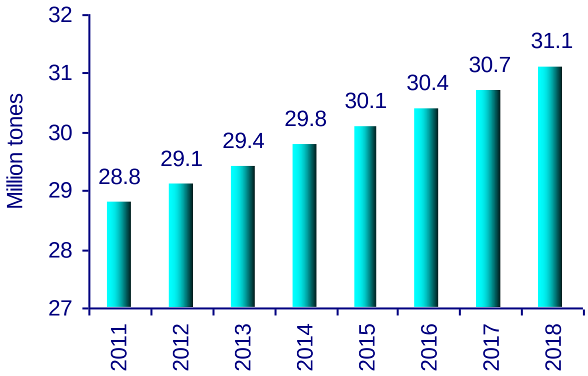


Figure 4.14.2: Volume of international road transport in 2011–2018

The recent years have seen significant investments in the road infrastructure (roads of international importance above all), yet, further improvements are necessary especially at the regional and local levels. Passenger railway and secondary and local roads do not meet demands and expectations.

The European Union, Japan International Cooperation Agency, the Millennium Challenge Corporation (MCC), the European Bank for Reconstruction and Development and the World Bank support the development of the road network of Georgia, providing technical assistance for institutional strengthening and private sector development in such areas as project management, traffic safety, personnel development, elaboration of training programs, procurements for road maintenance needs, etc.

Georgian Railway

The railway in Georgia is the state property. Its length is about 1600 km and it plays a less significant role in the passenger turnover than roads, but is far more important in terms of freight traffic. Unfortunately, the railway infrastructure and the entire industry with its capacity and equipment are far behind the standards and parameters of the European railway system and need upgrading and development.

The Georgian Railway is one of the most important segments of the Eurasian transport artery stretching between the Black Sea and the Caspian and connecting Europe and Asia in a beeline. The construction of the Georgian section of the Baku-Tbilisi-Kars railway has completed. The mainline unites the railways of Azerbaijan, Georgia and Turkey into a corridor between the Caspian Sea and Europe.

Seaports and Terminals

There are two seaports and three terminals on the Black Sea coast of Georgia. These are: Poti and Batumi seaports, Kulevi and Supsa oil terminals and Batumi Sea Terminal. The Poti Seaport offers all conditions for shipping operations, its freight turnover constantly increasing. The seaport connects to other Black Sea ports by means of vehicular ferries. The Batumi Seaport is the second largest port in Georgia, known for its favorable geostrategic location and conditions. The main factor contributing to the development of the Batumi Seaport is oil transportation from Baku to Batumi by rail. The port has long been known as an important part of the Eurasian and international transport corridors. The Batumi Sea Terminal and the port constitute a developed maritime infrastructure on the Black Sea coast of Georgia. The oil terminal has annual throughput capacity of up to 15 million tons. It is intended for processing crude oil and all types of cargo. The Kulevi Sea Terminal, located between Poti and Anaklia, opened several years ago. Its capacity is up to 6 million tons with potential increase to 10 million tons. The Supsa Terminal was established in parallel with the construction of the Baku-Supsa oil pipeline and became operational in 1999. It is one of the largest Black Sea terminals and is mainly intended for processing oil supplied via the Baku-Supsa pipeline.

Air Transport

Georgia became a full member of the International Civil Aviation Organization (ICAO) in 1994. This means that the country's civil aviation operates in accordance with international standards and recommended practices. In 2005, Georgia joined the European Civil Aviation Conference (ECAC).

Currently, Georgia has one local and three international airports. Tbilisi International Airport is the busiest, accounting for more than 76% of total passenger turnover and operating most international and domestic flights. The airport can accommodate and serve all types of aircraft and the annual capacity of its passenger terminal is 4 million people. Kutaisi International Airport, operating since 2012, is the second largest airport in Georgia, which served 617,373 domestic and international passengers in 2018. The airport offers regular international flights to the CIS and European countries, as well as domestic flights, particularly to Mestia – one of the main tourist destinations in Georgia. Mestia Airport opened in 2011 to perform domestic flights, while Batumi Airport operates both domestic and international flights.

Expected Climate Change

Negative impacts of climate change vary depending on type of transport and climate change factor. Consequences may depend on local situation, natural conditions, socio-economic parameters and other factors. In assessing climate change impacts, the focus was on the highways connecting Georgia with the neighbor countries - Turkey, Azerbaijan, Armenia and Russia (L-1/E60, L-2/E70, L-3/E117, L-5 and L-6/E117). These roads also provide an access to Batumi and Poti seaports and a gateway to Europe. The key railway sections are located in the same places as the L-1/E60 and L-2/E70 highways.

According to the climate scenario, in the two 30-year forecast periods (2041–2070 and 2071–2100) average temperatures in localities (cities) along the above listed highways will rise compared to the base 30-year period (1971–2000). The rise in temperatures will be the most significant in the hottest months of July and August. Table 4.14.1 shows changes in average temperatures in several localities along the highways. The calculations are based on data from weather stations located in these cities. As is seen from the table, average temperatures rise significantly in all the cities in both forecast periods.

Table 4.14.1: Expected change in average temperatures for the forecast period

City/highway	Parameter	2041–2070/1971–2000		2071–2100/1971–2000	
		July	August	July	August
Batumi (L-2)	Tmean, ^{0}C	24.3	24.6	24.9	25.2
	ΔTmean, ^{0}C	1.9	2.0	2.4	2.6
Poti (L1 and L2)	Tmean, ^{0}C	24.6	24.7	25.2	25.2
	ΔTmean, ^{0}C	1.6	1.6	2.2	2.1
Kutaisi (L-1)	Tmean, ^{0}C	25.4	25.8	26.1	26.3
	ΔTmean, ^{0}C	2.2	2.5	3	3

City/highway	Parameter	2041–2070/1971–2000		2071–2100/1971–2000	
		July	August	July	August
Gori (L-1)	Tmean, ^{0}C	23.9	23.7	24.6	24.1
	ΔTmean, ^{0}C	1.9	2.0	2.6	2.3
Tbilisi (L-1)	Tmean, ^{0}C	26.8	26.2	28.3	27.9
	ΔTmean, ^{0}C	2.2	2.2	3.7	3.9
Bolnisi (L-6)	Tmean, ^{0}C	26.4	26.0	27.4	26.1
	ΔTmean, ^{0}C	2.1	2.3	3.1	2.4
Lagodekhi (L-5)	Tmean, ^{0}C	26.8	26.1	28.7	27.5
	ΔTmean, ^{0}C	2.0	2.1	3.9	3.5

Temperature increase will be particularly sharp in the afternoon. Table 4.14.2 shows maximum temperatures recorded in the cities in 1986-2015 and the possible upper threshold of maximum temperatures for the given months in 2050, 2070 and 2100 (with 95% confidence interval). The maximum monthly temperature may exceed the upper limit with a 5% probability. Simple linear regression analysis was used to model the relationship between the maximum monthly temperature and the year of observation.

Table 4.14.2: Highest maximum temperatures (in 0C) in the hottest months of 1986–2015 and estimated upper thresholds of maximum monthly temperatures in 2050, 2070 and 2100

Year	Poti		Kutaisi		Gori		Tbilisi		Bolnisi		Lagodekhi	
	VII	VIII	VII	VIII	VII	VIII	VII	VIII	VII	VIII	VII	VIII
2015	39.9	40.0	43.1	42.2	36.4	39.0	39.9	40.3	37.8	37.5	40.4	43.3
2050	40.4	42.3	44.9	42.6	38.4	41.8	40.5	42.1	40.4	43.4	42.3	43.9
2070	40.8	43.3	46.0	43.4	38.8	43.3	40.8	42.9	40.7	44.4	43.3	45.4
2100	41.5	44.8	47.8	44.8	39.5	45.7	41.5	44.3	41.4	46.1	44.9	47.7

A sharp increase in temperatures is possible in the future in July and especially in August. As of 2100, maximum temperatures may rise by 2.6^{0}C-8.6^{0}C in August and by 1.6^{0}C-4.7^{0}C in July as compared to 1986-2015.

According to the climate scenario, the number of heatwaves along the key highways (except Lagodekhi) will increase in both forecast periods compared to the base period, with a significant increase in Tbilisi (by 180% and 307%). Table 4.14.3 shows the change in the number of heatwaves over the two forecast periods.

Table 4.14.3: Change in the number of heatwaves in the two forecast periods

Locality	Number of heatwaves			Change in the number of heatwaves			
	2041-2070	2071-2100	1971-2000	I - Base		II - Base	
	I	II	Base	Days	%	Days	%
Batumi	6.5	7.1	1.8	4.7	163	5.3	197
Poti	6.1	6.5	1.9	4.2	116	4.6	137
Zugdidi	6.5	9.9	1.6	4.9	213	8.3	432
Kutaisi	4.7	5.6	1.5	3.2	113	4.1	172
Gori	5.1	5.6	1.7	3.3	92	3.9	124
Tbilisi	6.5	8.6	1.7	4.8	180	6.9	307
Bolnisi	6.1	6.9	1.7	4.4	152	5.1	196
Lagodekhi	2.8	3.9	1.8	1.0	-47	2.0	11

Warm Spell Duration Index (WSDI) (count of days with at least 6 consecutive days when the daily maximum temperature exceeds the 90th percentile) has also been calculated, showing a significant increase for all the cities (Table 4.14.4).

Table 4.14.4: Warm spell duration (in days) and change

City	2041-2070	2071-2100	1971-2000	Δ (I - Base)	Δ (II - Base)
	I	II	Base		
Batumi	29	39	2	27	37
Poti	23	31	2	20	29
Zugdidi	14	31	2	12	29
Kutaisi	13	18	3	10	15
Gori	23	26	5	18	21
Tbilisi	29	87	4	25	83
Bolnisi	29	35	4	25	31
Lagodekhi	35	71	5	29	66

According to the climate scenario, precipitation decreases throughout Georgia (with few exceptions) during both forecast periods. However, in certain areas maximum monthly 1-day precipitation (Rx1day) will increase. Figure 4.14.3 shows Rx1day values in the base period and in the first and second forecast periods, while Figure 4.14.4 shows Rx1day changes (percentage) in the first and second forecast periods as compared to the base period.

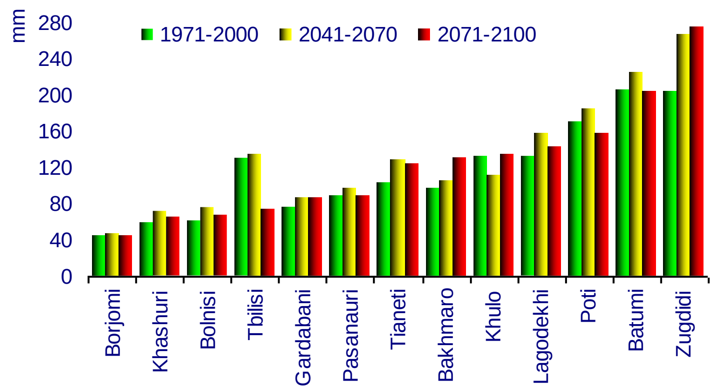


Figure 4.14.3: Rx1day values (mm) in the base, first and second forecast periods

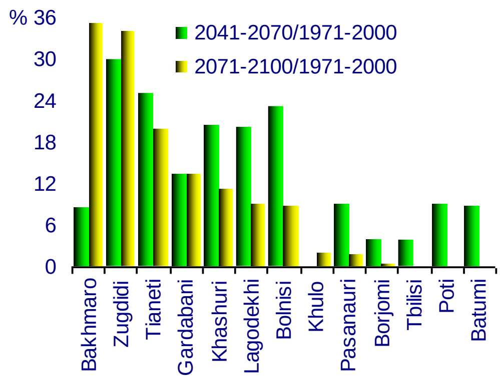


Figure 4.14.4: Rx1day change over the forecast periods compared to the base period.

The effects of climate change are mainly related to safety, operation and maintenance of road infrastructure. The effects can be direct (damage, deformation, flooding, erosion) and indirect (economic, environmental, demographic and related to spatial planning).

Temperature increase: Extreme temperatures can pose the following risks to the transport infrastructure:

Railway

- Expansion of rails. This effect cannot be controlled from the control center, since low voltage current still continues to flows through the rails;
- Expansion of electricity transmission lines will affect the rolling stock;
- Speed reduction and consequent frequent delays resulting in disruption of train services. Railway points and signaling operate under the specified temperature regime;
- Overload and malfunction of passenger train cooling systems;
- Railway bridges are designed within a specified range of structure expansion or narrowing coefficients, therefore, associated effects and risks shall be taken into account.

Roads

- Road surface damage, in particular cracking, ageing/oxidation, melting of asphalt, heaving of concrete pavement;
- Bridges are designed within a specified range of structure expansion or narrowing coefficients, therefore, associated effects and risks shall be taken into account.

Extremely cold and frosty days

Railway

- Frequent narrowing of rails damages them causing a loss of signal connection.

Roads

- *Freezing temperatures* cause water that is trapped beneath the *pavement* to freeze, and as the water freezes it expands and causes the ground to heave.

Increase in precipitation

- Flooding and/or washing out of roads, overloading of drainage systems, washing out of bridge supports and degradation of bridges, flooding of tunnels.

Rising sea level / local flooding

Both local flood and strong wind can disrupt the operation and potentially damage transport infrastructure. Rising sea level and recurring strong winds can damage the road surface and corrode structural elements of concrete pavement.

Maritime infrastructure is also vulnerable to climate change. Particular attention should be paid to rising sea levels and consequences of storms in the vicinity of seaports.

Risks from geological processes

Geological processes can cause a serious damage to road and rail transport, which is particularly true with Georgia, where highways and railways often pass via mountainous terrain with complex geological settings. At the same time, construction and rehabilitation of roads and railways is likely to cause changes in geological environment, leading to natural disasters of various scale.

Periodic intensification and triggering of mudflow and landslide processes are caused by climatic and meteorological conditions and engineering activities that affect slope stability, causing critical stress. Roads and railways running parallel to rivers are in turn damaged by bank erosion and floods. In 1977–2010, floods damaged and washed out 100 km of roads and 16 km of railways.

Since 2004, the National Environmental Agency has been conducting regular regional geo-monitoring and recording reported geological disturbances related to roads and other infrastructure facilities in its annual bulletin, regularly submitted to the Ministry of Regional Development and Infrastructure.

In 2009-2018, landslide and mudflow processes on highways significantly increased in scale and number. Geologic hazard is particularly high for roads in Mtskheta-Mtianeti region. It is also high in Racha-Lechkhumi, Kvemo Svaneti and Imereti regions, and is relatively low, though still significant in other localities. Landslide and mudflow processes jeopardize the railway too, but here the risks are much lower than with highways. In 2009–2018, 33 cases of railway damage were reported, most of them in Imereti (16 cases) and Shida Kartli (13 cases).

Adaptation Measures

Adaptation measures aim at preventing disruption of passenger and cargo transportation and efficient operation of transport corridors.

Key Steps of Adaptation Assessment

1. Development and implementation of adaptation strategy and action plan;
2. Monitoring and revision/reassessment;
3. Mainstreaming climate change issues in transport sector policies, strategies and development plans;
4. Updating design and construction standards;
5. Redefining and/or modifying technical criteria when planning project scope and location;
6. Mapping the risks of transport infrastructure vulnerability to climatic stress;
7. Considering investment risks;
8. Identifying and implementing cost-effective methods of network adaptation to extreme climatic conditions for mitigation of expected risks;
9. Assessing available resources and information/data necessary to ensure preparedness and coordinated work of parties involved in infrastructure planning, construction, operation (functioning) and maintenance.

4.15 Tourism

Tourism is one of the fastest growing and high-income sectors in the global economy. The tourism industry promotes job creation and revenue growth, diversifying the economy, protecting the environment, promoting historical and cultural values and bringing cultures closer together. Consequently, tourism is one of the priority areas of the country's economic development.

Despite the high competition in the field of tourism in the world market, the prospect of development of the Georgian tourism industry is quite optimistic. Operation of the tourism market and related sectors is highly seasonal, which depend on many factors. The primary factors for functioning of the tourism market are natural climate, while the secondary factors are economic, demographic, psychological, technological, etc.

The World Meteorological Organization (WMO) has organized a number of events to support tourism. It provides World Tourism Organization (WTO) members with early warnings about natural disasters, glacier recession, water resources and climate change. WTO closely cooperates with WMO. Forecasts of climate and extreme hydrometeorological events provided by the National Hydrometeorological Services are particularly important in today's world, as regional climate variations have emerged in the wake of global climate change.

Thus, it can be said that in tourism business, when assessing tourism and recreational resources a detailed study of the environmental and climate impacts is one of the most important issues both in terms of ecology and economy.

Development of the tourism industry directly depends on the geographical location, topography, vegetation, weather and climate of the region. Weather and climate are the two main factors that determine the bioclimatic resources of a place. Therefore, the study of these resources, which are essential for organization and development of the resort industry plays a key role and much focused.

The climate has a direct and indirect impact on tourism. The climate in the tourism sector is an essential factor influencing for tourists. Adverse climatic conditions and their changes can affect the tourist flow or seasonal alternation of tourist activities. Seasonality of tourism and changes in the consumer sector, caused by climate variations, also affect the related sectors of tourism. The study of seasonality in the field of tourism allows to determine the degree of influence of natural-climatic conditions on tourism product formation and to identify the factors that drive seasonality in tourism, as well as to develop a system of measures to reduce seasonality inequality.

Climate resources are one of the principal components of tourism-recreational resources. For the first time in 2008, the WMO and MTO adopted a resolution stating the need for countries in these organizations to assess the potential of tourism and recreational resources in different tourism regions and to develop appropriate recommendations. Georgia, as a member of both organizations, believes that the potential of tourism and recreational resources should be re-evaluated. Georgia's diverse climate conditions create tremendous potential for tourism development. However, the definition of climate potential in Georgia according to tourism standards, as is the case in developed countries, has not been implemented yet. This may have a negative impact on attracting potential tourists to Georgia.

Climatic indices were used to assess tourism and recreational resources. There are more than 200 climate indices. In general, the tourism climate indices can be classified into three categories. Elementary indices are a synthesis of the values of several meteorological parameters, but they do not contain bio-meteorological information and are thus less acceptable for evaluating recreational resources in the tourism industry.

To evaluate tourism-recreational resources in Georgia for the first time the Tourism Climatic Index (TCI) [115] was used, based on the combination of different meteorological elements (air temperature, atmospheric precipitation, relative humidity, average duration of sunshine). In order to develop the tourism industry, it is necessary to identify the potential of tourism resources by seasons and months. Only TCIs can calculate annual values. At the same time, this index does not fully incorporate the thermo-physiological component necessary to evaluate tourism-recreational resources.

To study the impacts of climate change on the development of the tourism industry, the Holiday Climate Index (HCI), which is a complex climatic feature and is defined on the basis of various meteorological elements, has been identified. The Holiday Climate Index was designed for this study with the purpose of overcoming all identified deficiencies and limitations of the Tourism Climate Index. The definition of HCI takes into account that different destinations require different types of climate information for two major segments - urban and mass tourism.

The five climatic variables used for the HCI input are maximum air temperature (^{0}C) and relative humidity (TC) (the set of these two parameters is the effective air temperature T) (%), cloud cover (A) (%), precipitation R_d (mm) and wind (W) (m/sec).) The Holiday Climate Index (HCI) score is calculated according to the following formula:

$$HCI = 4 \cdot T + 2 \cdot A + 3 \cdot R_d + W.$$

The effective air temperature is calculated according to a special nomogram [116].

Table 4.15.1: HCI's Rating Scheme

Rating	Effective Temperature (ET) T (°C)	Cloud Cover A (%)	Amount of Rain R_d (მმ)	Wind speed W, m/sec
10	23–25	11–20	0	1–9
9	20–22 / 26	1–10 / 21–30	<3	10–19
8	27–28	0 / 31–40	3–5.99	0 / 20–29

Rating	Effective Temperature (ET) T (°C)	Cloud Cover A (%)	Amount of Rain R_d (მმ)	Wind speed W, m/sec
7	18–19 / 29–30	41–50		
6	15–17 / 31–32	51–60		30–39
5	11–14 / 33–34	61–70	6–8.99	
4	7–10 / 35–36	71–80		
3	0–6	81–90		40–49
2	(-5)–(-1) / 37–39	90–99	9–12	
1	<-5	100		

Unlike other climatic indices, HCI categories are scored in points (Table 4.15.2).

Table 4.15.2: HCI Categories and Rating

HCI Score	Rating	Category
90 – 100	1	Ideal
80 – 89	2	Excellent
70 – 79	3	Very good
60 – 69	4	Good
50 – 59	5	Acceptable
40 – 49	6	Marginal
30 – 39	7	Very unfavourable
20 – 29	8	Extremely unfaourable
10 – 19	9	Impossible
- 30 – 9	10	Impossible

The study parameters were compared for two 30-year periods, I (1956–1985) and II (1986–2015) according to the Student's criterion, when $\alpha \leq 0.15$. The regularities of changes to the HCI Index and its constituent parameters for the 12 tourist destinations of Georgia are defined by regions. Mathematical statistics methods were used in data analysis.

Samegrelo-Zemo Svaneti Region (Mestia)

The monthly values of the HCI score in Mestia vary from 34 (category "unfavorable", January) to 95 (category "ideal", September-October) in 1956-2015. The mean monthly mean values for HCI changed from 56.2 (category "Acceptable", January) to 83.5 (category "Excellent", August). Table 4.15.3 shows the statistical characteristics of HCI during the two observation periods in Mestia.

Table 4.15.3: HCI Statistical Characteristics in Two Observation Periods in Mestia

Parameter	Month						Cold period	Month						Warm period	Year
	I	II	III	X	XI	XII		IV	V	VI	VII	VIII	IX		
HCI_Mean	**56.2**	58.4	59.8	72.1	61.2	57.5	60.9	66.6	76.9	83	82.7	**83.5**	84.3	79.5	70.2
HCI_Min	**34**	45	45	53	49	51	55.2	51	66	59	69	74	68	72.7	64.3
HCI_Max	70	66	68	**95**	75	66	67.8	81	89	93	91	91	**95**	84.5	74.3
II (1986–2015)	54.1	58	59.1	70.9	59.9	56	59.7	66.9	76.9	82	81	81.7	83.6	78.7	69.2
I (1956–1985)	58.2	58.8	60.5	73.3	62.5	59	62	66.3	76.9	83.9	84.4	85.3	85	80.3	71.2
Difference (II - I)	**-4**	-0.8	-1.4	-2.4	-2.6	-2.9	-2.3	0.6	0	-1.9	**-3.3**	**-3.7**	-1.4	-1.6	-2

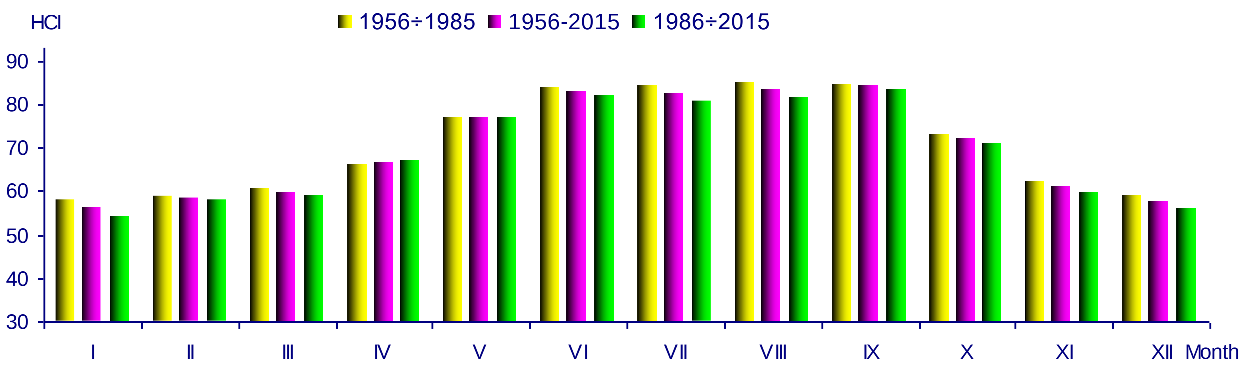


Figure 4.15.1: Average monthly values of HCI over the three observation periods

The average monthly HCI in Mestia for the whole period of observation generally has a negative tendency. Significant negative trend in HCI values is observed in January, July, August, December, during the cold and warm periods of the year and throughout the year. Significant decreases in mean monthly and seasonal values over the second period were observed in January, July and August, in the cold and warm periods and throughout the year..

Table 4.15.4: HCI categories in Mestia during three observation periods

Month / Year	1956-1985	1956-2015	1986-2015
January	Acceptable	Acceptable	Acceptable
February	Acceptable	Acceptable	Acceptable
March	Good	Good	Good
April	Good	Good	Good
May	Very good	Very good	Very good
June	Excellent	Excellent	Excellent
July	Excellent	Excellent	Excellent
August	Excellent	Excellent	Excellent
September	Excellent	Excellent	Excellent
October	Very good	Very good	Very good
November	Good	Good	Good
December	Acceptable	Acceptable	Acceptable
Year	Very good	Very good	Good
Cold period	Good	Good	Good
Warm period	Excellent	Very good	Very good

Table 4.15.5 shows the recurrence of HCI categories over the three observations. In 1956–2015, the highest repeatability of the HCI index was noted as “Excellent” (29.3%), and the least repeated as “Unfavorable” (0.1%). There are favorable bioclimatic conditions in Mestia during all three observation periods. During the second period (1986–2015) as compared to to the first (1956–1985), climate change in Mestia has led to changes in the categories of the Tourism Climate Index (HCI). The HCI category “Acceptable” increased from 21.7% to 30.0% (from 79 days to 110 days, respectively). The category "Good" decreased from 29.3% to 19.7% (108 and 72 days a year), the category "Very good" increased from 13.9% to 19.2% (51 and 70 days a year). The category "Excellent" decreased from 30.3% to 28.3% (111 and 103 days a year).

Table 4.15.5: Recurrence of HCI categories in Mestia in percentages and days during three observation periods

Category / Year	Repeatedness, %			Repeatedness, day		
	1956-1985	1986-2015	1956-2015	1956-1985	1986-2015	
Very unfavourable	0	0	0	0	0	0

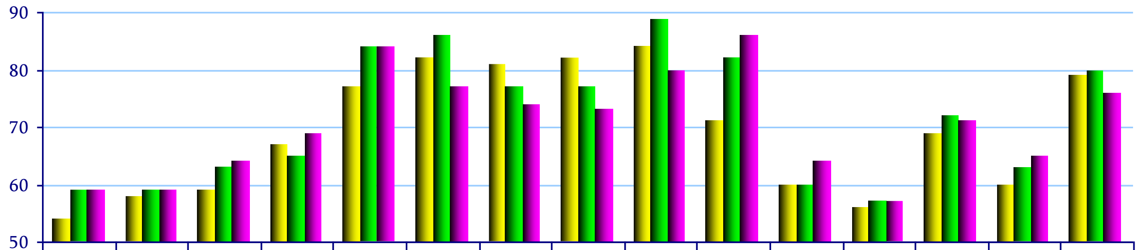
Category / Year	Repeatedness, %			Repeatedness, day		
	1956-1985	1986-2015	1956-2015	1956-1985	1986-2015	
Unfavourable	0	0.3	0.1	0	1	1
Marginal	0.6	1.4	1	2	5	4
Acceptable	21.7	30	25.8	79	110	94
Good	29.3	19.7	24.7	108	72	90
Very good	13.9	19.2	16.5	51	70	60
Excellent	30.3	28.3	29.3	111	103	107
Ideal	4.2	1.1	2.6	15	4	10

In order to determine the expected climate change in the tourism business, the average monthly, mean annual and mean seasonal values of the HCI index for the three thirty years were determined: baseline period (1986-2015), first forecast period (2041-2070) and second forecast period (2071- 2100 years).

As a result of climate change, a slight change in HCI categories is expected in Mestia. Compared to the baseline period in March, May and October, as well as the warm season and the whole year, the category is improved by one step (green cells). One step worse in July and August (purple cells). In the second forecast period, one-step category improvement is in March, May and October, as well as the whole year, with one-step deterioration in June-August. Given the above, it can be said that the expected climate change will not have a significant impact on Mestia's tourism potential.

Table 4.15.6: Average Monthly, Average Annual and Seasonal Values of HCI in Mestia (1986-2015, 2041-2070 and 2071-2100)

Month / Period	1986-2015	2041-2070	2071-2100
January	Acceptable	Acceptable	Acceptable
February	Acceptable	Acceptable	Acceptable
March	Acceptable	Good	Good
April	Good	Good	Good
May	Very good	Excellent	Excellent
June	Excellent	Excellent	Very good
July	Excellent	Very good	Very good
August	Excellent	Very good	Very good
September	Excellent	Excellent	Excellent
October	Very good	Excellent	Excellent
November	Good	Good	Good
December	Acceptable	Acceptable	Acceptable
Year	Good	Very good	Very good
Cold period	Good	Good	Good
Warm period	Very good	Excellent	Very good



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	Cold
1986–2015	54	58	59	67	77	82	81	82	84	71	60	56	69	60	79
2041–2070	59	59	63	65	84	86	77	77	89	82	60	57	72	63	80
2071–2100	59	59	64	69	84	77	74	73	80	86	64	57	71	65	76

Figure 4.15.2: Average Monthly, Annual and Seasonal Values of HCI in Mestia (1986-2015, 2041-2070 and 2071-2100)

Similar assessments were made for the other 11 important mining tourism sites. The categories in Table 4.15.7 are listed in accordance with the rankings in Table 4.15.2. Table 4.15.7lists: I (30-year baseline period from 1986–2015), II (2041–2070), and III (2071–2100). Green is the category improvement over the baseline period, and purple is the decline category.

Table 4.15.7: HCI categories for three periods

Point	Mestia			Khaishi			Lentekhi			Khulo			Bakhmaro			Bakuriani		
Month/Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
January	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5
February	5	5	5	4	4	3	5	4	4	5	5	4	5	5	5	5	5	5
March	5	4	4	4	4	3	4	4	4	4	4	4	5	4	4	4	5	4
April	4	4	4	3	3	3	4	3	3	3	3	3	4	4	4	4	4	4
May	3	2	2	2	2	3	2	2	2	2	2	2	4	4	4	3	3	3
June	2	2	3	3	2	3	3	2	3	2	3	3	4	3	3	2	2	2
July	2	3	3	3	3	3	3	3	3	2	2	3	3	3	2	2	2	2
August	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2
September	2	2	2	2	2	3	2	2	3	2	2	2	3	3	3	2	2	2
October	3	2	2	3	2	3	3	2	2	3	2	2	4	4	4	4	3	3
November	4	4	4	4	4	3	5	4	4	5	4	4	5	4	4	4	4	4
December	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	4	5	5
Year	4	3	3	3	3	3	4	3	3	3	3	3	4	4	4	3	3	3
Cold	4	4	4	4	4	3	5	4	4	4	4	4	5	4	5	4	4	4
Warm	3	2	3	2	2	3	3	3	3	2	2	2	3	3	3	3	2	2

Continuation

Point	Gudauri			Pasanauri			Shovi			Stepantsminda			Tbilisi			Borjomi		
Month/Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
January	5	5	5	4	4	4	5	5	5	4	4	4	4	4	4	4	5	5
February	5	5	5	4	4	4	5	5	5	4	4	4	4	4	4	4	4	4
March	5	5	5	4	4	4	5	4	4	4	4	4	4	4	3	4	4	4
April	4	4	4	3	3	3	4	4	4	4	4	4	3	2	2	3	2	3
May	5	4	4	3	2	2	3	3	3	4	3	3	2	2	3	2	2	2
June	4	3	3	2	2	2	3	2	2	3	2	2	3	3	3	2	2	3
July	3	2	2	2	3	3	2	3	3	2	2	2	3	3	2	3	3	3
August	3	2	2	2	3	3	2	3	2	2	2	2	3	3	4	3	3	3
September	3	3	3	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2
October	4	4	4	3	2	2	3	4	3	3	3	3	2	2	2	3	2	2

Point	Gudauri			Pasanauri			Shovi			Stepantsminda			Tbilisi			Borjomi		
Month/Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
November	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4
December	5	4	4	4	4	4	5	5	5	4	4	4	4	4	4	4	4	4
Year	4	4	4	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3
Cold	5	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4
Warm	4	3	3	2	2	2	3	3	3	3	2	2	3	3	3	3	2	3

It was found that the expected climate change in Georgia would not have a significant impact on the tourism bioclimatic resources (HCI). It is only possible to change the HCI category in one step or increase. Thus, it can be said that bioclimatic conditions in Georgia have not changed significantly and we should not expect any substantial changes in the future.

In order to increase the country's resort and tourism potential, more detailed study of the bioclimatic resources of individual areas should be undertaken in order to make the most optimal use of this natural resource - to improve the quality and attractiveness of different types of resort and tourism industries to potential customers.

Regulations of snow cover change at Georgian winter resorts

Mountain-ski tourism is particularly sensitive to climate change, thus, it is necessary to take into account the climate change challenges for its reasonable development.

For several Georgian ski resorts (Mestia, Goderdzi, Gudauri, Bakuriani), the patterns of change in snow cover duration between two 30-year periods (I period 1956–1985 and II period 1986–2015) were assessed. Snow cover data are incomplete - data are not available for all years (Table 14.15.9).

In Mestia, during the study period, the average snow season began on November 30 and ended on March 19. The average duration of snow cover was 108 days. Snow coverage trend is negative. -Duration of snow cover in period II decreased by 17% compared to period I.

Table 4.15.8: Duration of snow cover characteristics at winter resorts.

Station	Years	Season's beginning	Season's ending	Season's duration		Season's number
				days	change, %	
Mestia	1956-2015	30 November	19 March	108		32
	1986-2015	26 November	2 March	95	-17	6
	1956-1985	1 November	28 March	111		26
Gudauri	1956-2015	23 November	5 May	162		35
	1986-2015	29 November	3 May	154	-12	19
	1956-1985	15 November	7 May	172		16
Goderdzi	1956-2015	8 November	10 May	182		46
	1986-2015	10 November	15 May	185	3	20
	1956-1985	6 November	6 May	180		26
Bakuriani	1956-2015	26 November	28 March	122		35
	1986-2015	19 November	17 March	118	-8	19
	1956-1985	15 November	22 March	127		16

During the observation period in Gudauri, the average snow season started on November 23 and ended on May 5. The duration of the snow cover was 162 days throughout the observation period. The trend of snow cover is negative. During the second period the duration of snow cover is reduced by 12% compared to the first one.

In Goderdzi, the average snow season for the observation period began on November 8 and ended on May 10. The duration of the snow cover was 182 days throughout the observation period. The trend of snow cover is positive – the duration of snow cover has increased by 3% compared to the first period.

In Bakuriani, for the observation period the snow season started on average on November 26 and ended on March 28. The duration of the snow cover was 122 days throughout the observation period. The trend of snow cover is negative. During the second period the duration of snow cover is reduced by 8% compared to the first one.

The results show that the duration of the winter season in addition to climatic factors depends on physical and geographical factors such as the location of the tourist site and the altitude. Evaluations are of a benchmark nature, further studies are required.

In the future, climate change may significantly affect the length of the ski season. According to the climate scenario, average temperatures are expected to increase every month compared to the baseline 30- year period (2041–2070) compared to the baseline 30-year period (1971–2007) (Table 4.15.9). Precipitation throughout the whole territory of Georgia, with the exception of a few low-lying stations, has reduced precipitation. In the future, as temperatures rise and precipitation falls, snow cover will likely decrease.

Table 4.15.9: Average temperature change (°C) in individual months compared to baseline during the first forecast period

Station	Month						Season			Year
	October	November	December	February	March	April	Spring	Autumn	Winter	
Mestia	4.4	2.1	2.8	2.4	5.9	1.6	3.5	3.3	2.5	2.9
Gudauri	3.4	3.1	2.9	2.7	2.8	2.1	2.9	3.0	2.9	3.0
Goderdzi Pass	2.7	1.7	1.3	1.5	2.0	1.7	2.1	2.3	1.3	2.0
Bakuriani	2.8	2.6	1.8	2.1	2.3	1.7	2.2	2.7	1.9	2.1

It is accepted that a ski area with sufficient snow cover for skiing is considered reliable when snow cover depth (artificial or natural) exceeds a 30 cm threshold for the 100-day rule.

Table 4.15.10 gives the statistical characteristics of the maximum snow cover depth in Bakuriani and Gudauri from 1956 to 2015. As shown in this table, the average depth of snow cover in Bakuriani is highest in February (61.3 cm) and minimum in June and September (0.1 cm). During the whole observation period, the maximum depth of snow cover was 130 cm in Bakuriani in March 1956. The average depth of snow cover in Gudauri is highest in March (115.1 cm), minimum in October (0.7 cm). The maximum depth of snow cover at 330 cm in Gudauri was recorded in February 2008.

Table 4.15.10: Statistical characteristics of maximum snow cover depth in Bakuriani and Gudauri 1956-2015

Month	Mean		Min		Max	
	Bakuriani	Gudauri	Bakuriani	Gudauri	Bakuriani	Gudauri
January	49.0	81.2	0	0	83	300
February	61.3	99.8	0	0	112	330
March	54.2	115.1	0	0	130	294
April	23.9	91.9	0	0	109	260
May	2.3	37.6	0	0	23	312
June	0.1	0.0	0	0	3	0
July	0.0	0.0	0	0	0	0
August	0.0	0.0	0	0	0	0
September	0.1	0.7	0	0	2	35
October	4.9	6.8	0	0	28	50

Month	Mean		Min		Max	
November	20.2	26.1	0	0	80	121
December	35.2	55.8	0	0	70	244

Table 4.15.11 and Figure 4.15.3 provide the statistical characteristics of maximum snow cover depths in Bakuriani and Gudauri.

In Bakuriani, from 1956 to 1985, a noticeable change in the average mean depth of maximum snow cover was observed in January (decrease of 17%), in February (decrease of 19%) and in November (increase of 17%) in 1986-2015. The average maximum depth of snow cover in Gudauri increased in April (18%) and in November (30%).

Table 4.15.11: Change in mean depth of maximum snow cover between two periods

Month	Bakuriani			Gudauri		
	1956–1985	1986–2015	Change, %	1956–1985	1986–2015	Change, %
January	54	45	-17	81	82	1
February	70	57	-19	98	101	3
March	55	56	2	110	116	5
April	22	23	5	83	98	18
November	18	21	17	20	26	30
December	30	30	0	58	61	5

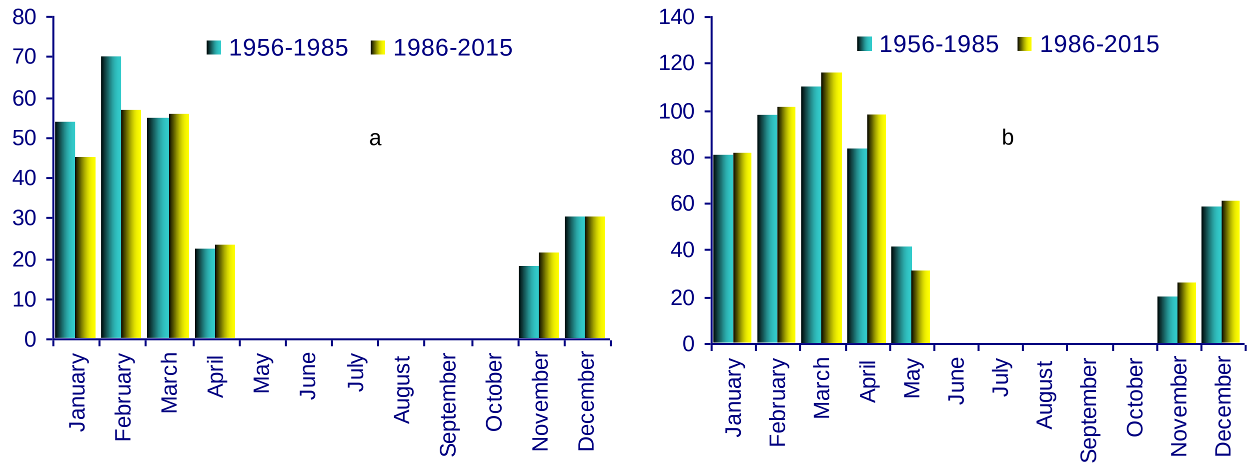


Figure 4.15.3: Maximum snow cover depths in Bakuriani and Gudauri in 1956–1985 and 1986–2015

Adaptation Measures

- Involvement of climate change issues in tourism policy, strategies and action plans;
- Assessing and taking into account the possible risks of climate change when investing;
- Promoting / stimulating cooperation with other sectors / industries (transport, meteorological services, insurance, finance ...);
- Integrating adaptation issues into tourism industry consulting and education programs;
- Raising awareness of businessmen, tour operators and other stakeholders on the impact of climate change on the tourism sector;
- Seeking/ attracting funding for implementation of adaptation projects;
- Movement of skiing run at higher elevations on colder north slopes;

– Ski slope alignment to reduce snow depth requirements;
– Snowmaking at winter resorts to ensure adequate skiing and skating;
– Planning and implementation of anti-caving (shore cutting) activities as a result of sea-level rise.

4.16 Biodiversity

Overall Review

It is recognized that biodiversity and climate change are interconnected phenomena. Climate change is changing the rate of total biomass generation and the relationships between species. Climate change has a particular impact on species areas, both onshore and in aquatic ecosystems. Impacts have been observed in plants as well as in animals, with changes occurring in various developmental organisms ranging from molluscs to birds and mammals.

Changes in the temperature and precipitation structure significantly aggravate the biodiversity situation. Biodiversity is already under serious stress due to anthropogenic factors such as habitat degradation and loss, species destruction, etc. Recent research has shown that climate change is one of the major causes, along with 4 factors of biodiversity reduction (degradation of livelihoods, surplus extraction, environmental pollution and invasive new species). It is widely recognized that biodiversity provides ecosystem sustainability and is therefore an essential component of ecosystem services. Many studies show that species are particularly vulnerable to climate change, which are characterized by certain limitations of spread. Such a category primarily belongs to species distributed in the highlands and species whose life cycle depends on the relationships between plants and insects. Changes in the structure and composition of organisms in the soil are also observed.

Against the background of impending climate change, species and communities that are highly anthropogenic are at high risk. For example, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) says that "a large fraction of species faces increased extinction risk due to high projected rates of climate change during and beyond the 21st century." The risk of climate change is increased by the combined impact of factors such as habitat modification and degradation, as well as intensive natural resource extraction, environmental pollution and invasive new species invasion.

This issue is particularly relevant as most habitats in the world are under serious anthropogenic impact. For example, according to surveys by the European Environment Agency [117], 65% of European habitats are in poor condition. At the same time, 52% of all species in Europe are also granted "Unfavorable" status. European protected areas are no longer able to adequately protect species and habitats.

It is important to emphasize that, according to the same reports, a serious reduction in biodiversity across Europe leads to a decline in the supply of ecosystem services, leading to disruption of climate regulatory functions. Based on data submitted by EU Member States in accordance with the requirements of Article 17 of the Habitats Directive, climate change has a negative impact on the 45 European habitats and 144 species listed in the relevant annexes to the Habitats Directive and the Berne Convention.

Since living organisms play a key role in regulating the carbon cycle, the stability of ecosystems is one of the important determinants of climate stability. A well-studied and proven fact is that reducing biodiversity also deepens and enhances the process of climate change. The higher the ecosystem's sustainability and biodiversity index, the higher the ecosystem's ability to accumulate carbon and thus promote climate stability.

Some positive effects should also be noted here. According to some data, climate factors are influenced by pure vegetation biomass, which is likely to be explained by an increase in carbon dioxide concentration and an increase in the duration of the vegetation period.

Finally, it should be noted that:

1. Modern ecosystems, communities and species have evolved under changing climates. Geological studies indicate that today's biosphere, as we know it, was formed by the influence of various factors, including climate factors, over the last million years;
2. Nevertheless, today's climate conditions create such conditions in which modern ecosystems, communities and species have no precedent for existence [118];
3. In radically new conditions, many species may be at risk of extinction. In addition, significant changes are expected at both community and ecosystem levels, which in turn will have a significant impact on ecosystem services and hence on sectors of the modern economy such as agriculture, energy, water supply, transport, etc. All of this poses significant challenges for the fate of modern civilization.

Major threats for biodiversity – National Context

The negative effects of climate change can be different for different regions. In Georgia, according to the experts, climate change impacts will be strong in alpine, arid and semi-arid ecosystems, forests and wetlands. As a result of intense absorption of carbon dioxide from the atmosphere, increased acidity of water in the world Oceans and Black Seas is expected, leading to damage to marine ecosystems and plankton depletion. These trends are also relevant to Georgia in various ways.

Highlands

High mountain ecosystems are home to many unique species. Most of them are adapted to low temperatures and often represent local endemics. Current forecasts suggest that rising average annual temperatures caused by climate change may be particularly dangerous for high mountain species, as vertical migration of heat-loving species is expected. The process must be followed by the intensification of inter-species competition, as many species in the highlands have already reached their maximum vertical limits of distribution. Plants adapted to low temperatures, characterized by low growth rates, are particularly at risk. Their place can easily be occupied by heat-loving species, the extent of which is currently limited to low temperatures in the upper parts of the mountainous regions..

This is especially true of alpine vegetation, which can be reduced, and in some cases (especially in the nival zone), leading to the complete disappearance of certain communities. An important part of this category of plants is endemic to Georgia or the Caucasus, for example the vegetation of the nival belt, which resides directly in the glacial melting zone. Due to the high melting rate of glaciers (averaging 15-30 m per year), vegetation directly inhabiting the ice melting zone is at particular risk as their rate of propagation and vertical migration does not exceed several meters per year. They simply cannot follow the ice retreat process and lose their habitat. Such events have already been observed in the European Alps, where over 60 sites are being monitored under the long-term monitoring program GLORIA. Studies starting in 2001 have shown that warmth-loving species actively occupy subnivial belt areas that are not characteristic of them.

Similar observations are being made under the auspices of Ilia's University of Highland Ecosystems Research Program [119] GLORIA. The study aims to observe high-mountain vegetation transformation and soil temperature change in the central Caucasus (2000–3000 m above sea level). A re-inventory of the sub-alpine belt vegetation communities described during the middle of the last century is also being re-inventoried and modified, for which a long-term monitoring plot has been established in 2019 by GIZ with the support of GIZ on the upper border of the subalpine alpine forest (2500 m above sea level). Based on studies, it is predicted that some parts of the Caucasus (Kazbegi Region) may be altered by the end of the century, possibly replacing low-moisture vegetation. Also reduce the number of native endemic species, some of which may become extinct [120].

The natural meadows of the mountainous regions of the Caucasus, which constitute an important and integral part of Georgia's biodiversity, are also undergoing significant changes, which are also under extreme pressure due to grazing. Due to the current critical state, natural wildlife is at risk from climate change. In this regard, recent studies have highlighted the process of degradation of natural meadows, which, among other factors, must be largely caused by climate change.

In 2018-2019, Centre for Biodiversity Conservation and Research "NACRES" carried out a project "Assessment of carbon accumulation potential in Truso Gorge", within the framework of which were evaluated the foresting processes on natural grasslands in Kazbegi Region. Research has shown that in Truso Gorge for the last 20 years, the area covered by forests has grown by 9.4% naturally. The timber plants occupy the former mowing pasture, and their spreading height reached 2500 meters. Birch (Betula) is dominated (91.8%) in the composition which is a pioneer species.

It should be noted that similar results were observed in other regions of Georgia (Racha, Svaneti, Tusheti, Khevsureti). Research in these areas is still ongoing and will be available by the end of 2020.

Forest Ecosystems

The impacts of climate change on forest ecosystems are complex and have not been fully studied. Among the different risks are forest fires, strong winds, soil washout and erosion, the spread of forest diseases, etc. A separate problem is the change in forest species composition and the spread of invasive species caused by climate change.

In temperate or tepid zones, including Georgia, the current distribution of forests depends to a large extent on developments following the completion of the previous Ice Age. 21,000 years ago, in today's temperate zones, forests were left only in small reefs (shelters) that for some reason were not covered with ice. Such areas include the Caucasus region (including Colchis). Distribution of forests during the post-glacial warming period, including in the Caucasus, happened in a very unique way, the determinant of which was the species's ability to occupy new areas. Special emphasis was also put to the ability of the species to withstand temperature or other climatic parameters.

According to some scholars, the modern distribution and structure of the beech has been largely determined by the distance from the refugium since the Last Glacial Maximum (LGM). Research suggests that the closer the modern beech anchovy refugum is, the higher their biodiversity and importance. This assumption further enhances the importance of the forests of the Caucasus, and in particular of Georgia, as they were established in close proximity to such a refugium and the biodiversity that characterizes the forests of the region should be correctly identified.

Impacts caused by climate change are delayed. The species is in a state of increasing stress, which results in reduced reproduction and loss of ability to regenerate the forest. Vulnerable species are primarily affected. Over time, it is expected that the forest density will decrease or even disappear completely. Species that are better adapted to changing natural conditions take precedence and gradually take the place of other species. However, even more severe scenarios are likely to occur when the entire forest masses can disappear.

In order to predict possible changes, ecological studies of forest ecosystems are being carried out all over the world and various types of climate models have been developed which allow to assess the responses of different species and forest types in the light of climate change. Such data gives a good basis for forest management, as well as preparing adaptation and mitigations plans.

It should be noted that this type of research has already begun in Georgia. The purpose of the ongoing study, based on the Institute of Ecology of Ilia State University, is to model the distribution of forest species in Georgia affected by climate change on both forest vegetation [121], and some fauna representatives (Capra caucasica, etc.) [122]. Across the Caucasus, similar studies were also conducted by the WWF Caucasus. The so called CART (Classification and Regression Tree analysis) [123] model of evaluation was used.

According to the forecasts, negative events are expected in light of the climate change in the South Caucasus, which is reflected in the reduction of favorable conditions for forests in the region. According to relatively optimistic scenario, it is expected to reduce forest cover by 8% and pessimistic scenario by 33%.

Forest Diseases

Climate change has a significant impact on the rate of invertebrate reproduction and development. Insects are likely to play a significant role in the forest ecosystem functioning and dynamics. A significant proportion of the insect species in the forests are low density, but some species are characterized by massive propagation and spread, which can result in massive damage or loss of woody plants.

The annual mean temperature change has a significant effect on the rate of propagation and development of the poikilothermic organisms (insects, etc.). The temperature regime plays a crucial role in the process of insect death. During harsh and prolonged winters there is a significant reduction in the population of wintering insects (by some 90%), while in warm winter conditions most individuals survive and reproduce accordingly. In case of forest, such developments significantly increase the impact on timber plants and often cause massive destruction. As a result of such combined impacts, there was a massive destruction of the Christmas tree population in Montana (USA) [124]. Precipitation changes play a greater role in the growth of forest pathogens than in temperature change [125].

Climatic conditions, in turn, can indirectly affect insect populations through the physiology and spread of host organisms (mainly woody plants) as well as biological enemies (predators, microorganisms, fungi, etc.). It is believed that the decrease in precipitation significantly weakens the ability of woody plants to resist and cause populations of a number of forest parasites.

Finally, the joint impacts of drought and pathogenic organisms are greatly enhanced by the impact of climate change. In addition, Existing forecasts and models also indicate a tendency to complicate the problem [126].

Unfortunately, unambiguous conclusions cannot be reached without detailed research in this area. However, according to Georgian experts, it is possible to complicate the situation. For example, along with warming, there will be a vertical barrier to restrict insect spreading, followed by spreading to higher altitudes. According to Japoshvili, the Agrarian University Professor, for the last 10 years, there has been a rise in the prevalence of many insects up to 2500 meters above sea level. Under such circumstances, subalpine forests may have been affected, which have so far been less affected by insects and fungi causing forest disease.

Many experts also believe that the spread of invasive species in Georgia in recent years, such as the spread of the American white butterfly or lily bug, can be largely caused by climate change, which allows these organisms to dry out in Georgia. The growth of forest pathogens is also observed in the Lentekhi district, where a 20% increase in the area of damaged forests has been observed. There, in 1986-2015, the annual mean temperature increased by about 0.6^{0}C compared to 1956-1985. Similar results were obtained with the WWF Caucasus PO model mentioned above, which also predicts an increase in the number of forest-borne organisms amid rising temperatures.

A certain database of Georgian forests is available at the following web-sites: https://atlas.mepa.gov.ge/ (prepared with the financial support of World Resources Institue and GEF) and http://caucasus-mt.net/regional-research-agenda?fbclid=IwAR2JSf2riciOr6H-l0npnS4YUIHFN3FjaZPg-nEYuHhRzVg5Wq33aShbaMo (prepared within the scope of Caucasus Mountain Forum initiative).

On the other hand, the relationship between tree plants, insects and pathogens (fungi, viruses, etc.) is more complex than can be predicted at first glance. For example, prolonged droughts significantly reduce the exposure to pathogens such as fungi that require large amounts of sediment for the life cycle. Droughts, as mentioned above, weaken the host organism's resistance to both pathogens and forest parasites.

In this regard, it is important to carry out detailed studies in order to predict the distribution of organisms causing forest diseases. The following table lists species that already have a negative impact on Georgia's forests and that could be a major threat to Georgia's biodiversity in the wake of climate change.

Table 4.16.1: List of organisms causing various diseases in Georgian forests at different times

Pests	Pathogen
Dendroctonus micans	
Hypantria cunea	
Lymantria dispar	
Operophtera brumata	
Erannis defoliaria	
Tomicus pinniperda	
Tomicus minor	
Ips acuminatus	
Ips typographus	
Ips sexdentatus	
Cydalima perspectalis	
Cerambyx cerdo	
	Ophiostoma ulmi
	Cryphonectria parasitica
	Cylindrocladium buxicola

Finally, it should be noted that if certain actions are not taken, climate change will result in the following:

1. A sharp reduction in the number of timber and non-timber products (mushrooms, berries, nuts, etc.);
2. Creating favorable conditions for the spread of invasive species;
3. Reduction of ecological services provided by forest ecosystems, such as:
   - Volume and quality of water;
   - Erosion and landslide protection;
   - Reducing regional biodiversity, including within protected areas;;
   - Reducing the recreational value of landscapes;

Accumulation potential of carbon stock

Along with the negative effects of climate change, some formations may also have positive effects. In this regard, it is important to assess the potential for carbon accumulation in the forest. Due to climatic or other events (eg abandonment of pastures) in the mountainous regions of Georgia, the process of former grazing has significantly increased, resulting in the absorption of carbon from the atmosphere and its accumulation in biomass.

Several projects have been implemented in this regard in recent years. Studies conducted by the Agrarian University have shown that the forests of the Svaneti region of the Caucasus (*Abies nordmanniana)* absorb about 189.3 thousand tons of carbon dioxide annually, while the total forests of Svaneti accumulate 8.98 million tons of carbon [127]. The carbon accumulation potential of Georgia's oak forests was also identified [128], which totaled 10.324 million tonnes of carbon, of which 24.8% comes from underground biomass. In addition, the same group estimated the carbon accumulation potential of Georgia's pine forests, which amounted to 59.6 thousand tonnes of carbon per year [129]. A similar study was conducted by Centre for Biodiversity Conservation and Research "NACRES" in the framework of the project "Assessment of carbon accumulation potential in Truso Gorge". The process of deforestation in Kazbegi Region was evaluated, where the carbon accumulated during the development of natural forest was 119 ha at 613.5 tonnes, the average carbon accumulation on the mountain slopes is 8.3 tonnes / ha.

REDD+ Reducing Emissions from Deforestation and Forest Degradation

Since 2005, a new mechanism for emission mitigation measures has been put on the agenda of the Convention on Climate Change to assist developing countries in addressing their challenges. In this regard, in 2007 within the framework of the so-called Bali Action Plan, a new mechanism was introduced - Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks (REDD+).

Georgia's Biodiversity Conservation Strategy and Action Plan (NBSAP) provided an analysis of the potential use and implementation of the relevant international risk mechanism (REDD +) and international CO2 mechanisms proposed by the Convention on Climate Change. To this end, a study was conducted at the Ministry of Environment and Natural Resources of Georgia (currently, the Ministry of Environmental Protection and Agriculture) to better understand the various relevant mechanisms developed worldwide and identify investment potential..

The study found that the greatest potential for carbon growth in the Georgian forest sector is where carbon stocks fall to a minimum, such as degraded, overgrown, clear cut areas. According to the authors of the study, the primary focus should be on preparing project proposals in such areas and raising funds for these projects.

Arid and Semiarid Ecosystems

A separate issue is the expected changes in arid and semiarid ecosystems. Model studies have shown that these types of ecosystems will inevitably be strongly affected by climate change. Traditionally, such regions are expected to decrease in precipitation and increase in temperature, followed by replacement of existing species with invasive thermophilic and more resistant species.

Frequent or longer drought periods, which are predicted to occur in arid and semiarid regions, should result in vegetative disturbances, reduced vegetation growth, and in some cases, even the disappearance of certain plants. Amidst prolonged droughts, the risks of fires are expected to increase, followed by the destruction of vegetation and soil erosion. As a result, the risk of desertification in such regions is increasing, which is unfortunately often irreversible.

According to Georgia's Second National Communication (SNC) to the Convention on Climate Change, the Dedoplistskaro Region, which is fully enclosed in arid and semiarid zones, has already been characterized by desert and semi-desert species, such as Hystrix indica and Allactaga elater, however, the presence of these species is not likely to be a phenomenon of area expansion and was not directly related to climate change. In any case, this is supported by the opinion of some experts, such as Nitraria schoberi, the population of which is marginal to Georgia and whose populations are characterized by periodic disappearance or emergence, which may be misinterpreted as a climate change event.

The project "Sustainable Management of Pastures in Georgia to Demonstrate Climate Change Mitigation and Adaptation Benefits and Dividend for Local Communities" played an important role in the conservation of biodiversity in the semiarid areas and the study of the situation in steppe pastures. The purpose of the project was to mitigate the impact of climate change on Vashlovani Protected Areas and to rehabilitate degraded pastures, as well as to promote and to implement sustainable pasture management practices for farmers / shepherds in Dedoplistskaro Region (as one of the most vulnerable areas in Georgia in terms of climate change). Among other activities, the project aimed at assessing the state of vegetation of Vashlovani Protected Areas and preparing a map.

Pasture status was assessed with the help of international and local experts. As a result of the study, most of the pastures of the traditional use zone of Vashlovani Protected Area were assessed as medium or in good condition. The most degraded section of 300 ha was also identified and a pilot project was carried out for its rehabilitation. The study failed to assess the potential impact of climate change on pasture status. However, the pasture management plan developed during the project still addressed issues of climate change adaptation and increasing sustainability of local communities.

The Institute of Ecology of Ilia University also conducted research on these areas. The purpose of the study was to study the impact of climate change on orbi propagation sites. Research has shown that with the projected change in annual mean temperature by the end of the century (according to the climate scenario, the annual mean temperature will rise by 3.6^{0}C in 1971-2000 as compared to 1971-2000), expansion of the orbi area to the north and high mountains is expected to be accompanied by changes in migration (including wintering stops) periods. The same study predicts (at the expense of studying Normalized Difference Vegetation Index (NDVI)) a further decline in vegetation cover and a reduction or relocation of the snowy season in 1-2 months.

Wetlands and Marine Ecosystems

Wetland ecosystems are also at risk due to changes in rainfall periodicity and unsustainable management of these ecosystems. Inland waters, especially peat lands, on the one hand represent unique and biodiversity-worthy ecosystems, distinguished in terms of carbon accumulation capacity and play a vital role in global climate processes. Peat marshes, which cover less than 3% of terrestrial land, contain as much carbon as accumulated in all other terrestrial ecosystems taken together. Unfortunately, as a result of unsustainable and irrational use of wetland ecosystems, there is a large amount of carbon emissions into the atmosphere. Wetlands drying and peat fires are one of the most important sources of carbon emissions. In the drainage process through drying the wetlands, every single meter section of the outlet channel generates 90 tonnes of carbon dioxide emissions, calculated per drained hectare [130].

The two main regions of Georgia in terms of wetland ecosystems are the Kolkheti lowland and the Javakheti basin. Targeted surveys reflecting the biodiversity risks in these regions have not been undertaken.

According to Georgia's Second National Communication (SNC) to the Framework Convention on Climate Change (UNFCCC), the following is expected by 2050:

1. sea-level rise above 0.8 meters of coastal wildlife habitats;

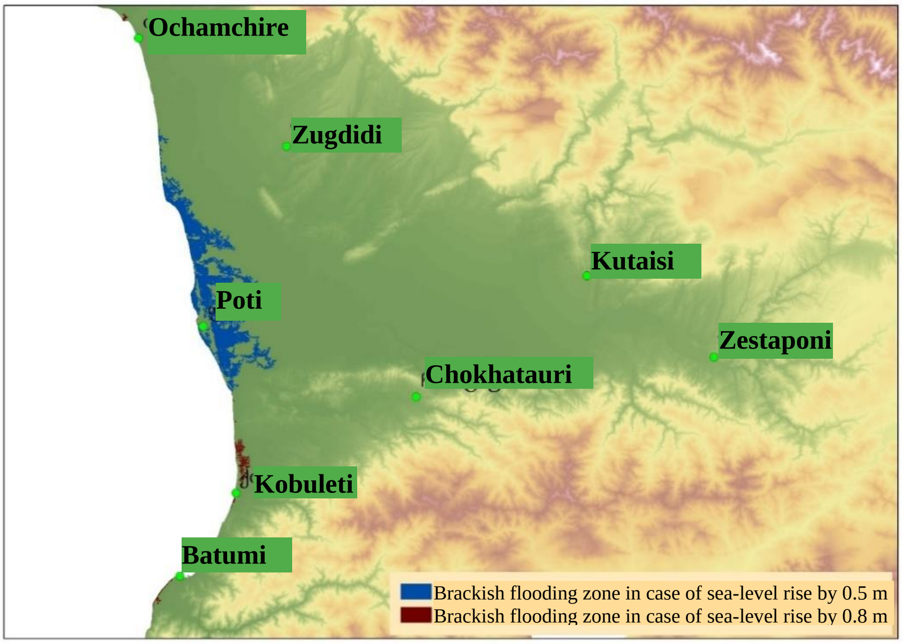
2. covering some unique coastal habitats by eustatic processes;
3. partial or total replacement of fresh water in estuaries or other habitats with brackish (salt) water.

The rise in sea level in Paliastomi Lake and the Rioni Delta is followed by the replacement of fresh water with brackish water, which in turn will lead to changes in habitat biophysical parameters. In some cases, even freshwater habitats may be expected to be completely replaced. For example, in the Rioni Delta, from 1925 to the present, the increase in eustatic seawater (reflecting the rise in mean sea level to terrestrial) has been 20 to 25 centimeters, and the sea-level has doubled and is currently 40-45 kilometers in the riverbed. The Paliastomi Lake, which has been connected to the sea since the 1970s, is also at risk.

Based on the obtained results, Prediction Models for Landscape Development in GIS were developed, for which a Digital Elevation Model was used, and the Habitat Distribution Database according to the EUNIS classification system, which is a habitat classification system applicable at a pan-European level, and throughout Europe it provides unified harmonized approaches to habitat description and data collection. This system is mandatory for the activities planned for Georgia under the Berne Convention, as well as for the environmental impact assessment and for the reporting of habitats monitoring under the Association Agreement between Georgia and the EU.

GIS modeling was performed in two scenarios: I: sea-level rise by 0.5 meters and II: sea-level rise by 0.8 meters. Habitat distribution maps prepared by Centre for Biodiversity Conservation and Research "NACRES" as well as maps of the distribution of key habitats of the Kolkheti lowlands prepared under the auspices of the Caucasus Mountain Forum initiative were used during the analysis (http://caucasus-mt.net/regional-research-agenda?fbclid=IwAR2JSf2riciOr6H-l0npnS4YUIHFN3FjaZPg-nEYuHhRzVg5Wq33aShbaMo).

The survey showed that in case of sea-level rise by 0.5 meters, coverage of the areas adjacent to Kolkheti National Park is expected to be covered by brackish water, and in case of sea-level rise by 0.8 meters, extra territory is expected to be covered by the seawater adjacent to Ochamchire and Kobuleti. Habitats in the area of Kolkheti National Park, including those strictly protected by the Berne Convention, will be significantly affected by the expected sea-level rise.



Map 4.16.1: Brackish flooding zone in case of sea -level rise by 0.5 m and 0.8 m.

Factsheet showed that the following habitats could be flooded with brackish water:

A2.2 Littoral sand and muddy sand

A2.5 Coastal saltmarshes and saline reedbeds

C1.2 Permanent mesotrophic lakes, ponds and pools

D1.1 Raised bogs (D.12, D1.16)

D2.2 Poor fens:

D2.3 Transition mires and quaking bogs

D 5.2 Beds of large sedges normally without free-standing water

D4.1 Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks

D5.3 Swamps and marshes dominated by Juncus

E5.3 [Pteridium aquilinum] fields

G1.52 Broadleaved bog woodland on acid peat

Conclusions

The research identified the key problems that biodiversity can cause as a result of climate change:

1. Significantly increased climate change threats in Georgia, which could have a significant impact on biodiversity;
2. The expected climate scenarios are quite different and depend on the geographical location and climatic features of the region. In case of Georgia, the risks are mainly related to average annual temperature rise, precipitation volume and periods, and sea-level rise;
3. Risks posed by potential threats are significantly increased in the wake of habitat degradation and modification, especially in mountainous regions, the Black Sea coast, freshwater, forest and semiarid ecosystems;
4. Current climate change has little effect on temperate belt vegetation, although changes in mean annual temperature and precipitation structure can significantly alter vegetation structure, condition, and types in such vulnerable regions as highlands and semiarid zones;
5. Important habitats of Kolkheti National Park are expected to be covered during the sea level rise, which is a major risk to Kolkheti National Park and rare habitats in Georgia, some of which are protected by the Berne Convention;
6. Climatic parameters are expected to increase the prevalence of forest pests and diseases, as well as increase the intensity and quantity of forest fires;
7. There is a high anthropogenic pressure on aquatic ecosystems, especially in the lower reaches of rivers, which inevitably require more detailed forecasts, especially for Kakheti and Shida Kartli Regions;
8. Sustainable land use, natural resource extraction and environmental degradation can significantly exacerbate the negative effects of climate change;
9. 10. There is a lack of detailed research and information in Georgia that accurately reflects the actual impacts of climate change on habitats and species.

Recommendations

1. To preserve Georgia's habitats, it is essential to maintain their natural or close to the natural state, as well as maintain an ecological balance, which increases the ability of the ecosystem to adapt to climate change;

2. It is important to identify and monitor climate change-sensitive species and habitats using the approaches and methodologies used by the EU, which include:
   - Reducing existing pressure
   - Maintaining ecosystem heterogeneity
   - Maintaining / restoring natural hydrological regimes
   - Managing fires, floods and other extreme events
   - Exercising control over alien and invasive species
3. Monitoring of habitats and species areas is important, especially in protected areas ე ;
4. To reduce the impact of climate change on biodiversity conservation and biodiversity, it is necessary to strengthen and expand protected areas and ecological networks;
5. It is recommended to restrict the use of natural resources in protected areas and ecological networks (Emerald Network, Ramsar sites, etc.);
6. The urgent need to integrate climate change adaptation and mitigation measures into protected area management plans;
7. A detailed forecast of climate change impacts in the Kolkheti National Park is required to protect it from flooding the important habitats;
8. Evaluation of forest ecosystem services and products, as well as assessment of forest potential in terms of poverty reduction and sustainable development (Decision 1/CP.16/Annex 1, paragraph 2 (c-e) of the Conference of the Parties to the Convention on Climate Change);
9. It is important to integrate actions into national-level sector strategies and action plans to reduce climate change biodiversity;
10. When building hydropower facilities, it is necessary to assess the possible impacts of climate change on aquatic ecosystems;
11. It is important to assess the role of forests as a key carbon reservoir for accumulation in terrestrial ecosystems in terms of adaptation and mitigation (Decision 1 of the 16th Conference of the Parties to the Convention on the Protection of Biodiversity, Paragraph 70);

10\. It is necessary to monitor the process of deforestation and grazing;

11\. Whereas the Convention on Biological Diversity (CBD) identifies biodiversity and ecosystem services as a key factor in climate change adaptation and disaster risk reduction, it is necessary to study these issues in detail in Georgia and to present the results in all national reports to the Convention;

12\. It is necessary to evaluate and to reflect in relevant reports the risks and consequences of loss of biodiversity as a result of climate change and loss of products, functions and services through ecosystem services;

13\. It is necessary to implement adaptation measures on the principles of natural solution and green infrastructure development, which in turn will contribute to the conservation of biodiversity;

14\. It is necessary to accelerate the process of preparing sector strategies and adaptation plans (including with the involvement of civil society organizations, local government), which requires all types of background information. Along with the accumulation of background information, it is necessary to develop models and forecasts with high detail and reliability. The results obtained should be used in the process of correcting or updating elaborated plans;

15. It is important to raise the people's level of education and environmental decision-makers in the field of biodiversity conservation and climate change.

4.17 Cultural Heritage (Historical Monuments)

Georgia is a country rich in cultural heritage. As of 2019, there are 26,524 immovable and 5,322 movable objects of cultural heritage in the unified database of Georgia. On the basis of historical or cultural value, antiquity, uniqueness or authenticity, the status of immovable cultural heritage is granted to 7,689 monuments and the status of movable monuments to 4,221 patterns. 1,011 monuments from those with cultural heritage status were assigned the category of national significance in terms of its distinctive artistic, aesthetic value or historical significance, its connection with the developmental stage of the nation and its distinctive general values.

Cultural heritage sites include architectural (buildings, palaces, houses of worship (cult buildings), etc.), engineering (bridges, tunnels, etc.), urban (urban structures, street networks), and archaeological (cultural stratum, underwater and underground remains of more than 100 years) sites, monumental painting (frescos, wall paintings, mosaics, etc.), palaeographic, ethnographic, documentary materials (publications, manuscripts, etc.), works of fine art.

Monuments of cultural heritage are scattered on the entire territory of Georgia. There are about 1,800 immovable listed sites in Tbilisi, more than 900 in Kakheti, more than 700 in Samtskhe-Javakheti, over 600 in Shida Kartli, about 650 in Samegrelo-Zemo Svaneti, up to 600 in Imereti, over 500 in Mtskheta-Mtianeti, Kvemo Kartli. More than 450 in Kartli, 400 in Racha-Lechkhumi and Kvemo Svaneti, more than 150 in Adjara, 40 in Guria and more than 70 in Abkhazia. Movable monuments are preserved in more than 230 museums. Museums are of different profiles (historical, art, memorial, etc.) and subordination (Ministry of Culture and Monument Protection of Georgia, local self-government and municipalities, as well as various state institutions, private sector, etc.).

The sites of material patrimony are created using materials of various compositions and properties such as stone, lime-stone mortar, brick, metal, wood, fabric, leather, paper, etc. The cultural heritage sites located outdoor (the open-air sites) and inside the buildings, as well as their constituents are constantly exposed to one or more of the climatic factors and processes of natural deterioration. The open-air monuments and their constituents are affected by changes in air temperature, relative humidity, precipitation and wind velocity and direction, as well as increases in CO_2, NOx, SOx concentrations in the air. The main factors affecting it inside the monument are changes in temperature and humidity.

Vulnerability of an object to climate change depends on its structure, properties of materials used (composition, porosity, hygroscopicity) and condition. Climatic conditions can affect mechanical stress, chemical and biological processes of decay. Some climatic factors have cumulative effects, and the impacts on the monuments have been noticeable for a relatively long time.

Implemented Projects

USAID-funded Initiative "Institutionalization of Climate Change Adaptation and Mitigation in Georgian Regions (ICCAMGR)" was implemented in 2016 within the framework of which the Georgian Road Map on Climate Change Adaptation was developed
(http://nala.ge/climatechange/uploads/RoadMap/RoadMap_Geo.pdf).

The Road Map focuses on the risks that threaten and/or will threaten the cultural heritage sites in the future due to increased frequency of various types of natural disasters (landslides and erosion, floods, landslides, tidal processes: rock-falls, rockslides and boulders prolapse, snow avalanches, erosion, soil settlement) and their magnitude. Specifically endangered monuments are Martvili Church, Vardzia Monastery (World Heritage Site), Alaverdi Cathedral, Timotesubani Monastery, Uplistsikhe Rock-Out City, Shatili, Mutso - Fortress Village, Kortskheli Church of X-XI century, Ikalto Monastery Complex, Rkoni Compalex, Shiomghvime Complex, Bebristsikhe, Bodbe Monastery, Kheti (Kortskho) St. Theodore's Church, Zemo Bia Church of the Archangel, Khobi Church Complex, Katskhissveti.

Possible Impact of Climate Change

Temperature changes contribute to materials damage due to thermal stresses, freeze-thaw cycle. Temperature affects biological growth, the rate of chemical reactions. Freeze-thaw cycles of wet stone causes mechanical damage to the stone surface. This damage is more typical for places where temperatures are close to 0^0C. When temperatures drop below 0^0C, the formation of ice crystals in wet porous materials can lead to the processes of physical damage to materials susceptible to frost. Crystals in general, and ice crystals in particular, can easily grow into large pores and cracks upon reaching crystallization conditions. Increasing the volume of ice crystals puts pressure on the pore-clad, thin walls. When the temperature rises above 0^0C, the ice crystals melt and the water spreads through pores and cracks. Further freezing of the water again exerts pressure on the walls of the pores and cracks. The processes of damage due to alternating freeze-thaw in the porous materials are also referred to as depletion caused by freeze-thaw cycles.

At low temperatures (about <-10^0C), there is a danger of spreading cracks on the stone surface. The materials absorb energy during the day and expand by exposure to sunlight, and give off energy during the night and shrink. In the case of geological origin/porous construction materials (stone, brick, plaster, mortar) which are not good heat conductors, thermal stress between the surface layer (a few µm) and the mass beneath it creates thermal stress both during the material heating phase and during the cooling phase of the thermal cycle. In large crystalline materials, for example in the case of granite, other types of stress occur. When heating, the crystals expand in one direction (usually in the direction of the main axis) and at the same time shrink in another direction (usually perpendicular to the main axis). As a result, the daily or annual (summer-winter) thermal cycles are subject to periodic fluctuations in the size of the building materials, leading to a progressive weakening of their structure. As a result of periodic changes in the size of materials, stresses develop in the structures as well. Increasing temperatures can be accompanied by an increase in solar radiation, which can accelerate the use of organic materials such as stone preservatives or paint layers.

According to the climate scenario, compared to the baseline 30-year period (1971–2000 years), both in the first forecast period (2041–2070) and in the second forecast period (2071–2100 years) almost throughout the year, as well as in winter, spring, and winter, the cool night frequency is reduced in the fall (**TN10p** - Percentage of days when TN <10th percentile). The exception is in Khaishi, where there is an increase in the number of cool nights during the year, spring and fall. In addition, during the first forecast period the number of cool nights increases in spring in Mestia and Kvareli and in winter in Ambrolauri.

According to the climate scenario, **FD** is the number of days per year when the minimum temperature TN<0^0C is significantly reduced in all regions in both the first and second forecast periods, although at some stations Fd increases in individual months (Table 4.17.1 and Table 4.17.2).

Table 4.17.1: FD change during the first forecast period

Station	Month								
	III	IV	V	VI	VII	VIII	IX	X	XI
Kvareli	2	2							2
Lagodekhi		3	4	3	4	4	4	4	1

Station	Month								
	III	IV	V	VI	VII	VIII	IX	X	XI
Gurjaani									1
Lentekhi			2				1		
Ambrolauri							5	15	
Mestia		1	1						
Khaishi	2	2							2
Kobuleti						1	1		

Table 4.17.2: FD change during the second forecast period

Station	Month							
	IV	V	VI	VII	VIII	IX	X	XI
Kvareli	3	4	3	4	3	3	3	
Lagodekhi						2	5	4
Sagarejo	3	4	4	4	3	3	3	
Borjomi		1						
Lentekhi		2						
Ambrolauri						3	14	
Khaishi	3	4	3	4	3	3	3	

CSDI - Cold spell duration indicator, the annual count of days with at least 6 consecutive days when TN>10th percentile decreases in virtually all stations in both forecast periods, with the exception of Lentekhi, Borjomi and Khashuri.

The annual, seasonal and monthly mean temperatures (TMeam) throughout the country increase in comparison with the baseline period throughout Georgia. The average annual temperature rise is in the range of 1.6-3.0^{0}C. The highest change is in the highlands, Stepantsminda and Gudauri - by 3.0^{0}C, Pasanauri - by 2.7^{0}C, Tianeti - by 2.6^{0}C, Mestia - by 2.9^{0}C and Lentekhi - by 2.7-2.8^{0}C. The annual, seasonal and monthly mean temperatures are even higher during the second forecast period. The average annual temperature rise is in the range of 2.1-3.7^{0}C. The average annual increase in all Kakheti stations is by 3.4-3.7^{0}C, in Mtskheta-Mtianeti by 3.0-3.6^{0}C, in Tbilisi by3.4^{0}C, in Borjomi by 3.0^{0}C, in Akhaltsikhe by 3.2^{0}C, in Racha by 3.4-3.5^{0}C, in Imereti by 3.1-3.2^{0}C, Zemo Svaneti by 3.0-3.5^{0}C and Adjara by 2.7-3.3^{0}C.

Compared to the baseline period, the number of heat waves in the territory of Georgia increased by 157% in the first forecast period, and by 187% in the second forecast period. The number of heat waves has increased especially in Zugdidi (by 213% and 432%), in Tbilisi (by 180% and 307%) and in Telavi (by 168% and 302%). The duration of the longest heat waves has also increased, on average in the country, by 340% in the first forecast period and 510% in the second forecast period. The longest heat wave duration was particularly increased in Tbilisi (by 188% and 656%), Poti (by 384% and 650%), Telavi (by 191% and 549%) and Batumi (by 358% and 506%).

Variations in temperature, **relative humidity and rainfall** affect crystallization, wetting and drying processes of the porous materials, the length of the material's thickness, and hence the processes of biological deterioration, corrosion of metals. When wetting, the salts dissolve in the material in various ways, dissolve in water and move with water. Increasing the temperature may increase the solubility of some salts, but at the same time promote evaporation and crystallization. The gradual evaporation of salts dissolved in the porous material results in the gradual evaporation of salt-saturated water. The warm, windy, dry climate promotes the crystallization and accumulation of salts below the upper layer. Crystallization of salts is facilitated by the capillary rise of water - building materials and structures in contact with wet soil - and by subsequent evaporation from surfaces.

Like ice crystals, salt crystals pressure adjacent materials, such as pore walls, wall paintings. The effect of salt crystals depends on the type of salts, the pore size and distribution of the material, the depth of the crystals. The problem of salt crystals is often found in the structures of historical buildings, such as archaeological sites.

With high **relative humidity** in the surface layer there are favorable conditions are for the formation of moist layers on the surface of metal and stone. Changes in relative humidity affect crystallization, wetting and drying processes of the salts in the porous materials, the length of the material's thickness, and hence the processes of biological deterioration, corrosion of metals. Relative humidity> 75% is considered the risk for the material damage. Relative humidity indices are particularly important in buildings (enclosed space).

In the period of 1986–2015 as compared to 1956–1985, **RH80 -** the number of days during the year when relative humidity ≥80%, increased at virtually every station (at 33 stations from 39 stations).

According to the climate scenario, mean values of relative humidity increased for all stations in the summer of 1971–2000, as well as in 2041–2070 and 2071–2100 (details are given in Table B3 of the Annex). In 2071–2100, there is a significant increase in August, with regions excluding mountainous areas in Kakheti (according to stations- within the range of 5-12%), Kvemo Kartli (by 21% in Bolnisi), Samegrelo (7–10%) and Adjara excluding mountainous areas (by 11% in Kobuleti).

Compared to the baseline period, in both the first and second forecast periods, relative humidity increases practically on the entire territory in May-September, exceeding 85% in individual areas (Adjara, Guria, Samegrelo-Zemo Svaneti). In Zugdidi, Poti, Batumi and Kobuleti the relative humidity exceeds 90%.

Precipitation contributes to deterioration of building materials as the result of expansion-contraction and opening and crystallization of salts related to alternation of wetting and drying cycles. Wood and sandstones, tuffs and other clay substitutes are particularly susceptible to wetting-drying cycles. Heavy rainfall can cause stress on roofs, waterways, accumulation of excess water on surfaces and in structures. Heavy rainfall and slanting rain increase the likelihood of water penetration in building materials and buildings. Increasing the concentration of CO_2, NOx and SOx in the environment decreases the pH of atmospheric sediments, which results in acid attacks and chemical degradation on materials (limestone, marble, plaster etc.). Precipitation affects the water content in the soil, the chemical composition of the soil, which in turn affects the archaeological sites. Increases in precipitation, heavy rainfall and consistently wet days, relative humidity, increase the material's wetness (the material remains wet), thus enhancing biological colonization and corrosive processes at sites. Wet stone is more susceptible to frost damage. The risks of extreme events are increasing.

At both forecast periods, most stations are expected to reduce the highest annual 5 consecutive days precipitation amount (RX5day). Significant growth is expected in Zugdidi, as well as in Poti, there is a growth trend in Sagarejo, Tianeti and Lagodekhi. In some places, where annual rates drop, there may be an increase in precipitation in 5 days during some seasons or months.

During the forecast period, the number of heavy rainfall days (Rx50day) decreases or does not change over the forecast period - the number of days per year when PR ≥ 50 mm.

In both forecast periods, a large number of stations per day (Rx1day) tend to decrease at multiple stations over the forecast period, although the dynamics of change at different points and periods vary.

For example, in the case of Kakheti it decreases in Kvareli, Telavi, Gurjaani, Sagaregio and Dedoplis-tskaro, but increases in Lagodekhi.

Rx1day index rises in Zugdidi, Tianeti, Bolnisi, Kha-shuri, Gardabani, Paravani, Poti, Pasanauri, Bakhma-

Batumi, Shovi, Borjomi and Tbilisi (Figure 4.17.1)

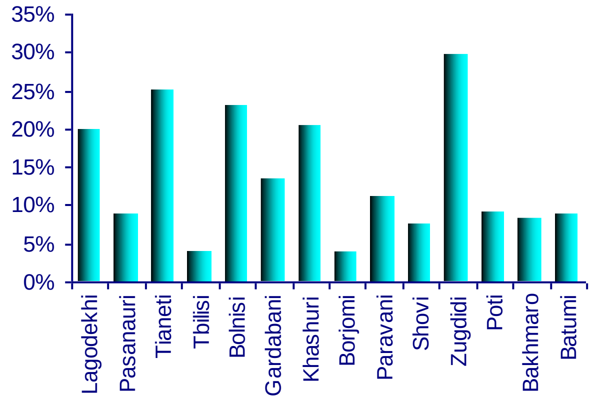


Figure 4.17.1: Change in the maximum number of rainfall per day during the first forecast period according to stations.

Wind affects the deterioration of the surfaces of building materials, the sustainability of architectural structures, and a significant detrimental factor is slanting rain. At this time, the possibility of water penetrating deeper into the material increases, leading to the development of other undesirable processes.

The number of extremely strong wind days (≥25 m/s) increased in 2001–2015 as compared to 1986–2000. There is a significant increase of 12 days in such point. Significant increases are in Poti (by 4 days), Kobuleti and Dedoplistskaro (by 3.4 days), Gori (by 2.1 days), Chokhatauri (by 1.7 days), Sachkhere (by 1.4 days) and Kvareli (by 1.1 days).

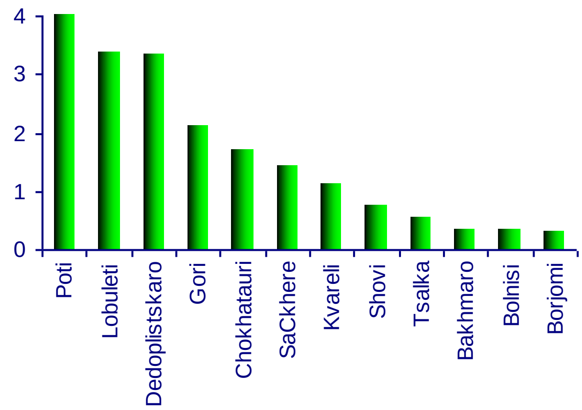


Figure 4.17.2: Changes in the number of extremely strong wind days in 2001–2015 as compared to 1986–2000 according to stations.

In both the first and second forecast periods, the minimum mean daytime temperatures (TNm) and maximum mean daytime temperatures (TXm) increase everywhere during the year, season and month.

The environment and climate changes - extreme events affect the climate in the interiors of buildings and the patterns preserved there. Buildings of different sizes and architectures respond differently to external climate change. Impacts will be different in buildings where microclimate conditions are regulated and in buildings where no such facilities are available. Interiors of cultural heritage patterns are influenced by temperature and relative humidity fluctuations, causing physical, chemical, and biological damage to wall painting, stone, wood, paper, textiles. Injuries have been linked to attacks by mold fungi and insects, as well as salt crystallization, wetting-drying and freeze-thraw cycles.

To wrap it up, it can be concluded that due to climate change, Georgia's cultural heritage sites may be endangered by increased relative humidity, extreme precipitation that can be followed by strong winds, as well as by increasing frequency and duration of heat waves.

Key Issues in Adaptation of Cultural Heritage Sites to Climate Change

- Incorporating climate change issues into cultural heritage policies, strategies and action plans;
- Planning climate change adaptation measures using complex, multidisciplinary approaches;
- Active involvement of stakeholders involved in the cultural heritage sector, sharing of international experience, mobilization of human, technical and financial resources;
- Organizing trainings and internships in order to share international experience and modern approaches in the field of cultural heritage conservation, involvement in international research, implementing joint projects;
- Raising awareness of specialists, decision makers, and the public on vulnerability of cultural heritage sites and their constituent materials in terms of impact of climate change;
- Conducting complex scientific research to assess the impact of climate change on cultural heritage;
- Systematic and long-term monitoring of microclimate conditions in interiors (enclosed space) of different types of buildings;
- Furnishing museums, libraries with modern equipment needed for microclimate monitoring; developing and tightening microclimatic conditions in museums, libraries and other buildings (storage, exhibition halls, etc.);
- Planning, selecting and implementing conservation actions in response to climate change threats;
- Improvement of buildings, especially buildings of regional museums, and their adaptation to changing climatic conditions.

5 Other information

5.1 Integration of climate change issues into the social, economic and environmental policies of Georgia

Since the submission of Georgia's third National Communication (NC) to the Convention, the country has made significant progress in integrating climate change issues into its sectoral and inter-sectoral development policies. The issues related to the climate change are reflected in the major part of social, economic and environmental policies, including the energy, agriculture, health care and environment protection. On the one hand this progress is a result of increased awareness and expertise among the governing structures, and the commitments pledged under the Paris Agreement on the other. Paris Agreement put the government of Georgia within the new reality, when the country shall make decisive steps to respond the challenges related to the climate change. On the one hand it requires better assumption of responsibilities by each sector, and on the other it refers to better coordination among the sectoral agencies. Well realized responsibility is usually reflected in sectoral policies and action plans.

The analysis of the country's social, economic and environmental policies has identified what forms are used for reflecting climate change issues in key strategic documents and action plans and how detailed they are.

5.1.1 Bilateral agreements and other supporting initiatives

Prior to accession to Paris Agreement in 2016, under the Georgia-EU Association Agreement signed in 2014 Georgia made certain commitments almost within all areas, including the climate change.

Within the frame of Association Agreement the following fields have been identified for cooperation between the EU and Georgia: (a) Climate change mitigation; (b) Climate change adaptation; (c) Carbon trading; (d) research, development, demonstration, use and dissemination of safe and sustainable low-carbon and adaptation technologies; (e) Integration of climate issues into sectoral policies.

Among other issues the cooperation also includes preparation and implementation of the following documents:

- National Adaptation Plan of Action/NAPA;
- Low Emission Development Strategy/LEDS;
- Nationally Appropriate Mitigation Action/NAMA;
- Measures to promote technology transfer;
- Measures related to ozone depleting substances and fluorinated GHG

In 2021, through the support of Green Climate Fund the country starts to elaborate National Adaptation Action Plan.

In 2017 the United States Agency for International Development (USAID) supported Georgia in developing the Low Emission Development Strategy (LEDS), which covers the period until 2030. The vision of the LEDS and its strategic dimensions have partially been integrated into sectoral policies after 2017, which can be assumed as certain indirect form of its implementation.

According with official registry of NAMA[96], there are three NAMAs registered on behalf of Georgia; however, only one is implemented, while the other two are in the process of seeking funding.

In 2012 Technology Needs Assessment/TNA was elaborated, which determined country's policy with regard of climate technologies. The document includes the Action Plan for introducing mitigation and adaptation technologies. The Plan needs to be updated in line with the latest circumstances and new obligations. Modern technology issues are also reflected in the relevant sectoral policies, although these issues are not reviewed within the climate change context. Georgia's accession to the Energy Community Treaty in 2016 also encouraged the inter-sectoral integration of the climate-related issues. The Protocol of Georgia's accession to the Treaty requires harmonization of Georgian legislation with the EU Directives and Regulations. In the context of climate change the Treaty includes some obligations, which require: increase of energy efficiency; facilitate the use of renewable energy sources (which serves to decarbonization of economy); safety of energy supply; and elaboration of National Energy and Climate Plan. At a local level 6 cities and 17 municipalities joined the EU initiative Covenant of Mayors. This process is of national importance, since the signatories represent about 60% of the total population and with even more share in the GDP. The signatories committed to achieve by 2030 40% reduction of GHG emission from 1990 level. In 2014, under the umbrella of the Covenant of Mayors, the European Commission launched the new initiative related to the climate change adaptation as one of the actions, which is aimed at engaging the cities in adaptation to the climate change. In 2015 the European Commission combined two initiatives in climate and energy fields for developing the integrated approach.

[96] https://www4.unfccc.int/sites/PublicNAMA/SitePages/Country.aspx?CountryId=66

5.1.2 Cross-sectoral and sectoral development policies

Climate change issues are addressed in almost all sectoral or cross-sectoral strategic documents. The documents in Table 5.1.2.1 below are divided into two main categories - on the one hand, existing national policy documents and action plans, in which climate risk mitigation and climate resilience are prioritized (so-called "climate- priority" documents), and on the other, the documents, which do not formalize the linkage of priority goals and objectives with climate change, however, they indirectly contribute to addressing climate change issues in industry policy. In Table 5.1.2.1 such documents are included within the category “other documents”.

Table 5.1.2.1: Climate change issues in the sectoral and cross-sectoral policies and actions plans

Type of document	Cross-sectoral and sectoral policies/ action plans	Date of adoption	Sector / Area
Policy papers on climate change mitigation and adaptation			
Climate-priority documents	INDC – Intended Nationally Determined Contribution	2015	Cross-cutting
	UNDC – Updated Nationally Determined Contribution	2020	Cross-cutting
	Georgia 2020	2014	Cross-cutting
	Third National Environmental Action Programme of Georgia 2017-2021	2017	Cross-cutting
	Agriculture Development Strategy 2015-2020 Agriculture Development Strategy 2021-2027	2015 2019	Agriculture
	National Forest Concept of Georgia	2013	Land use, land-use change, and forestry-LULUCF
	Biodiversity Strategy and Action Plan of Georgia 2014-2020	2014	LULUCF
Other documents	State Strategy of Regional Development of Georgia 2010-2017	2009	Cross-cutting
	Government Programme Freedom, Rapid Development, Prosperity 2018 – 2020	2017	Cross-cutting
	Protected Area System Development Strategy of George 2018-2030 Protected Area System Development Action Plan of Georgia 2018-2021	2019	LULUCF
	Education for Sustainable Development 2020-2024	2020	Awareness
Documents of local importance	Environmental Strategy of Tbilisi 2015-2020	2015	Energy

Type of document	Cross-sectoral and sectoral policies/ action plans	Date of adoption	Sector / Area
			Disaster risk reduction (DRR)
Climate change mitigation-related policies			
Climate-priority policies	Low Emission Development Strategy	2017	Energy Industrial Processes and Product Use/IPPU
	Energy Strategy of Georgia 2020-2030	2020	Energy
	National Renewable Energy Action Plan 2019-2020	2019	Energy
	National Energy Efficiency Action Plan 2019–2020	2019	Energy
	Energy and Climate Change Integrated Plan 2030	In progress	Energy
	Regulation of Ozone Depleting Substances	2017	IPPU
	Regulation of fluorinated greenhouse gases	In progress	IPPU Energy
	Waste Management National Strategy 2016-2030 and National Action Plan 2016-2020	2016	Waste
Other documents	Biodegradable Municipal Waste Management Strategy	At the stage of adoption	Waste
Documents of local importance	State Programme on Measures to Support the Reduction of Ambient Air Pollution in Tbilisi	2018	Energy
	Sustainable energy action plans for cities / municipalities	2010-2020	Energy
Documents with climate change adaptation issues			
Climate-priority documents	National adaptation action plan	In progress	Cross-cutting
	Second National Action Programme to combat Desertification 2014-2022	2014	LULUCF
	Irrigation Strategy of Georgia 2015-2025	2015	Water sector
	National Disaster Risk Reduction Strategy and its Action Plan 2017-2020	2017	DRR
Other Documents	National Security Concept of Georgia	2012	DRR

Climate-priority Policies

- **2015** Intended Nationally Determined Contribution / INDC). Details are provided in BUR2

- Updated Nationally Determined Contribution / UNDC). Details are provided in the Chapter on Mitigation
- **Georgia 2020** is the document on country's Social-economic Development Strategy for 2014-2020. It reflects the risks related to the global warming and its potential impact on Georgia's economy. The documents underlines the need to take into account negative impact of global warming in the process of planning and developing infrastructure projects; it also refers to the disaster risk reduction and the need in early warning systems. Among other important directions for social-economic development the document determines increased energy efficiency, development of modern system for solid waste management, and arrangement of environment-friendly landfills, which have the direct relation with the climate change mitigation.
- **Strategy for Agricultural Development in Georgia 2015-2020.** In this document climate change adaptation is recognized as one of the strategic directions, while priority measures are to be guided by the principles of"good agricultural practices", to create/manage a genetic bank to preserve agro biodiversity and enmdemic species, and to promote the introduction of climate-friendly agricultural practices.
- **Third National Environmental Action Programme 2017-2021** determines the priorities: GHG emission reduction and increase of adaptation potential; and implementation of obligation in regard of reporting to the Climate Change Framework Convention. It is planned to develop a series of documents aimed at determining the state strategy for reducing the GHG emission. The document makes references to the specific industries and identifies the priority measures. The specific measures for fostering energy efficiency of buildings and reducing emissions from transport sector are also identified under this direction. The priority task of adaptation is a wide introduction of the system for early warning of natural disasters in the country and to use climate-related information in decision-making. In addition, under the plan it is intended to develop a national plan for adaptation to climate change, which will design more specifically the country's priorities for adaptation.
- **National Forest Concept of Georgia 2013** is focused on the role of forest in climate change mitigation and on elaboration of strategies regarding the potential adaptation capacity of Georgian forests. In particular, extension of protected areas, forest-restoration and aforestation, attaching categories to the forest stands according to forest composition and climate change vulnarebility, and capacity building for assessing the vulnerabilities. **National Biodiversity Strategy and Action plan of Georgia 2014-2020** underlines the threats against biodiversity and forests of Georgia caused by climate change and formulates strategic approaches for fostering resilience of forest ecosystems. One of the important directions of the Strategy is to assess the potential impact of climate change on biodiversity and ecosystem sustainability. The Strategy is aimed at increasing the contribution of biodiversity to carbon sequestration in Georgia through nature conservation and restoring at least 15% of degraded ecosystems.
- **Future visions for the development of Georgia's energy sector in 2020-2030** refer to the risks posed by climate change to the industry**.** The document considers potential change of the hydrological regime of the rivers and the increase of the risks to the safe operation of the power system due to intensive natural events.

  In order to address the challenges in the context of climate change, the following relevant areas have been identified: (a) increasing the reliability, efficiency and sustainability of the electricity transmission network; (b) construction of hydropower plants with seasonal regulation reservoirs; (c) the use of variable renewable energy sources, including mainly solar and wind energy, and the introduction of a wind and solar energy forecasting system for reliable integration into their generation network; (d) promoting the development of geothermal energy potential; and (e) promoting the uptake and use of biogas from organic waste. In addition, the most important direction of the strategy is to improve energy efficiency, including in terms of providing a legal framework, as well as setting targets for primary energy savings by sector and the distribution of savings by sectors.

The detailed list of measures for achieving the targets is provided in **National Energy Efficiency Action Plan 2019-2020**. The measures determined in **National Renewable Energy Action Plan 2019-2020** mostly are focused on removing barriers and creating enabling conditions, and introducing adapted schemes for the use of renewable energy, as required by the Commission Directive 2009/28. At the current stage the work on long term (2030) action plan is in progress. Long term planning/vision for energy efficiency development will be considered in the Integrated Energy and Climate Plan 2021-2030, which is currently being developed by the Ministry of Economy and Sustainable development and the Ministry of Environment Protection and Agriculture. In addition, the perspectives for the development of renewable energy by 2018 will be discussed in the decarbonization part of the Integrated Energy and Climate Plan.

- **The policy on reducing emission of Ozone Depleting Substances/ODS.** With regard of ODS, Georgia has made significant steps in this direction. From 2016 production and import of any type of Hydro-chlorofluorocarbons / HCFC is prohibited, except of HCFC–22, HCFC–142, HCFC–142b and Methyl bromide. Through the import quota system introduced in 2017, Georgia plans to gradually reduce the import of ODS from HCFC Group and methyl bromide and suspend their imports by 2030. In order to regulate fluorinated GHG, Georgia plans to introduce rules for registration, use, prevention and control of these gases by September 2021

- **Waste Management National Strategy 2016-2030 and National Action Plan 2016-2020,** along with other measures, imply reduction of GHG emissions. For this purpose, the strategy determines a number of measures that directly or indirectly contribute to the reduction of GHG emissions. Namely, (a) the construction of new, modern regional landfills, where the generated methane will be used as an additional source of energy, thus helping to reduce methane emissions; (b) closure of existing landfills by 2023 and closure of natural landfills by 2020;

  In particular, these measures include (a) the construction of new, modern regional landfills, where the generated methane will be used as an additional source of energy, which will help reduce methane emissions; (b) closure of existing landfills by 2023 and closure of spontaneous landfills by 2020; (c) reduce the disposal of municipal biodegradable waste to landfills by 2025. The Action Plan of the Strategy identifies promotion of biodegradable waste recycling and composting as one of the important directions. Elaboration of a biodegradable municipal waste management strategy is currently in progress and will include a series of measures aimed at gradual reduction of share of this waste in the landfill, thus reducing methane emissions.

- The National Disaster Risk Reduction Strategy 2017-2020 and its Action Plan integrate the goals of three important instruments of the UN - the 2015-2030 Disaster Risk Reduction Framework Program, the Sustainable Development Goals and the Framework Convention on Climate Change. The main goals of the strategy are to reduce the risks stemming from natural factors in Georgia, including extreme climate developments, and to establish a disaster risk reduction system, which, among other components, includes the integration of early warning and alarm systems in the national disaster risk reduction system. The latter is particularly relevant in the light of the growing number of natural disasters in the country.

- **The Second National Programme on Combating Desertification for 2014-2022** focuses on the implementation of the Convention on Combat Desertification, but the document also outlines the measures that would play an important role in climate change adaptation. In particular, it refers to the measures having the aim to introduce practices that promote the sustainable management of land resources and climate change adaptation. It is also noteworthy that this document determines activities aimed at informing decision-makers and raising awareness on interconnection between desertification, extreme climate events and climate change. The Action Plan also is focused on expanding monitoring of soil-induced desertification processes, identifying vulnerable areas and adapting to climate change, mitigating drought impacts and recovering degraded soils.
- The strategic objectives of the **2018-2022 National Environment and Health Action Plan (NEHAP)** includes climate change issues as well. The plan envisages assessing the impact of climate change on health and adaptation of the health system (health aspects) and developing a national health adaptation strategy and action plan, including for medical institutions. The plan also focuses on raising public awareness and reducing the share of GHG emissions by healthcare facilities.
- Government Programme **Freedom, Rapid Development, Prosperity 2018-2020** includes a number of measures to mitigate and adapt to climate change, although these measures are not mentioned in the document as such. Namely, according to the Programme, the government intends to continue development of renewable energy sources and implement energy-efficient measures, as well as to expand protected areas and introduce sustainable forest management practices that will help in mitigating climate change; also continue to develop a safe and stable transmission and distribution system for gas and electricity, which is very important in the context of frequent natural disasters. Great attention is paid to restoration-improvement measures of degraded soils and increase of water supply areas. The programme outlines the need to promote modern irrigation systems and other climate-friendly activities. Moreover, the programme focuses on the development of agribusiness-oriented researches, which should be an important precondition for the development of local solutions/approaches to adapt to climate change in the agricultural sector. The programme also is focused on expansion of the hydrometeorological observation network in order to reduce the risks of natural disaster threats and to strengthen forecast-capabilities in parallel with the establishment of a national early warning system.
- **Regional Development Strategy of Georgia 2010-2017.** Chapter 5 of this document is dedicated to the agriculture development and environment protection. In the part of agriculture development climate-related issues are reflected with a lesser degree, although these issues are widely reflected in the subsection on environment protection. In this document the following areas are identified as priority: improvement of management of extreme natural events, natural disasters and the risks stemming from them; secure efficient use of forest resources, including, among others, the cultivation of targeted plantations and long-term maintenance of cultivated plants, as well as restoration of windbreaks. The strategy also states that in the event of reduction in runoff, which could have a serious impact on agriculture, energy supply and drinking water supply, the local government should prepare an action plan for the efficient use of local water resources, and this plan should be part of the self-governing unit development plan. Establishment of early warning systems and implementation of preventive measures are also components of the strategy. The document provides the review of protection measures against climate change for the Black Sea coastal zone. It also considers the need to plan and implement appropriate adaptation measures, support the development of renewable energy resources (hydropower, wind, firewood, solar, biomass, biogas, geothermal resources) and elaborate the standards for use of agricultural land to protect it from degradation.

- **2018-2021 Regional Development Programme of Georgia** not directly addresses climate change, but the need, which are identified in the document, reflect the ways to solutions of challenges posed by climate change in Georgia. The priorities of the programme include the development of infrastructure that will ensure the wider use and availability of renewable energy sources.[97] The document requires the green economy development to be promoted in some regions and to modernize technologies in agriculture. The programme action, which directly addresses the improvement of natural disaster protection infrastructure, focuses on increasing the accuracy of hydrometeorological forecasts and the effectiveness of reporting on expected hydrometeorological hazards.

  According to the programme, the state plans to invest 521 million GEL (approximately 170 million USD) for this action in 2018-2021. The pilot regions of the programme are Kakheti, Imereti, Guria, Racha-Lechkhumi and Kvemo Svaneti. The programme also focuses on increasing the capacity of research institutes, thus enabling them to create the innovations that are necessary for long-term economic growth.

  Although the climate research and innovation are not specifically addressed, however, potentially, this measure should help develop technological solutions to adapt to climate change. The programme intends to invest 230 million GEL (approximately $ 70 million) to support the research sector. Priority areas are defined as the agricultural science sector, promotion of engineering and technology development, with special emphasis on environmental engineering issues.

- **Education for Sustainable Development 2020-2024** is the instrument under which the actions are identified for increasing awareness and involvement in the principles of sustainable development. This document, along other goals for sustainable development, includes Goal 13, which deals with climate change.

- **Tbilisi Environmental Strategy 2015-2020** implies mitigation measures, such as 24% reduction in GHG emission by 2020, as well as adaptation measures focused on disaster risk reduction.

- **State Programme on Measures to Reduce Ambient Air Pollutions in Tbilisi** was adopted in 2018. The programme envisages gradual replacement of old vehicles by introducing an ecological class of vehicles and introducing certain prohibitions. It is planned to create and expand the fast charging infrastructure of electric vehicles; also the development of public transport that uses environment-friendly technologies; improve traffic flow management and expand green zones in the city.

  - **The National Security Concept of Georgia** came into effect in 2012. There is no direct reference to “climate change” in the document, but under the sub-chapter on Environment Security it emphasizes the significant reduction of natural resources and the need to prevent crises caused by natural disasters, which are known to be directly related to climate change.

  - **The Strategy for Development of Protected Areas System of Georgia 2018-2030** and the **Action Plan for Development of Protected Areas System of Georgia 2018-2021** have the special focus on the need to address the potential impacts of climate change on species and habitats during the protected area planning process. The research (modeling) of expected impact on climate change on species and habitats and determination of adaptation measures is intended as a priority. It is important to note that the EU Project “EU4Climate” is currently underway. The actions planned

[97] Attention is paid to the use of potential for production of hydro, wind, biomass, geo-thermal and solar energy

under this project will have the focus on improving climate policy and legislation, in particular, the project will provide recommendations for better integration of climate change issues into the development policies of three key sectors (energy, agriculture and health).

5.1.3 Key findings

Based on the analysis of the country's general and sectoral development policies and action plans, it can be noted that climate change issues are reflected in one way or another in most of the country's social, economic and environmental policies and cover all important areas related to climate change: energy, agriculture, health care and environmental protection.

Here it should also be noted that part of the policies and action plans address the challenges associated with climate change, but do not address these processes in the context of climate change. This trend is especially visible in a general development policies. For instance, measures mentioned in this document aimed at reducing the risk of natural disasters, restoring degraded soil fertility, reducing water loss in irrigation systems, or increasing energy efficiency are not referred to as adaptation or mitigation measures, irrespective the fact that they, in addition to direct social and economic benefit, also serve to the climate risk reduction and climate resilience.

It should be noted that most of the policies and action plans reviewed do not have a clear system for implementation monitoring and evaluation system. They lack evaluation indicators, which makes it difficult to monitor their implementation and assess progress in a particular area. Exceptions are the environmental policy documents and the National Environment and Health Action Plan 2018-2022 / NEHAP-2. These documents clearly set out the priority objectives, relevant target indicators and indicators, which make it easier to monitor the progress achieved and measure the results.

In order to improve the monitoring and evaluation of the implementation of policy documents, an Ordinance of the Government of Georgia came into force on 1 January 2020 setting out the methodology and standards for the development, monitoring and evaluation of policies. For the purpose to measure long-term and medium-term results in the development of policies, it has become mandatory to develop Key Performance Indicators (KPIs). The document should also specify the agency responsible for collecting such data. Interim and annual reports should be developed to monitor the implementation of policies. National (other than government programme) and sectoral policies are also subject to detailed evaluation of outcomes and achievements through established criteria that assess, along with other criteria, policy effectiveness, sustainability and impact.

The analysis of policies and action plans identified migration and tourism sectors, whose strategic documents (Migration Strategy and Action Plan of Georgia 2016-2020 and Tourism Strategy of Georgia 2025) do not yet address climate change, although each of these sectors is important in terms of both climate change mitigation and adaptation.

5.2 Research and Systematic Observation

In the country, a number of important studies are underway in terms of studying climate change issues, although the scope of research and the diversity of topics are still limited. There are several reasons for this. First of all, the lack of a strategic vision for the priority research issues for the country should be noted. Therefore, most of the current and ongoing research works come either under the interest of individual or small groups of researchers, or is initiated under some international project. The latter makes efforts in this direction more spontaneous, dependent on external resources and therefore less systematic. The second important factor is a poor material and technical base of research institutions, which is a determining factor of a small scale and low quality of researches on climate issues.

5.2.1 Researchers at the academic institutions

Information on climate change research was collected and analyzed at four leading Georgian universities (Ivane Javakhishvili Tbilisi State University, Ilia State University, Free University and Technical University) and Shota Rustaveli National Science Foundation of Georgia. The latter is one of the main supporting tools of research activities at the national level, which sets national research priorities and facilitates the implementation of specific researches in various areas.

Based on the analysis of collected information, it has been found that the involvement of academic institutions in climate change issues is at an initial stage and still implemented within narrower frame. For the most part, climate change and related issues are integrated into the programmes of various academic disciplines (mainly related to the physical environment). There are relatively few academic programs directly related to the climate change process and its consequences. In addition, the degree of integration of modern digital technologies into academic programmes in this area is relatively low, including the integration of software into academic disciplines required for long-term forecasting of climate change (including GHG emissions) and analysis of mitigation measures. There is a need to strengthen the relevant knowledge in this area. It is important to elaborate training curriculum in academic institutions to provide long-term forecasts of GHG emissions and mitigation measures, as well as to analyze their cost-effectiveness. It is also important to procure and implement forecasting models, facilitate research using remote sensing databases, and strengthen the capacity of local specialists and institutions, including technical equipment.

Table 5.2.1.1 below provides basic information on current researches and research priorities at those four universities mentioned above.

Faculty of Exact and Natural Sciences of **Ivane Javakhishvili Tbilisi State University**, conducts scientific research on climate change and various components of the natural environment, including ecology, soil science, geomorphology, glaciology, hydrology and natural hazard. Various climate models are being developed and changes in environmental components are identified on the basis of those models. Climate change issues are fully integrated into the faculty curricula and widely represented in ongoing academic works within the faculty (including doctoral programs).

Scientific research related to various components of the physical environment has been actively performed at **Vakhushti Bagrationi Institute of Geography of Tbilisi State University** since 1933. Currently, the main directions of the research activities of the Institute are: research of natural disasters (analysis and forecast); research and evaluation of the country's natural resources; development of the basics of the methodology of landscape planning and geo-ecological expertise of mountainous regions. All of these areas include climate change monitoring and research. The glaciological direction is especially noteworthy, within the framework of which the Georgian glaciers are actively investigated, as well as the potential impact of climate change on them.

Ilia State University – the University pays special attention to research activities in the field of natural sciences. They conduct monitoring over the climate change processes and learn the impact of these processes on the energy sector, biodiversity, agriculture and other environmental components or individual sectors of the economy.

Among the research directions of climate change there is ongoing programme “Highland Ecosystem Research” at the Institute of Ecology of Ilia State University, which actively explores global changes, including the ecological perspectives and consequences of climate change, and their impact on highland ecosystems. Currently the Institute implements research programme determining the Effect of Global Change of Climate on High-mountain Vegetation Transformation in the Central Caucasus (the EU Fifth Framework Programme Network, Global Observation Research Initiative in Alpin Enviroments / GLORIA-EUROPE).

A number of studies by the Botanical Institute of Ilia University are related to the study of the possible impacts of climate change on vulnerable ecosystems. The institute is involved in the project "Conservation Crop Wild Relatives of Georgia", which aims to conserve wild ancestors of varieties used in agriculture in Georgia and to create a seed bank.

The University Institute of Energy and Sustainable Development conducts studies of the interaction and sustainable development of energy, environment, economy and social systems, as well as on sustainable and innovative energy technologies. The priority direction of the Institute is the study of Georgian and international energy policies and strategies; long-term planning of the energy sector; cost-effectiveness analysis of infrastructure projects; energy security research; investigation of renewable energy sources given the circumstances related to the climate change and associated risks (reduction of water resources, change of hydrological regimes, increase of energy load, etc.). The Institute participates in providing information and expert opinion on state policy and the legislative environment.

In addition to the aforementioned, the issue of climate change and its possible impacts is one of the priority issues of the University doctoral programmes and is widely represented in doctoral studies.

It should be noted that the high quality inventory of GHG requires quality control and quality assurance procedures. Quality assurance is provided by an independent third party - a group of experts who are not involved in the inventory preparation process. In 2018, the United Nations Development Program and Ilia State University signed an agreement on quality assurance procedures

The Agrarian University (including Gulisashvili Forest Institute) and its School of Agrarian and Natural Sciences provide master’s and bachelor’s programmes in areas such as biology, Agronomy, viticulture and forestry. Climate change teaching component is thematically integrated in these programmes. At the same time, the issues related to climate change and its impact are integrated into current academic activities of the research institutions under the Agrarian University. Among them are the institutes of viticulture and winemaking, fruit-growing, agriculture, soil science, plant protection and forestry (one of the main directions of its activity is to determine carbon stock in the forest stands sequestered from the ambient air). In general, the scientific potential of these institutions is an important resource for research on climate change in the agrarian and forestry sectors.

At the Technical University the research activities cover important issues related to climate change, such as engineering ecology, natural disasters, soil and water resources engineering, reclamation, agriculture, agro-engineering and forests. In terms of studying climate change issues, the research institutes of the Technical University should be mentioned, including the Water Management Institute, which addresses one of the important directions / programmes on environmental protection and modern problems of water management in the context of climate change. Within the frame of this programme, the Institute conducts research on exogenous processes caused by climate change, as well as natural disasters, the seas and reservoirs, reclamation, environmental and engineering ecology, reclamation systems in terms of climate change. And the Institute of Hydrometeorology conducts fundamental and applied researches in the fields of meteorology (atmospheric physics), agro-meteorology, hydrology (hydrosphere physics), glaciology, climate and its change, renewable energy sources and other processes. The Institute also determines the climate change adaptation measures and develops the relevant plans, including in terms of agro-biodiversity conservation.

Rustaveli Research Foundation is a legal entity of public law under the Ministry of Education, Science, Culture and Sports of Georgia, which promotes the development of science, technology and innovation system in the country. In order to achieve this goal, the Foundation conducts state grant competitions, implements targeted programs and projects, is involved in international scientific networks and joint initiatives, finances international scientific potential and innovative fundamental and applied scientific research projects in all areas of science. At the same time the Foundation supports the active involvement of Georgian scientists in the international academic space, their international mobility, the presentation of the results of current and innovative researches in Georgia at scientific events abroad, and the organization of large-scale international conferences, symposia and seasonal schools in the country. The Foundation also finances various scientific fields, including exact and natural sciences and the sciences studying Georgia. It should be mentioned that the promotion of long-term research projects in engineering, technological and exact sciences and natural sciences is recognized as one of the priority areas of the Foundation. Under this direction, several scientific studies on climate change are funded every year.

The consultations with stakeholders shows that for Rustaveli Foundation more active and closer cooperation with sectoral agencies, NGOs and experts engaged in climate change issues and identification of priority research issues on climate change is a very important task. The results of such research will have better practical application in assessing the climate change impact and in effective planning of climate change mitigation processes.

It should be mentioned that in addition to academic and research institutions, the NGO sector also is engaged in academic activities. Such research activities obviously are performed with the frame of different project and in many cases, stemming from the specific objectives of the project, they are focused on different aspects of climate change (e.g. impact on biodiversity, water resources, health, etc.).

Table 5.2.1.1: climate change related research at the leading universities of Georgia

University	Institute/department	Ongoing research and priorities
Ilia State University	Institute of Ecology	High mountain ecosystem study - Identification of ecological perspectives and consequences of global change, including climate change, and exploration of their impacts on mountain ecosystems; Detection of ecological prospects of global changes on high mountain flora of the Central Caucasus; Transformation of Alpine Flora in relation to the global changes.
	Botanical Institute	Conservation Crop Wild Relatives of Georgia - Conservation of wild ancestors of species used in agriculture in Georgia and to create a seed bank.
	Institute of Energy and Sustainable Development	Interaction of energy, environment, economic and social systems and the issues related to sustainable development;

University	Institute/department	Ongoing research and priorities
		Study sustainable and innovative energy technologies; Study energy policies and strategies; Energy sector long-term planning; Analysis of cost-effectiveness of infrastructure projects; Energy security research; Study the renewable energy sources given the circumstances related to the climate change and associated risks (reduction of water resources, change of hydrological regimes, increase of energy load, etc.);
Javakhishvili Tbilisi State University	Faculty of Exact and Natural Sciences	Scientific studies, including the fields of ecology, soil science, geomorphology, glaciology, hydrology, disasters caused by natural factors; Elaboration of different climate models and the forecast of environment change on the basis of models.
	Vakhushti Bagrationi Institute of Geography	Study natural disaster processes (analysis and forecast); Study country's natural resources and evaluation; Landscape planning of mountain regions; Elaboration of methodology for landscape planning of mountain regions and geo-ecological expertise; Glaciology – study Georgian glaciers and potential impact of climate change on them;
Agrarian University	Institutes of: Viticulture and Oenology; Horticulture; Farming; Soil science; Plant protection; and Forestry	Climate change and its impact on the relevant sectors; One of the main directions – determine ambient ($C\text{-}CO_2$) stocks in the forest stands
Technical University	Water Management Institute	Environmental Engineering; Natural disasters; Soil Land and water resources engineering; Reclamation; Agriculture; Agro-engineering and forest sector.
		Study environment protection and modern problems of water management against the background of climate change; Exogenic processes caused by climate change;

University	Institute/department	Ongoing research and priorities
		Study of natural disasters, the seas and reservoirs, reclamation, environment protection and engineering ecology, reclamation systems from the point of climate change.
	Institute of Hydrometeorology	Fundamental and applied studies of meteorology (atmospheric physics); agro-meteorology; hydrology (hydrosphere physics); glaciology; climate and its change; pollution of natural environment; renewable energy and resources; regulation of atmospheric processes; dangerous hydrometeorological events (including frequency of floods and flash floods and risk assessment against the background of climate change) and elaboration of methods to combat them.

5.2.2 Systematic observations

Georgia has international and regional commitments under the Framework Convention on Climate Change, and due to these commitments, it has set national priorities in a number of areas.

In Georgia, the Ministry of Environmental Protection and Agriculture is the nationally responsible body for the Framework Convention on Climate Change and Paris Agreement, which determines national policy in this area and is responsible for the implementation, monitoring and reporting regarding fulfillment of international obligations. Therefore, this state institution, together with its legal entities under public law, is responsible for collecting relevant information and preparing reports. Alongside with the Ministry of Environmental Protection and Agriculture, the sectoral ministries, other government agencies, municipalities, non-governmental and academic sectors are involved in honouring the requirements of the Convention.

The **National Environment Agency** is one of the leading structural units under the Ministry of Environmental Protection and Agriculture providing the main source for monitoring and analyzing climate parameters at the state level. The agency monitors and maintains meteorological parameters (temperature, precipitation, wind, humidity, atmospheric pressure, snow cover, etc.), as well as hydrological and agro-meteorological parameters. In addition, the agency monitors, records and analyzes geological and hydrogeological processes, weather extremes and Georgian glacier dynamics. The agency operates with automatic and non-automatic sensing stations (currently 89 meteorological and 56 hydrological stations). Consolidation of existing climate information is carried out in the Climate Data Management System "CliData". In 2014-2019, the network of hydrological observations in Georgia expanded significantly, although it still lags behind the figures of the 1980s, when there were 149 hydrological stations operating in the country[98]. In 2020, hydrological observations are made at 55 checkpoints, meteorological observations at 89 stations and checkpoints, and agro-meteorological observations at 10 stations. In 2013, after a lengthy suspension, hydrogeological monitoring of groundwater has been resumed in Georgia, which is gradually

[98] 2017 Runoff map of Georgia - Hydrological modelling of water balance, 2017. Norwegian Water Resources and Energy Directorate.

expanding. By 2020, the number of water-points in the groundwater monitoring network will be 56 (monitoring of 50 wells and 6 natural springs).

Since 2013 the National Environment Agency has been carrying out the restoration of the state monitoring network of fresh groundwater, which was suspended in the country in the 90s of the XX century. At the current stage, with the efforts of the state and the assistance of various donor organizations, observations and studies are underway on 56 water-points. The monitoring network covers Kakheti, Mtskheta-Mtianeti, Shida and Kvemo Kartli, Guria and Samegrelo-Zemo Svaneti and the Autonomous Republic of Adjara. Equipment installed at the wells exercise control over the quantitative and qualitative parameters of water (water level and yield, temperature, pH, electric conduction, common mineralization, etc.) in automated and uninterrupted regime. Chemical-bacteriological testing of samples taken from the monitoring network is carried out twice a year to assess the use of potable water. Based on the results of hydrogeological monitoring studies, newsletters are prepared twice a year (eight newsletters from the monitoring surveys). The agency annually plans to increase the number of monitoring points and install modern monitoring equipment at new water-points.

The National Environment Agency is the principal state body focused on the identification, research, and partially on management of natural disasters, including natural geological events. According to the Action Plan of the National Strategy for Disaster Risk Reduction of Georgia for 2017-2020, the Agency, from a geological point of view, acts in the following main areas: permanent geological monitoring (spring-autumn) and assessment of natural geological processes in *force majeure* situation; Geomonitoring on the territory of Tbilisi and updating the zoning map of geological hazards (landslides, flash-flood, etc.) (Scale 1: 25,000); and compiling state geological maps (geological planning). The Geology Department of the Agency issues an annual publication/bulletin, which analyzes, generalizes, processes and summarizes the regional monitoring *and force majeure* information obtained during the year with a forecast for the coming year and outlines appropriate management measures. The bulletin is distributed among all regional and municipal authorities. It is also provided to the Ministry of Environmental Protection and Agriculture, the Ministry of Regional Development and Infrastructure, the Emergency Management Service and all other interested ministries and agencies.

At the current stage the Agency is facing the following needs:

- Due to the difficult terrain and climate diversity of Georgia, the density of existing hydrometeorological, agro-climatological, geological and hydrogeological network of observation is insufficient. In this regard, the project "Scaling-up multi-hazard warning system and he use of climate information in Georgia" deserves to be mentioned, within which it is planned to increase the monitoring network to 140 units, thus significantly increasing the country's monitoring capacity.
- Much of the meteorological, hydrological and geological data has already been converted into digital format. It is necessary to fill in the existing data on digital carriers and carry out additional verification.

Table 5.2.2.1 provides information on the monitoring and research activities of the Ministry of Environmental Protection and Agriculture and other government agencies.

Table 5.2.2.1: Monitoring / Research Activities on Climate Change Issues of the Ministry of Environmental Protection and Agriculture and Other Government Agencies

Sectoral Ministry	Department / subordinate structure	Ongoing research works and research priorities
Ministry of Environmental Protection and Agriculture	Climate Change Division of the Environment and Climate Change Department	Preparation and regular updating of the NDC; Assessment of climate change impact and risks to the economic sectors and ecosystems; Elaboration of National Adaptation Plans; Conduct of GHG emission national inventory and submit the report to the Secretariat of the Convention; Preparation of National Communications (NCs) and submit to the Convention; Preparation and submission of Biannual Updated Repot (BUR).
	Ambient Air Division of the Environment and Climate Change Department	Inventory of emissions of Ambient air pollutants; Processing and analysis of data for state registration of emissions of harmful substances into the ambient air from stationary air pollution facilities; Atmospheric Emissions Information Reference Database.
	KEPL National Forest Agency Department of Biodiversity and Forestry	National Forest Inventory; Forest Management Inventory; Performance of functions of the Agency ensures the necessary information needed to assess the potential of forests as a source of GHG absorption in the national GHG inventory process, also assessment of the impact of climate change on forests and, in the event of a negative impact, to plan adaptation measures (thus ensuring an increase in forest absorption potential).
	LEPL Environmental Information and Education Centre	Create a unified database of environmental information and promote its publicity; Draft the report on GHG National Inventory through the support of independent experts.
National Statistics Office of Georgia		Agrarian statists, which is collected on a monthly basis by the Statistics Office

Sectoral Ministry	Department / subordinate structure	Ongoing research works and research priorities
		through selective survey of agrarian facilities and households; National Energy Balance, including sectoral use of fuel.

In terms of observations and research, the needs of the agencies listed above are diverse. For example, the Climate Change Division has to collect large amounts of data in the reporting process, which requires written appeals and data requests from different agencies each and every time. At the current stage, the data necessary fir GHG calculation are not stored in a single database, thus making them difficult to access. It should be noted that the LEPL the Environmental Information and Education Centre, with the financial support of the United Nations Development Program and the Global Environment Facility, has developed a web-based environmental information and education management system within the frame of the project "Harmonization of Information Management in Improving Global Environment Monitoring and Awareness". This system is designed to provide relevant information to the offices involved in the inventory process and allows consolidation of data collected in different public or academic organizations into a single database. Currently the work on textual component of the system and on removing the gaps is underway. Having functional such database allow the stakeholders to work online. Also, data obtained from the local level (municipalities) should be integrated into the database.

One of the challenges for the Ministry of National Forest Agency and the Department of Biodiversity and Forestry is that much of the data needed to inventory forests as sources of absorption or emissions, assess their vulnerability and select adaptation measures has not yet been fully processed. Typical values of this data from IPCC guidelines are used. Among them, the annual increase of carbon according to climatic zones and species, indicators of forest degradation, the vegetation cycle of the species and the required temperature and precipitation, etc. are especially important.

For the National Forest Agency and for the Department of Biodiversity and Forestry of the Ministry of Environmental Protection one of the challenges is the insufficient and not fully processed data, which is necessary for forest inventory, both as source of absorption or emission, also for assessing their vulnerability and selecting adaptation measures. Default values of this data from IPCC guidelines are used. Among them, the following data is especially important: annual increase of carbon according to climatic zones and species; forest degradation indicators, the vegetation cycle of the species; and the required temperature and precipitation, etc.

LEPL “National Statistics Office of Georgia” covers all sectors of the country's economy in terms of statistical data collection and research; however, at the current stage, there are areas where the data is not collected yet, for example, there is no information on the use of agricultural land according to the type (perennial and annual crops, pastures, etc.) and the degree of degradation, which complicates the national accountability for climate change processes and to some extent also affects the degree of its accuracy.

5.3 Education, awareness raising and information share

In Georgia a number of activities and initiatives are being implemented for different target groups with the aim to promote environmental education and awareness raising. Climate change issues are usually integrated into these measures and initiatives. It should be noted that educational initiatives directly related to climate change are rarely implemented, except when such initiatives are presented within the framework of projects implemented mainly by non-governmental organizations.

Such educational activities / measure are implemented in both formal and informal education formats.

5.3.1 Climate change and formal education

The activities of the Environmental Information and Education Centre (EIEC) of the Ministry of Environmental Protection and Agriculture of Georgia are based on the principles of the Aarhus Convention of the UN Economic Commission for Europe (UNECE) on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters and on the visions and directions of the Strategy of Education for Sustainable Development / ESD). The Center promotes sustainable development through education and access to comprehensive information on environmental components.

The Environmental Information and Education the Centre prepared the National Strategy “Education for Sustainable Development” and the relevant Action Plan, although these documents have not yet been approved. The aim of the strategy is to promote sustainable development processes in the country through changes in the education sector, which should contribute to the formation of a responsible society. The strategy includes formal, informal and unofficial education initiatives that are directly related to the concept of "Education for Sustainable Development". Climate change issues generally are reflected in such environmental education programmes and initiatives.

Approach of the state towards environmental education implies provision of continues formal education for the students of pre-school, general, vocational and higher education institutions.

Pre-school education

For a pre-school environmental education, an environmental component is included in the State Educational Standard for School Readiness. The Environmental Information and Education Centre (EIEC) developed and updated in 2019 the Guide for Educators for Effective Teaching of Environmental Issues at Preschool Level (“Preschool Environmental Education”). Methodists and educators from all kindergartens in the country have been retrained in order to introduce the teaching to the educational institutions. For effective promotion of the Guide the EIEC organized certain cognitive projects and competitions (for example, "Meet the Little Environmentalists" and "Green Award").

School education

Climate change issues are integrated into the curricula and evaluation criteria of all three levels of general education - elementary (grades I-VI), basic (grades VII-IX) and secondary (grades X-XII), according to which the textbooks are graded.

In terms of school education, the EIEC has developed a cross-cutting standard - Environmental Education for Sustainable Development (EESD), which addresses climate change issues. One of the cross-cutting competencies of the National Curriculum is "Ecological Literacy", which implies a combination of knowledge, skills and attitudes, enabling to understand the importance of the earth as a living space, and the importance of sustainable development, also, to deepen the knowledge about the arrangement of ecological system and its regularities.

Environmental Information and Education Centre has developed a training module "Teaching Environmental Issues in Primary School Subjects", which is used for training of primary school teachers and curriculum experts.

The Centre currently works on an Auxiliary Handbook for Primary School Teachers "Environmental and Agricultural Education at School", which provides effective teaching of environmental issues at this stage of education. The guide presents 7 environmental topics, including climate change and natural disasters. Each topic includes theoretical part for teachers and a variety of topic-related activities that are integrated into a variety of subjects and complex assignments.

Currently the Centre works on supplementary manual for primary school teachers "Environmental and Agriculture Education at school", which will ensure effective teaching of environmental issues at this stage of education. Seven environmental topics are presented in the Manual, including climate change and natural disasters. Each topic consists of theoretical material for teachers and multiple activities related to the topic, which are integrated in different subjects and complex homeworks.

In the context of school education, environmental training courses have been developed within the frame of various projects, including climate change issues among the others. From the materials developed the textbooks should be mentioned, which officially received the status of auxiliary textbooks and are considered as a part of formal education. Among those textbooks the "Free Lessons" deserve special attention, which is an auxiliary guide for teachers developed by the Environmental Information and Education Centre.

Another publication, "Mtkvari Box" was prepared and issued within the frame of UNDP / GEF project *Advancing Integrated Water Resources Management across the Kura river basin through implementation of the transboundary agreed actions and national plans.*

Vocational education

In addition to school education, the training module ("Environment and Climate Challenges") was developed for institutions implementing vocational education programmes. This module is mandatory and it is included in the framework document of various professions. In addition, a training module "Environmental Basics" has been developed - which also addresses climate change issues - to be integrate into the framework document of different professions.

Higher education

Climate change issues are included in most undergraduate and graduate programmes atin higher education institutions. However, as a rule, climate change is an integral part of the programmes of other disciplines (environment, ecology, geography, etc.). At this point, there is no independent curriculum directly related to climate change. The short certificate course "Climate Change and Sustainable Development" deserves special attention. It was designed with the support of the World Experience Georgia / WEG and the Heinrich Böll Foundation at Ilia State University. The course is designed for public officials working on climate change issues, representatives of the non-governmental sector and academia (masters and doctoral students) and journalists. The aim of the course is to promote climate change awareness and dialogue between representatives of the governmental and non-governmental sector.

One of the higher education courses is the Master's program "Environmental Management and Policy" introduced in 2016 at the Georgian Institute of Public Affairs (GIPA). The program offers two courses in the form of optional courses: "Climate Change and its Aspects" and "Sustainable Energy Policy".

5.3.2 Public Awareness Raising

Public awareness raising on climate change matters is one of the priority directions of the Ministry of Environmental Protection and Agriculture of Georgia and it is mainly implemented by the Environmental Information and Education Centre through activities for various target groups. Meetings, conferences, competitions, briefings, awareness-raising campaigns, educational lectures-seminars, trainings are regularly held for the general public, including schoolchildren, students and local communities; various promotions, eco-tours, eco-camps and media-tours are organized; documentary films and info/Ad video clips are made; information and educational brochures are published and distributed.

The Center implements a programme Voluntary Lecturer, with the special emphasis on the climate change. The programme is led by the staff of the Center and of the Ministry of Environmental Protection and Agriculture of Georgia. They conduct environmental thematic lectures for various target groups. In addition, the Center regularly conducts trainings to improve the qualifications of the employees of the Ministry of Environment Protection and Agriculture of Georgia. Training often covers climate change issues as well.

On the basis of Memoranda the Center cooperates with the National Youth Palace, Akaki Tsereteli State University, the National Parliamentary Library of Georgia and the National Center for Children and Youth with the aim to raise public awareness on environmental issues. The Center also cooperates with the “Radio Kommersant”, through which it offers to the listeners the programme "Green Business", which, along with raising public awareness on environmental issues, aims at promoting "green" innovative technologies.

The Center cooperates with the National Youth Palace, Akaki Tsereteli State University, the National Parliamentary Library of Georgia and the National Center for Children and Youth on the basis of memoranda on raising public awareness on environmental issues. The Center also cooperates with “Radio Kommersant”, with which it offers listeners the rubric "Green Business", which, along with raising public awareness of environmental issues, aims to promote "green" innovative technologies.

Here it is worth to mention the project Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia, which is financed by the Green Climate Fund (GCF) and implemented by the United Nations Development Progarmme. The Environmental Information and Education Centre is one of the project partners in the field of environmental education and capacity building. The project aims at reducing the impact of natural hazards on the population of Georgia caused by climate change through the use of Multi-Hazard Early Warning System / MHEWS and application of informed actions at a local level. One of the important parts of the project is the capacity building and educational component, which includes: the preparation of community adaptation textbooks; develop textbooks and educational materials for teachers, municipal authorities, media, women and youth groups on multidisciplinary threats; also, strengthen the capacity of local authorities and non-governmental organizations, community organizations and community members to raise awareness of community-based disaster risk management and adaptation. At the same time, the project plans to evaluate the capacity of all government agencies involved (both at national and local levels) in a unified system of disaster risk reduction. Based on the evaluation, an appropriate plan will be developed and awareness-raising and capacity-building measures will be implemented for each agency. In this regard, one of the major beneficiaries of the project is the Environmental Information and Education Centre.

Projects funded by various donors and international organizations play an important role in the awareness-raising process. In the implementation of such projects, in parallel with government agencies, non-governmental organizations are actively involved. On the basis of such cooperation, important documents for the country are being prepared, including Georgian National Communications (NC) to the Framework Convention on Climate Change, Updated Biennial Reports (BUR) and other documents. Among the active donors and financial organizations in the field of climate change in the country are: GEF, German Bank for Reconstruction (KfW), European Union, European Commission (EC), US Agency for International Development (USAID), Austrian Development Agency (ADA), Swiss Agency for Development and Cooperation (SDC)), The Adaptation Fund (AF) and the Green Climate Fund (GCF). The United Nations

Development Program, the German Organization for International Cooperation (GIZ), as well as global NGOs, such as Care International, Mercy Corps and Winrock International / Georgia play an important role in funding and implementing climate change projects.

It should be noted that the local potential and awareness-raising component on climate change is practically included every project or programme in the field of climate change in the country, no matter which sector implements a particular programme. However, the non-governmental sector is usually more active in terms of informal education and awareness raising.

The information provided above demonstrates that the country implements considerable number of measures to raise the level of education and awareness on climate change issues. However, there are still a number of challenges that need to be addressed in order to fully cover climate change issues in the education sector. The key challenge include the following:

- Educational programs directly related to climate change are rare. At the current stage in any of the components of formal education there is no thematic training course / module designed solely for climate change;
- There is a visible lack of climate change issues in school textbooks. Climate change issues, as a rule, take only a small part in conjunction with other environmental disciplines. The same problem applies to both vocational and higher education institutions. In additions, there is a lack of age- and sector-specific educational resources.
- A weak coordination between awareness-raising activities on climate change conducted by various structures or organizations;
- Given the prevalence of information and awareness campaigns on the essence of the climate change process, there are relatively few measures to address climate change resilience, relevant skills development and behavior change.

5.4 Sharing the information

One of the key conditions for the implementation of the International Principles on Climate Change at the national level is the civil society engagement. Therefore, it is important to strengthen communication and information sharing between government and civil society organizations, as well as among this type of organizations and the academia.

From this point of view the project "Harmonization of Information Management for Improved Knowledge and Monitoring of the Global Environment in Georgia" should be mentioned. It was implemented by the Environmental Information and Education Centre in 2016-2018, through the financial support from the United Nations Development Program and the Global Environment Facility.

As a result of the project, an environmental information and knowledge management platform has been created, which provides consolidated, analysis and sharing of environmental data / information. It is a good tool to have increased access to reliable environmental data / information. The system allows modeling, forecasting and reporting; risk management and decision support; publication of information from the public authorities; structured saving and review of the legislative base and referral; structural saving and referral of projects / programmes, as well as events, news, developments, etc. planned within the programmes; use of Geographic Information System (GIS) to analyze and explain spatial information.

For the purposes of strengthening cooperation on climate change, including information sharing, it was important to establish the Climate Change Council (CCC) (established on January 23, 2020) to coordinate the measures on climate change mitigation, GHG emission reduction and threat prevention caused by climate change in Georgia. The Climate Change Council was created under the Decree N 54 of the Government on 23 January 2020. According to this Decree the Council is led by the Minister of Environmental Protection and Agriculture, while the members are the deputy ministers of the Ministry of Economy and Sustainable Development; the Ministry of Finance; the Ministry of Education, Science, Culture and Sport; and the Ministry of Internally Displaced Persons from Occupied Territories, Labour, Health and Social Affairs. The Chairman of the Government of the Autonomous Republic of Abkhazia, the Chairman of the Government of the Autonomous Republic of Adjara, the Head of Coordination Team of the Covenant of Mayors of signatory municipalities and the Executive Director of Georgian Statistics Office participate in the Council's work. Organizational and technical support to the Council is provided by the Ministry of Environmental Protection and Agriculture, and the function of its secretariat is exercised by the Climate Change Division of the Environment and Climate Change Department, which is a structural unit within the Ministry of Environmental Protection and Agriculture. The aim of the Council is effective implementation of Georgia's climate change policy and climate-related international commitments, in particular, effective implementation of obligations pledged under the UN Framework Convention on Climate Change; Kyoto Protocol; and Paris Agreement. The successful performance of the Council will facilitate to integration of climate change issues into policies and strategic plans, as well as into the activities of public, private, non-governmental organizations and academic institutions. At the same time, it will facilitate coordinated cooperation with donors and financial institutions, improve legislation, raise public awareness on climate change issues, develop and introduce clean technologies, etc.

5.5 Capacity Development

Georgia's capacity to meet its obligations under the Framework Convention on Climate Change has significantly improved in comparison with its previous reporting period, as evidenced by a considerable increase in the number of climate change mitigation and adaptation measures. Improvements have been made through both country resources and technical assistance projects. In this context the following improvements have to be mentioned:

5.5.1 Disaster Risk Reduction

As mentioned in Chapter 5.2, in 2014-2019 the network of hydrological observations in Georgia expanded significantly, although it still lags behind the figures of the 1980s. The National Environment Agency plans to further expand the monitoring network to improve the forecasting of hydrological and geological hazards and reduce the risk of disasters. In particular, 44 hydrological stations, 73 meteorological checkpoints, 12 automated meteorological stations, 2 ambient air sensing stations and 10 snow-cover monitoring stations will be added to the network, thus improving country's climate monitoring and forecasting capabilities even further. In 2019 in western Georgia, modern meteorological radar was installed near Kutaisi. It which will enable the country to improve the quality of weather forecasting and help establish an early warning system for floods/flash-floods.

The National Environment Agency, on a regular basis, conducts the studies on the results and forecasts of development of natural geological processes reflecting the information on the geological hazards. Since 2015, the number of geographical points estimated during the monitoring of natural geological processes has increased by 17%. Based on the studies, appropriate recommendations and measures are developed, enabling to reduce significantly the negative effects caused by geological processes. In late 2016, a comprehensive early warning system was set up in the Amali-Devdoraki Gorge with the aim of safe operation of Mtskheta-Stepantsminda-Larsi section of the international highway.

It is also important to note that the National Environment Agency has converted into digital format all historical hydrological data (water level, flow), thus making it easier for water resources specialists and managers to have the access to the database and to analyze it. A runoff distribution map and hydrological model of the country were also developed, which is important for assessing the country's hydropower potential (with the assistance of the Norwegian Directorate of Water Resources and Energy). Hydrological modeling capabilities have been further developed under several technical assistance projects. The Geology Department of the Agency carried out the transfer of geological data and reports in digital format. Capacities have also been strengthened in terms of preparing geological hazard zoning maps. Geological risks have been evaluated for a number of river basins (the rivers Aragvi, Rioni, Vere and Gldaniskhevi) and the relevant geological hazard zoning maps generated; the forecast models have been adapted. Modern monitoring equipment was installed in three extremely vulnerable landslide areas within the Rioni River Basin. The above steps contribute to the further development of the country in terms of setting up early warning systems.

A number of technical assistance projects have been funded and implemented by donor countries in the area of risk assessment. Activities in this direction will be continued within the frame of the project Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia. During the coming 7 years, the project will ensure the introduction of the Multi-Hazard Early Warning System (MHEWS), which is an important prerequisite for enhancing the country's adaptation capacity. The project will create a centralized system of information and knowledge related to multiple risks. It should be noted that Georgia will finance the above-mentioned events with its own resources, for which it plans to invest 38 million USD. The total cost of the project with the participation of donors and the country is 74.3 million USD.

5.5.2 Reduction of soil degradation

Reduction of soil degradation is one of the priority strategic directions, which is outlined in the sectoral strategic documents, as well as in the country's development strategy and government action plans. The EU ClimaEast program and the EU initiative Shared Environmental Information System / SEIS, as well as the assistance provided by the Global Environment Facility and the German Federal Ministry for Economic Cooperation and Development / BMZ are especially noteworthy in strengthening Georgia's capacity in this area.

Through these donor-funded projects, specific measures have been taken in the country to introduce sustainable management for land resources, including pastures, in the municipalities that are particularly vulnerable to climate change, as well as to inform decision-makers and farmers and their capacity building; within the frame of these projects the measures for erosion control and knowledge sharing have been implemented; and capacity building in terms of soil cover assessment (in particular, introduction of the Corine Land Cover (CLC) methodology), which is essential for effective monitoring of soil degradation and desertification processes.

At the current state the USA National Aeronautics and Space Administration / NASA supports Georgia in implementing the project, which will enable the country to develop its expertise in remote sensing and use this method for implementing soil cover and land-use assessment.

Insufficient technical knowledge / expertise for the use of modern technologies and analytical tools for risk assessment still represent an insurmountable challenge for Georgia. Capacity building in this area is particularly important as there is a significant lack of information on soil cover and land use Georgia, which hinders evidence-based decisions and effective interventions.

In order to improve the monitoring over the land degradation monitoring, updated soil quality standards (National Indicators of Soil Degradation) and methodology for their determination have been developed. It is intended to approve the indicators on the basis of government decree. The updated soil quality standards will replace the outdated standard from the Soviet period thus allowing the country to monitor soil condition in line with European standards, which is also an important precondition for increasing the country's adaptation capacity.

5.5.3 Integrated Water resources Management (IWRM)

Georgia has the aspiration to introduce Integrated Water Resources Management / IWRM. Significant assistance in this direction was provided to the country by the European Union, USAID, GEF and SIDA. Capacity building included delineation of basins, introduction of bio-monitoring, modeling of hydrological processes, determination of ecological status of water bodies, development of management plans for a certain number of the river basins, development of water data and national information portal according to the concept of Water Information System for Europe (WISE), etc.

Certain steps also have been taken in terms of water quality monitoring. In 2014 the Laboratory of Ambient Air, Water and Soil Analysis of the National Environment Agency was accredited for the first time in accordance with the international standard ISO/IEC 17025, and in 2019 it was accredited according to the updated standard (ISO/IEC 17025: 2017/2018) which demonstrated that the laboratory's quality management is in line with international standard.

As part of the EU Water Initiative Plus / EUWI Plus project, the laboratory was equipped with a modern research equipment. Such a laboratory is an asset for the country as it has improved its ability to observe the effects of climate change on air, soil and water quality.

Creating efficient irrigation and drainage systems is an important component of the National Agricultural Development Strategy of Georgia. The issue is especially relevant in the context of climate change. This area was particularly affected in the 1990s, when due to the lack of funding the irrigated area in the country reduced from 400,000 ha (late 1980s figure) down to 45 ha in 2011. In recent years, significant efforts have been made to gradually increase the water supply area and now it covers 130,000 hectares. By 2025, such areas will be expanded up to 200,000 ha.

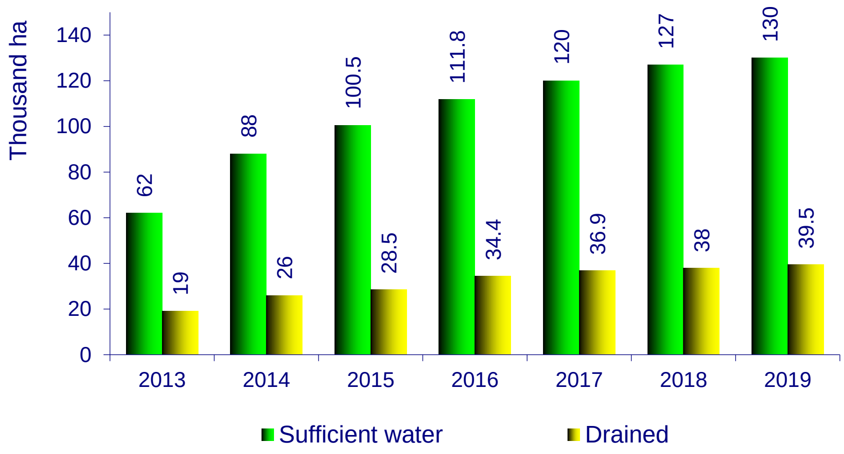


Figure 5.5.3.1: Watered and drained areas by years

Modern irrigation methods, such as drip irrigation and pivot irrigation are actively developed in this field and farmers are well informed about them. Issues related to the introduction of modern irrigation technologies are discussed in Chapter 6 (Technology Transfer) of the National Communication.

5.5.4 Forest Resources Management

One of the most important steps towards strengthening the forest sector capacity was the institutional reform of the sector, which, on the one hand, separated the policy, management and supervision of the forest sector, and clarified the role and functions of these three areas responsible for forest resources on the other and effective coordination between them has also increased.

Under the GIZ-supported project "Integrated Biodiversity Management. The South Caucasus" National Forest Inventory (NFI) started in 2018 and it will be completed in 2020. On the basis of NFI results the country will have an important data on forest status, which is the basis for sustainable forest management planning and decision-making in forestry, and at the same time will support international reporting.

Criteria and indicators for criteria and indicators for sustainable forest management have been developed and approved within the frame of the same project, which will be used to monitor the status and trends of the forest sector, as well as to assess progress towards sustainable development goals. Forest Information Monitoring System (FIMS) was also developed and implemented.

5.5.5 Increase of Energy Efficiency and use of Renewable Energy

The Covenant of Mayors played a catalytic role in developing the country's capacity for sustainable energy policy at the local level. In the municipalities participating in the Covenant of Mayors, a baseline scenario for CO2 emissions and a sustainable energy policy have been developed; measures were also taken to develop relevant institutional / managerial skills. As a result, capacity has been developed in this area and the country has developed expertise in sustainable energy policy development at the local level.

Following the adoption of the law on Building Energy Efficiency adopted in May 2020 and its by-laws (which, for example, set building energy standards and certification rules), significant work has to be done to increase capacity in the construction sector. It should be mentioned that the Demo projects of energy efficiency implemented in the framework of the technical assistance projects and the work done to establish energy audit expertise have made significant contributions to the development of capacity in this area, although it is necessary to continue this work in order to achieve a satisfactory level of capacity.

Certain steps have been taken in the private sector to develop capacity for optimizing energy management systems. In this regard a good contribution was made by the project[99] Reducing *Greenhouse* Gas GHG Emissions through Improved Energy Efficiency in the Industrial Sector in *Georgia* implemented in cooperation of the Ministry of Economy and Sustainable Development of Georgia and the United Nations Industrial Development Organization / UNIDO, and the programme Energy Management Systems Capacity Building and Implementation Programme / EnMs CBI Programme, which provided assistance to a number of industrial companies and consultancy services in the field of Energy Management Systems and Motor System Optimization / MSO. Also, in several companies, in the form of pilot projects, energy management systems were introduced in line with the ISO 50001 standard and engine systems were optimized to encourage integration of energy efficiency into the daily operations of companies and their investment solutions. Mechanisms for the production and use of clean energy have also been established. As a result, the use of renewable resources as an alternative to hydro resources was intensified from 2018. Currently, 21 wind (with total capacity 1204 MW) and 15 solar (with total capacity 543 MW) are at the stage of feasibility study.

[99] Project was financed by Federal Ministry of Sustainability and Tourism of Austria

5.5.6 Reducing GHG emissions through infrastructure projects

Since the submission of the Third National Communication, several important infrastructure projects have been implemented in Georgia, both in the field of wastewater treatment and solid waste management. These projects have a positive impact on reducing GHG, therefore, it may enhance country's capacity to address issues related to the climate change causes.

After the completion of the rehabilitation in 2018, the Wastewater Treatment Plant (WWTP) of Gardabani, which receives wastewater from Tbilisi, Rustavi and Gardabani, performs a full cycle of wastewater treatment and significantly reduces the potential of methane generation in wastewater. The facility collects generated methane and performs its utilization. In 2017, the Kobuleti Wastewater Treatment Plant (WWTP) was put into operation, where the installation of a methane-capture system is planned. Treatment plants were also installed in Ambrolauri, Anaklia, Telavi and Poti. After completion of ongoing rehabilitation of WWTP in Zugdidi and Poti, treatment plants will be equipped with methane-capture and disposal systems. Rehabilitation / construction of wastewater treatment plants is planned in the coming years in Abastumani, Bakuriani, Bolnisi, Gudauri, Vani, Marneuli, Martvili, Mestia, Zhinvali, Samtredia, Stepantsminda, Tkibuli, Pasanauri, Kvareli, Tskhaltubo and Khashuri, also in Kutaisi - in the second biggest city of Georgia. Part of these treatment facilities will be equipped with the similar systems, which will also have the effect of reducing GHG, in addition to improving wastewater quality.

In terms of solid waste management the country implements significant infrastructure projects. At Tbilisi and Rustavi landfills, which have a methane collection system, a methane disposal system is currently being installed. In the near future, new regional landfills will be built in Kakheti, Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti, Mtskheta-Mtianeti and Shida Kartli. These landfills will be in full compliance with modern standards, which, among other conditions, implies the installation of a modern system of GHG collection and disposal, in order to prevent the release of these gases into the atmosphere the GHG generated at the landfills.

5.5.7 Assessment of climate change economic impact

In this area the country started active capacity building in 2019 (the country is assisted in developing capacity by the GIZ / BMZ-funded project "Climate-Resilient Economic Development", project implementation period 2019-2022). In particular, capacity building of research institutions working on economics, climate and modeling, and relevant government agencies is underway aimed at improving integration of climate issues into planning of the economic development.

5.5.8 Inventory of GHG Emissions

The country has taken its first steps to institutionalize the process of GHG inventory. Environmental information and knowledge management system was established within the frame of the project Harmonization of Information Management for Improved Knowledge and Monitoring of the Global Environment in Georgia. The system integrates an analogue of the GHG inventory software that meets the the UNFCCC requirements.

5.5.9 Human capacity development

Capacity building component also are included in the programmes and initiatives that are directly focused on climate change. This process includes the implementation of educational and training programmes and the provision of information on best practices, as well as training on modern, climate-friendly approaches and practices. Experts have the opportunity to participate in regional and global events that help Georgia learn about new approaches to climate change mitigation or adaptation and share their experiences.

In this regard, the role of EU projects (ClimaEast and EU for Climate, EU4Energy and others) is particularly important, in which Georgian specialists participate in various thematic conferences and meetings on issues such as the Nationally Determined Contribution (NDC) and its implementation; adaptation; climate mainstreaming in sectoral policies, climate financing mechanisms, energy efficiency issues, etc. It can be said that at the current stage, the projects implemented by donor countries and organizations are one of the main tools for involving Georgian practitioners in the process of sharing information and experience and developing new networks both regionally and globally.

Within the framework of the project Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia, the institutional and technical capacities of the agencies involved in this system will be evaluated and a capacity development plan will be developed in this area. The plan will include short-term and long-term capacity development activities. Capacity building activities in this area will be implemented through this plan.

Taking into account developments mentioned above, it should be emphasized that the approach to the systematic development of the capacity of professionals in the field of climate change in the country has not yet been established and specialized target programmes have not been developed for various stakeholders, and capacity building measure within the frame of technical assistance projects have sporadic and non-permanent character. In this regard, it is very important to use potential of the Environmental Information and Education Centre and educational institutions (e.g., in the area of energy audit or climate-friendly agriculture technologies), which have the capacity to design targeted systematic training/re-training programmes for private and public sectors.

6 Constraints and gaps, needs for financial and technical support and capacity building

Background

According to Decision 17/CP.8 of the Conference of the Parties of United Nations Framework Convention on Climate Change (UNFCCC), non-Annex I parties to UNFCCC shall identify the constraints and gaps and development priorities, the needs for financial and technical support and capacity building in their countries, as well as the activities, measures and programs proposed and implemented to address the constraints and fill the gaps.

Constraints and gaps analyses is mainly based on the on the information provided in the Third National Communication of Georgia to UNFC, the First and Second Biennial Update Reports, and Technological Needs Assessment document. In addition, meetings were held with various stakeholders to obtain information on mitigation and adaptation projects implemented and planned by them, and to discuss the gaps and needs.

6.1 Climate Change Funding and Technical Assistance

In 1994, Georgia ratified the UNFCCC and in 1999 acceded to Kyoto Protocol. Since then, the country has been regularly reporting to the Convention.

Georgia submitted initial national notification to UNFCCC in 1999, the second national notification in 2009 and the third national notification in 2016. In 2016, Georgia presented the first Biennial Update Report (BUR) and in 2019 the second BUR.

In the abovementioned process, Georgia is provided with financial and technical assistance from the Global Environment Facility (GEF) and the United Nations Development Program (UNDP) as a GEF Implementing

Agency. Georgian government provides in-kind contribution to by active participation of the Ministry of Environment and Agriculture of Georgia and other ministries in coordinating the process and meeting logistics needs. Since 1997, the capacities of relevant state agencies, experts and organizations have significantly developed, which is reflected in a high quality of documents being developed and the effective management of the process.

In addition to the assistance provided in the preparation of National Communication, support rendered to the country in mitigation and adaptation to climate change is significant. It should be noted that some of the projects completed or ongoing in the country contribute directly or indirectly to climate change mitigation or adaptation, though this fact has not been identified and formalized by the project executors. For example, budget-funded shoreline protection in various municipalities are not considered as measures to support climate change adaptation. Similar examples can be cited from other sectors (energy efficient and renewable energy promotion activities, landscaping, etc.). Besides, a number of measures are taken by the private sector that are not directly aimed at mitigating or adapting to climate change, but have a significant impact on climate change processes (e.g. construction of hydropower plant, wind farms, etc.).

Georgia has received assistance from Annex II countries (including EU member states) and their development agencies, as well as from international financial institutions (World Bank, EBRD, ADB) and UNFCCC financial and technological mechanisms such as Global Environment Facility, the Green Climate fund (GCF), Adaptation Fund (AF), Climate Technology Centre and Network (CTCN) etc.

Since 2013, the quantity and price of projects implemented in Georgia in the field of climate change mitigation have been higher than in adaptation. Besides, it is clear that financial assistance in mitigation projects outweighs the technical assistance and capacity building assistance, while that in adaptation and pervasive projects is relatively smaller. In addition, most of the mitigation projects are in the field of energy, and the adaptation projects are mostly dealing with natural disasters and agricultural problems.

6.2 Barriers and Needs Analysis

The country's efforts on climate change are growing and, importantly, covering a wide range of sectors and measures. The analysis revealed the barriers that hinder the efforts to some extent.

6.2.1 Barriers

Coordination between public agencies: Although Georgia has been actively involved in national and international climate change processes since 1997, coordination between public agencies remains weak. One of the important preconditions for solving this problem is the establishment of a Climate Change Council (CCC) to coordinate measures for reducing greenhouse gas (GHG) emissions and climate change risks.

CCC composition, structure and functions defined by its statute provide an important message that the coordination of public agencies involved in climate change matters and the definition and effective implementation of climate change policy in general is a priority for the country. One of the important prerequisites for the implementation of this message (still open at this stage) is the human, technical and financial resources necessary for the effective functioning of the Council. According to the statute, Climate Change Division of the Department of Environment and Climate Change of the Ministry of Environment and Natural Resources will act as a CCC Secretariat, however, the current human resources, technical and financial capacities of the department need to be strengthened.

Poor institutional arrangement. In the state institutions of the country, especially in self-governing units, there is no structural unit or at least a working group dealing with climate change. In general, responsibility for climate change problems rests with one individual staff member who is also responsible for other duties.

This barrier can be overcome by institutionalizing the issue of climate change in ministries and self-governing units through setting up an appropriate service or, by allocating a targeted staff member. It is also important to redistribute responsibilities and powers between central and local governments, establish an effective format for coordination with the private sector, and take other appropriate measure.

Climate change is not yet fully formalized in public institutions. In most cases, climate change issues are not addressed in the regulations as an inter-sectoral and topical problem. Therefore, efforts should be intensified to integrate climate change issues into the strategies and plans of line ministries and municipalities, organize awareness raising activities and trainings for public servants to consider climate change issues in their day-to-day activities, including at the stage of planning the new projects and evaluating possible outcomes.

Low awareness of projects and initiatives to promote climate change mitigation and adaptation. The country is lacking a unified database to collect and organize information on projects and initiatives that directly or indirectly contribute to climate change mitigation or adaptation. The information on the projects implemented through /in coordination with the Ministry of Environment and Agriculture is easily accessible only, while on those projects implemented by other sector ministries, municipalities or private sector is usually scattered and difficult to obtain. Availability of relevant information base will help to (a) effectively set country priorities and identify needs, (b) fill the gaps, and (c) coordinate activities with donors and partner organizations.

Lack of national financial resources. Climate change projects are mainly funded by donor organizations and partner countries. Non-monetary contribution of the government is also noteworthy, though only on the project implementation stage. Thus it is not clear in advance how the state will monitor the initiatives under the project, maintain the progress and support it after the project completion. Therefore, it is required for the state to provide appropriate funds to support climate change projects when planning the state budget, and to ensure the sustainability of the results achieved with the help of partners.

6.2.2 Needs

Table 6.2.2.1 provides a list of the key barriers and needs that are relevant to greenhouse gas inventory and reporting, mitigation and adaptation projects and initiatives. Mitigation and Adaptation chapters in the Fourth National Communication present sectoral barriers and needs. Barriers and needs are grouped in Table 6.2.2.1 to identify strategic areas for capacity building and to plan appropriate steps.

The current projects will significantly help to alleviate the needs listed below. The projects include Georgia's Integrated Transparency Framework for the Implementation of the Paris Agreement, implemented by the Regional Environmental Center for the Caucasus (REC), which will assist in improving the GHG inventory process and increase the efficiency of data collection and processing at both local and central levels; UNDP project Reducing the risk of climate-driven disasters in Georgia, which aims to address the needs related to natural disaster risks in Georgia. However, in order to significantly increase the country's capacity for successful fulfillment of its commitments under the Framework Convention on Climate Change and Paris Agreement, it is required to seek additional funding from the budget, with the help of partner countries and local private sector.

Table 6.2.2.1: Key barriers and needs

Constraints/ gaps[100]	Needs	Type of need: Financial (F), technical (T), capacity building (CB)
Greenhouse gas inventory and reporting		
Lack of data collection and unified management system	Create a database to constantly update the data required for the inventory of greenhouse gases, as well as the information on mitigation or adaptation measures. Prepare the relevant legal framework and the functions / rights / responsibilities	technical (T) capacity building (CB)
Scarce and poor quality of primary data sources (both central and local)	Training of relevant personnel and certification to conduct data collection, audits and monitoring.	technical (T) capacity building (CB) financial (F)
Typical values of emission factors and poor methodology used	Identify national emission factors, and ensure the quality and availability of primary data required for the use of high-level methodologies; technical training for relevant staff.	technical (T) capacity building (CB)
Lack of software and knowledge for analysis of long-term forecasting and planned activities (both mitigation and adaptation)	Elaborate training programs in academic and research institutions on long-term forecasting of GHG emissions and evaluation of the effects of mitigation measures, and their cost-effectiveness analysis. Acquisition and introduction of forecasting models for GHG emissions and climate change parameters	technical (T) capacity building (CB)
Mitigation measures		
Shortage of qualified staff required for the introduction of clean and energy efficient technologies.	Promote staff training programs for the introduction of climate-friendly technologies.	technical (T) capacity building (CB)
High pre-costs and lack of funding for the introduction of clean technologies, especially from the private sector.	Preferential loans, government grants / subsidies and cost sharing programs to stimulate sector development; Development of a national "green" bank / fund type institution, which provides stable long-term and preferential loans to individuals and legal entities;	financial (F) technical (T)
Lack of energy efficient building standards / certification system for building and construction materials.	The law on energy efficiency of buildings was adopted in May 2020. However, the introduction of standards for energy efficient buildings and certification of building materials requires the development and adoption of additional by-laws, including setting energy efficiency standards for the building sector, and developing evaluation methodologies; energy efficient buildings and building materials are unavailable	technical (T) capacity building (CB)
Scarce statistics for effective planning of mitigation measures in the transport sector.	Develop a data collection and management system for the transport sector in self-governing cities and municipalities and strengthen staff capacity in this area.	technical (T) capacity building (CB)
Low awareness of farmers of "climate-wise" alternatives - including of fertilizers and technology.	Provide information to farmers in a systematic and organized manner and raise their awareness of "climate-wise" alternatives - including fertilizers and technologies, as well as available financial instruments	technical (T) capacity building (CB) financial (F)
Lack of information on land types and degradation degree in Georgia	identify, update and clarify data on land types and degree of degradation.	technical (T)

[100] Gaps and needs identified in Second Biennial Update Report / BUR2 are also reflected

Constraints/ gaps[100]	Needs	Type of need: Financial (F), technical (T), capacity building (CB)
		capacity building (CB) financial (F)
poor and unreliable information on the amount and composition of waste disposed of in the landfill	Strengthen the capacity of responsible agencies in waste management. Ensure technical assistance for the National Statistics Office, and capacity building through the sharing of international practices in data collection, processing and use	technical (T) capacity building (CB,) financial (F)
Lack of knowledge and experience in technological solution for landfill methane capture and use.	Ensure technical assistance in selecting the most appropriate technological solution.	technical (T) capacity building (CB)
Dependence of locals on firewood as an easily accessible and cheap energy resource, which in turn leads to forest degradation and weakening of its role in climate change mitigating	Ensure support for forest reform, which implies the abolition of "social cutting" practices, and sustainable forest management; Facilitate increased access to alternative energy sources, both in technological and financial terms	technical (T) capacity building (CB) financial (F)
Adaptation		
Lack of a unified coordinated system for natural disaster risk identification, early warning and response	promote Multi-hazard mapping and regular updating; Strengthen the hydro meteorological and agrometeorological monitoring network; Facilitate the analysis of identified threats, communication of information with relevant agencies; Create a unified database on natural hazards and facilitate continuous updating; Identify the process coordinating agency / unit and facilitating its capacity building; Facilitate the development of threat response and preparedness plans for high-risk municipalities; Promoting the awareness raising for decision makers (central and local level	technical (T) capacity building (CB) financial (F)
Lack of climate management knowledge (know-how) in all sectors of agriculture and systematic approach to the transfer of the knowledge	Improve the knowledge in management / care of climate-resistant varieties / genotypes and agro-technologies (various fields of agriculture)	technical (T) capacity building (CB)
Lack of institutional and legislative framework for sustainable pasture use	Develop principles for sustainable pasture management, improve the legal framework and establish a coordinating body	technical (T) capacity building (CB)
Lack of regular and systematic study, assessment, and analysis of climate change impact on forests, protected areas and biodiversity in general, and planning of appropriate measures	Facilitate the development of national and municipal strategies for climate change adaptation of forests; Facilitate the development of a forest fire monitoring and prevention system; Create a unified network of protected areas, which implies an interconnected network of protected areas integrated into a wide range of landscapes; Assist Georgia in developing a climate change response strategy; Ensure monitoring of disease-causing, harmful and invasive species, Assist in the planning and implementation of appropriate risk assessment and preventive measures	technical (T) capacity building (CB) financial (F)

Constraints/ gaps[100]	Needs	Type of need: Financial (F), technical (T), capacity building (CB)
Integration of health and climate change issues into health and climate change strategic documents is still weak	Facilitate the assessment of health aspects of climate change vulnerability, health impacts and adaptation, including the assessment of current and expected risks of climate change impacts on the health of the population; Harmonize legislation in line with the requirements of the UNFCCC and its impact assessment on health; Encourage research on climate change and health; Ensure planning and initiating heat wave adaptation measures by local governments, especially in vulnerable cities; Inform population about climate change impact on health and increasing public involvement in decision-making	technical (T) capacity building (CB) financial (F)
Consideration and inclusion of climate change issues in policies, strategic directions and plans for the development of the energy sector is required	Consider the problem of climate change in the long-term planning of energy supply and demand, develop appropriate adaptation measures; Facilitate the study of river runoff change under the influence of climate change in important river basins; Promote the study of wind and solar power plant development, taking into account the potential impacts of climate change and considering the principles of sustainable development; Address climate change issues in transport sector policies, strategies and development plans; Ensure mapping of risks of transport infrastructure vulnerability to climatic stresses	technical (T) capacity building (CB) financial (F)
Integration of Climate Change Issues into Tourism Sector Policy, Strategies and Development Plans is required	Incorporate climate change issues into tourism policy, strategies and implementation plans; Assess and consider potential risks associated with climate change when investing; Facilitate the integration of adaptation issues into consulting and educational programs in the tourism industry; Raise awareness of businessmen, tour operators and other stakeholders about the impacts of climate change on tourism sector.	technical (T) capacity building (CB) financial (F)

6.3 Technology Transfer

According to the updated Nationally Determined Contribution (NDC), Georgia undertakes an unconditional commitment that by 2030, greenhouse gas emissions will not exceed 65% of 1990 levels. The commitment to limit emissions may rise to 50-43% of 1990 level if the country has financial and technological support. This change will result in a decrease in GHG intensity per unit of GDP in purchasing power standards[101] (kgCO2eq/$). According to the World Bank, in 2016, the carbon dioxide (CO2) emission intensity in Georgia was 0.26 kgCO2/$, which is higher than the EU average (0.21 kg CO2 / $)[102].

As for the Energy Efficiency, in the household sector, Georgia consumes 40-50% more energy to heat 1 m2 of space than EU countries with similar climatic conditions[103]. Thus, in order to achieve the targets of national climate change measures, it is important to ensure access to modern technologies, and to promote their introduction and application in all sectors of the economy. In this regard, the introduction of new

[101] GDP PPP - Gross Domestic Product expressed in terms of Purchasing Power Parity

[102] https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD

[103] The Third Environmental Performance Review of Georgia, 2016

technologies is a priority for the country in those sectors that have a high potential for mitigation of GHG emissions. It is also important to introduce technologies enabling to increase the country's resilience to expected climate change and ensure risk reduction.

In recent years, Georgia has intensified its efforts to seek technologies, to create and improve conditions that are favorable to technology transfer and make active use of the various transfer mechanisms.

Technology Needs Assessment (TNA) [104] for climate change is a handbook for the country in this regard. TNA process has identified the priorities and technologies for the introduction of modern technologies for the country. It serves as a guide for donor countries and organizations in terms of technology transfer, taking into account Georgia's priorities. Technology Transfer Action Plans for Climate Change Adaptation and Climate Change Mitigation have been developed based on TNA. Table 6.3.1 provides information on Georgia's technology transfer priorities and technologies.

Table 6.3.1: Georgia's priority areas and technologies.

Sphere	Priority direction	Priority technology
Mitigation	energy use in residential and commercial buildings	Sustainable construction technologies - Complex designing of buildings/facilities, Energy efficient building materials and efficient construction practices
	Supply of renewable energy resources	Energy efficient wood stoves, Solar water heaters for household and commercial use
	Transport	Compressed Natural gas buses, electric buses, low-emission vehicles, traffic light control system, transport control systems.
Adaptation	Agriculture	Soil erosion control: ULSE method, terracing, windbreak, minimum and zero
		Irrigation, drip irrigation
	Disaster Risk Reduction	Low-cost landslide protection measures, riverbed cleaning, geological risk zoning, forecasting.
	Black Sea coast protection	Coast landfilling with inert material, construction of sediment control piers, expansion of coastal dunes, creation of artistic reefs, etc.

6.4 Assistance received for introduction of technologies and funding mechanisms

6.4.1 Assistance received for introduction of technologies

In the past few years, Georgia has received significant assistance in technology transfer from Annex II countries to UNFCCC within the framework of technical cooperation projects. Some of the projects with the main goal or one of the components being technology/know-how transfer are categorized as technology transfer ones and serve the effective implementation of mitigation or adaptation measures.

The assistance is in line with the priorities set out in the Technology Needs Assessment (TNA) and reflected in the Technology Action Plan and it greatly contributes to the implementation of the plan. Assistance from the priorities set out in the TNA was aimed at (a) increasing energy efficiency in homes and enterprises, (b) replacing old buses with low-emission ones in the transport sector, and moving to efficient management systems; (c) establishing disaster risk prediction and early warning systems; (d) introducing effective irrigation systems in the agricultural system; and (e) reducing soil erosion. Funds allocated for projects

[104] https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2013/12/technologyneedsassessment-mitigation-georgia-13.pdf
https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2013/12/technologyneedsassessment-adaptation-georgia-13.pdf

include grants and soft loans. Some of the projects are co-financed by the state (monetary and non-monetary contributions).

Among the technology transfer projects, climate change mitigation projects are clearly dominant. Energy sector is the leader in this regard. However, in recent years an increase in the number of projects promoting the introduction of adaptation technologies in early warning systems and agriculture is noticeable. An important component of adaptation projects was the transfer of know-how and capacity building.

In the economic sectors, there is activity of the private sector and municipalities in the introduction of climate technologies, although these measures are not labeled as initiatives for the introduction of climate technology. Private sector and municipalities have been active in the introduction and implementation of climate technologies, however, their measures are not labeled as initiatives to introduce climate technologies. The introduction of the above mentioned technologies contributes to the fulfillment of Georgia's commitments on climate change.

The main objective of technology transfer is (a) to introduce energy efficient technologies and practices in industry and construction sector; (b) increase the number of vehicles operating on low-emission technologies in the transport sector; and (c) the use of modern irrigation technologies in agriculture. The initiatives are implemented by companies, farmers, municipalities and individuals with their own financial resources.

Tbilisi Municipality is gradually introducing a smart traffic lights system throughout the city. By the beginning of 2020, there were 221 smart traffic lights in the city. It is planned to add an additional 20-25 smart traffic lights every year to reduces vehicle emissions.

In 2019, “Rustavi Azot” started to use the steam generated during the production process for generation of electricity by introduction of Siemens new technology, which increased the company's energy efficiency by 20%. In 2018, the rehabilitation of the Gardabani treatment plant, which receives wastewater from Tbilisi and Rustavi, was completed, and the equipment was replaced by modern, energy-efficient equipment from Siemens, Endress+Hauser and Ginzler. As a result, it can clean the wastewater in a complete cycle and consequently reduce methane emissions.

In Kakheti and Kvemo Kartli regions, drip irrigation and pivot irrigation methods have been introduced in some large farms. The technologies have been transferred mostly by Annex II countries.

6.4.2 Technology Funding Mechanisms

One of the barriers to widespread introduction of modern technologies in Georgia is a high initial investment cost of technologies and limited access to finances. The increase in the initial investment cost is also caused by the need for outsourcing of technical staff to implement the technology due to the lack of relevant knowledge and personnel in the country. Thus, the availability of international financing mechanisms for modern technologies is vital for the country. It is equally important whether Georgia can use these mechanisms and how effectively it will do it.

Leading position in technology transfer is occupied by energy efficient and renewable resource technologies. Low-emission technologies (electric buses and EURO VI bus technology) are also actively entering the transport sector. Active work on adaptation technologies is underway with the introduction of early warning systems, water-saving and degraded soil recovery technologies.

Georgia uses the following funding mechanisms to obtain climate change technologies:

- Climate Green Fund
- Adaptation Fund

- Eastern Europe Energy Efficiency and Environment Partnership fund - E5P
- EBRD Finance and Technology Transfer Centre for Climate Change (FINTECC)
- Global Environment Facility
- German Federal Ministry for Economic Cooperation and Development (BMZ)
- Climate Technology Center and Network
- Donor countries (bilateral funding)

Green Climate Fund plays an important role in climate technology transfer in Georgia. GCF-EBRD Sustainable Energy Finance Facility Program „Green Cities Facility“ is currently ongoing, under which low-emission vehicles will be introduced. Another GCF funded program is Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia, implementing by UNDP. It is especially important for small and medium-sized businesses to have access to funding for the introduction of climate technology through the Green Economy Financing Facility program. GCF funds are managed by the EBRD, which co-finances the program with significant resources.

The Dairy Modernization and Market Access project, funded by the Adaptation Fund, will include the transfer of mitigation technologies (energy efficient milk processing technologies, use of solar energy), as well as adaptation technologies (erosion reduction, manure composting, etc.). The Adaptation Fund also plans to fund a joint Georgian-Armenian project aimed at increasing the resilience of mountainous settlements in Georgia and Armenia to wildfires caused by climate change. Forest fire risk assessment and forecasting systems will be developed under the project as well.

E5P incentive grants and loans from international and governmental financial institutions (the Nordic Environment Finance Corporation (NEFCO), EBRD and Kreditanstalt Für Wiederaufbau (KfW), and co-financing from the governments of Denmark and Austria are used for transfer of energy efficient technologies in industry and construction sectors, facilitation of access to capital for small and medium-sized businesses to implement climate technologies.

With the financial support of BMZ within the framework of Integrated Biodiversity Management in the South Caucasus, sustainable ecosystem-based forests and pastures were piloted in the mountainous region of Georgia (Tusheti) and gully erosion management through bio-engineering activities. The project was particularly important in terms of transferring the know-how of adaptation technologies.

As a result of the project implemented in Georgia with the assistance of FINTECC, energy efficient and innovative technologies have been introduced in food, pharmaceutical and medical companies.

Table 6.4.2.1: Current technology transfer projects in Georgia

Field / direction	Project	Technology, know how	funding	Funds	Implementing agency
Energy consumption in residential and commercial buildings	Improving the energy efficiency of public buildings in Georgia and use of renewable and alternative energy	Energy efficient construction technologies	5.14 mln EUR	E5P NEFCO Government of Denmark	Municipal Development Fund (MDF)
Energy consumption in Tbilisi public schools	Improving the energy efficiency of public buildings in Georgia and use of renewable and alternative energy	Energy efficient construction technologies	21 mln EUR	E5P	MDF

Field / direction	Project	Technology, know how	funding	Funds	Implementing agency
				CEB[105]	
Energy consumption in industry	Incentive grants and loans to purchase energy efficient and innovative technologies	Modern power management systems; Innovative CO2 recovery system; Energy efficient construction technologies.	N/A	E5P (EU4Business) GEF EBRD FINTECC programm	EBRD
Supply of renewable energy resources; **Energy consumption in residential and commercial buildings**	Biomass energy and energy efficient technologies as sustainable energy solutions for cities that sign the Covenant of Mayors	Using vine pruned stems to heat the building; efficient construction technologies	600,000 EUR	E5P (EU4Energy)	Energy Efficiency Center (EEC)
Supply of renewable energy resources	Global Energy Efficiency and Renewable Energy Fund (GREEF NeXt) program	Run-of-river hydroelectricity (ROR) plant; Introducing best practices in the construction and operation of small and medium hydropower plants.	12.5 mln USD	GEEREF[106]	Caucasus Clean Energy Fund
Transport systems	Purchase of CNG buses for Tbilisi, Rustavi, Kutaisi, Zugdidi, Gori and Poti	CNG buses	97 mln EUR	EBRD – Green Cities Facility Programme E5P	EBRD
Disaster Risk Reduction[107]	Dissemination of multi-hazard early warning systems and use of climate information in Georgia	Multi-hazard early warning system; Methods and technologies based on standards for the preparation and assessment of hazard, risk and vulnerability maps	27 mln USD 5 mln USD 4 mln USD	Green Climate Fund Swiss Agency for Development and Cooperation (SDC) The Swedish International Development Cooperation (SIDA)	UNDP
Agriculture Energy consumption in industry	Modernization of dairy industry and market access	Manure composting; Livestock feed production and conservation technologies;	4.5 mln USD	Adaptatio Fund	International Fund for Agricultural Development *(IFAD)*

[105] CEB - Council of Europe Development Bank

[106] (GEEREF) Global Energy Efficiency and Renewable Energy fund. It is planned to build 10 small and medium-sized Run-of-river hydroelectricity (ROR) plants in Georgia..

[107] Project total price is 74,293,598 USD. Including donor share 36 mln USD and 38.3 mln USD cofinanced by Georgian Government

Field / direction	Project	Technology, know how	funding	Funds	Implementing agency
		Degraded pasture restoration technologies; Heavy rainfall impact mitigation technologies; Restoration of river-bank vegetation; Energy efficient technology of dairy processing			
Energy consumption, mitigation and adaptation	Green Economy Financing Facility	Introduction of high technologies for various purposes	54 mln USD	GCF EBRD – Green Economy Financing Facility[108] Austria	EBRD

Bilateral donors. The governments of Austria, Denmark and Switzerland provided co-financing for current technology transfer projects. The main focus of the projects is to introduce energy efficient practices and implement training programs, as well as ensure access to the technologies such as early warning systems, alternative renewable energy generation systems, etc.

6.4.3 Potential sources of funding technology transfer

The country needs awareness raising of the sources of funding for technology transfer and accreditation of institutions to have access to financial assistance. It is also necessary to develop the capacity of these institutions in project preparation, in order to make the projects submitted for funding competitive.

Clean Technology Fund (CTF) allocates funds for non-annex 1 countries to invest in clean technology projects. The CTF-funded projects promote the popularization, introduction and transfer of the low-carbon technologies, which have significant potential for reducing greenhouse gases in the long run.

GEF's Global Clean Technology Innovation Program (GCIP) enables to identify the best innovative ideas for climate technology development in Georgia through competition and to implement them through the private sector. Involvement in the similar programs would be particularly helpful for Georgia, because funding from public or private sector for climate technology studies is very scarce, which hinders the adaptation or local development of climate technologies and the systematic and efficient development of capacities.

Pilot Grant Program to Foster Innovation of Adaptation Practices in Vulnerable Countries, established by the Fund and CTCN in December 2019, will enable Georgia to receive finances for innovative adaptation projects.

6.5 Capacity building for introduction and application of technologies

Technology transfer initiatives and programs implemented in the country include a capacity building component aiming to acquire the experience and skills for using the technologies. The process includes

[108] Green Economy Financing Facility, EBRD program.

conduction of educational and training programs, provision of information on best practices, and trainings in technology transfer mechanisms.

Through the technology transfer projects, Georgia has been involved in sharing knowledge and experience between countries, which is crucial for the introduction and sustainable use of technologies. For example, EU-funded projects for the Eastern Partnership countries include activities aimed at sharing information and experience. Georgian experts can participate in capacity building seminars organized at the sub-regional and global levels and receive information on new mitigation and adaptation technologies. These measures are important though insufficient for raising the qualification of Georgian experts. However, there is a lack of practice in sharing the acquired knowledge and ensuring the continuity of it due to the lack of a clear policy, poor internal coordination and staff turnover.

Georgia is more focused on the transfer and implementation of climate technologies than on conducting studies on technology development, promoting the development of local technological solutions for adaptation to climate change and tailoring the existing technologies for local context. In recent years, however, the government has taken some steps to promote innovations. In 2014, the Georgian Innovation and Technology Agency (GITA) launched a small grants program ($ 20,000) to assist startups in commercializing products or services. To further support the program, a Technology Transfer project was piloted in April 2019, funded by the European Union and the World Bank. The project focuses on the commercialization of scientific projects that meet the market needs. Despite a different goal of the program, climate technology development projects can also receive financing. However, setting the climate technologies as one of the priorities of the program would greatly contribute to the intensification of research and innovations in the country. In 2019, with the support of GITA, Georgia joined the ClimateLaunchpad program, which aims to promote development and introduction of clean technology ideas.

It is important for the country to participate more actively in researches on climate change technologies especially on adaptive technologies, and gradually strengthen their capacities. In this regard, it is advisable for organizations / enterprises engaged in climate technologies to have access to state funds and low-cost private financial resources. Along with the technology transfer pilot program, Georgia can actively use the opportunities offered by CTCN, the Readiness Program and the Global CleanTech Innovation Program (GCIP) to the annex I countries to the Convention.

6.6 Facilitating factors and barriers to technology transfer

Following the submission of the Third National Communication in 2016, Georgia has taken serious steps to overcome barriers to technology transfer. Significant progress has been made in improving the **regulatory framework**. In recent years, relevant laws, strategic documents and action plans have been adopted, which greatly contributed to the technology transfer in the country.

The Law on Energy and Water Supply (2019) recognizes the introduction of smart technologies for the operation of electricity and natural gas systems as a general principle governing the country's energy activities. In addition, the law authorizes the Government of Georgia to set a minimum level of efficiency for the technology used during the construction of new power generation facilities, or the reconstruction of existing ones. Introduction of smart metering systems and high-efficiency technologies are reflected in more detail in the Energy Efficiency Action Plan adopted under the Law on Energy Efficiency. *The Law on Energy Efficiency was adopted i*n May 2020.

Law on Energy Labeling (2019) enables consumers to select more efficient products to reduce the consumption of energy and other resources. The law has made it mandatory to provide information on the energy efficiency class of products, which facilitates informed decision-making by consumers.

According to the Code of Spatial Planning, Architectural and Construction Activity of Georgia (2018), maximum energy efficiency must be ensured for buildings using various modern energy-saving equipment. Besides, the possible use of renewable energy should be considered during the design and construction of buildings/facilities.

Introduction of modern technologies is included in various industry strategies and action plans. For example, Ten Year Network Development Plan of Georgia (2019-2029) aims to introduce IT technologies and switch to state-of-the-art systems to ensure transmission network reliability and sustainability. The National Disaster Risk Reduction Strategy of Georgia 2017-2020 includes introduction of geospatial and space-based technologies and related services in the disaster risk reduction system. Agriculture Development Strategy 2017-2020 and Irrigation Strategy 2017-2025 outline the modernization of reclamation systems, which also includes the introduction of modern technologies and management approaches for the efficient use of irrigation water, as well as target indicators for drip and spray irrigation systems.

Some economic and financial progress has also been made in creating factors that facilitate technology transfer. Assistance from Annex II countries and international financial organizations in this regard is to be outlined. One of the main economic and financial constraints to access to technology is the limited financial resources, partial access to which has been provided with the assistance of international financial organizations. However, we still face significant difficulties in this regard, due to limited access to funding. In addition, to date, state purchases do not include environmental or energy efficiency indicators for goods or services, while government expenditures on procurement of products and services accounts for 18.4% of GDP. Changing the public procurement system and introducing relevant criteria in tender would allow to create demand for low-emission products and services, which in turn would help the business sector to develop in this regard.

The data analysis showed that it was especially difficult for Georgia to overcome the barriers related to technical know-how and capacity development, which hinders the long-term and effective use of the technologies, as well as the local development of climate technologies and innovation. Significant efforts are needed to intensify studies in the country, which along with the accumulation of knowledge, will contribute to the development of skills and capacities being a prerequisite for innovations. Research funding is not just about investing in high-tech studies. Investing in research also involves tailoring and adapting the technologies to local conditions, developing current traditional knowledge, increasing productivity, etc.

Overcoming barriers to technical know-how and capacity building through support for technical cooperation programs alone cannot provide a long-term solution to the problem. A systemic approach is needed to ensure a progressive increase in qualifications and technological capacities in the country and to encourage innovation. Investing in programs and projects that promote technology diffusion and stimulate business in this area is also crucial.

Today it is not easy for users to navigate the variety of information flows. The private sector and consumers often find it difficult to select optimal and adequate technologies. Thus, the scarcity of climate technology pilot projects in the country and the lack of technology reference examples make it difficult to obtain information on the best technologies tailored to local conditions and contexts. It is important to use the potential of the Center for Environmental Information and Education of the Ministry of Environment and Agriculture.

Table 6.6.1 provides information on facilitating factors and barriers

Table 6.6.1: Facilitating factors and barriers to technology transfer

Categories of facilitating factors and barriers	Facilitating factors to technology transfer	Barriers to technology transfer
Regulatory legal framework	**Energy efficient and renewable resource technologies** Nationally defined contribution. Joining the Energy Union. Law on Energy and Water Supply. Law on Encouraging Production and Use of Energy from Renewable Sources. Law on Energy Labeling. Code of Spatial Planning, Architectural and Construction Activities of Georgia. Amendment to the tax law. Reduction of excise rates set by the Tax Code for hybrid vehicles. Sustainable Energy Action Plans for 11 cities and municipalities. Ten Year Network Development Plan of Georgia (2019-2029). Energy Strategy of Georgia 2020-2030. National Renewable Energy Action Plan. Energy Efficiency Action Plan 2019-2020. Law on Energy Efficiency. Law on Energy Efficiency of Buildings. **Legislative framework facilitating the transfer of technologies for climate change adaptation.** National Disaster Risk Reduction Strategy of Georgia; Agriculture Development Strategy 2017-2020 Irrigation Strategy 2017-2025	**Mitigation** **Energy efficient and renewable resource technologies.** A long-term energy efficiency plan has not been adopted (planned for adoption in the nearest future) Lack of quantitative and target indicators of renewable energy and energy efficiency measures; Low-emission development strategy (re-processing and adoption of the developed document is planned); Law on Public Procurement (to integrate ecological and energy efficiency criteria into the law) **Adaptation** Climate change adaptation plan is not in place (under preparation)
Economical and financial	incentive grants for installation of energy efficient techniques; State Program "Produce in Georgia", which, among other projects, partially funds resource efficient and clean production (RECAP) projects; Technology Transfer Pilot Program of the Georgian Innovation and Technology Agency. Credit lines of international financial institutions for RECP projects of local commercial banks. Green loan program of individual banks (e.g. ProCredit Bank)	Inaccessible technologies to the private sector due to limited financial resources; Unavailable modern technologies due to high operating costs, which is mainly linked with the lack of relevant qualified staff and the need of outsourcing the services. Limited access to cheap (low-cost) long-term capital; Limited access to finance for SMEs; Lack of mobilization of local private sector investments due to low awareness of climate measures; State procurement system does not take into account the environmental and energy efficiency indicators of goods or services. capital market should be developed in order to mobilize climate finances
Technical know how **(Ability to use technology efficiently)**	Level of general education; Certification system for refrigerator technicians; Trainings for energy auditors; GITA Technology Transfer Pilot Program	Unavailable modern technologies on the market; Lack of reference examples of technology; Lack of certification system for energy auditor

Categories of facilitating factors and barriers	Facilitating factors to technology transfer	Barriers to technology transfer
		Current state of physical infrastructure, which complicates the introduction of certain technologies; Lack of experience in technological adaptation; Lack of improvement in acquired knowledge, skills and tools; Difficulty in developing innovations into commercial products / services
Qualification/ skills/ capacities	External financial assistance to develop qualifications and skills (capacity building activities implemented under technical assistance projects); Building energy efficiency demonstration projects; Awareness raising and training programs for energy auditors. Training programs on the use of installed energy-efficient / clean production technology; Training programs for introduction and use of early warning systems	Lack of state funded research programs that hinders development of qualification and skills; Lack of trained technical staff; Lack/poor specialized training and education programs in schools, VET institutions and universities;
Information /awareness	Climate change related Measures of Environmental Information and Education Centre; Awareness raising activities of international technical assistance projects; Demonstration projects on various technologies	Low awareness of climate technologies; Reliable information and know-how is unavailable.

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Annexes

Annex 1

Climate Indices

1. **TX90p** Amount of hot days. Percentage of days when TX > 90th percentile
2. **TN90p** Amount of warm nights. Percentage of days when TN > 90th percentile
3. **TX10p** Amount of cool days. Percentage of days when TX < 10th percentile
4. **TN10p** Amount of cold nights. Percentage of days when TN < 10th percentile.
5. **GSL** Growing season Length. Annual number of days between first occurrence of 6 consecutive days with TM > 5^0C and the first occurrence of 6 consecutive days with TM < 5^0C.
6. **WSDI** Warm spell duration index. Annual number of days contributing to events where 6 or more consecutive days experience TX > 90th percentile.
7. **CSDI** Cold spell duration indicator. Annual number of days contributing to events where 6 or more consecutive days experience TN < 10th percentile.
8. **GDDgrown** Growing degree Days. Annual sum of (TM – n), where n is a user-defined location-specific base temperature and (TM > n). n = 10^0C.
9. Hddheatn Heating Degree Days. Annual sum of (n – TM), where n is a user-defined location-specific base temperature and (TM < n). n = 18^0C.
10. **CDDcoldn** Cooling degree Days. Annual sum of (TM – n), where n is a user defined location-specific base temperature and (TM > n). n = 18^0C.
11. **HWN(EHF)** Heat wave number. The number of individual heat waves that occur each summer (May – Sep). A heat wave is defined as 3 or more days where the Excess Heat Factor (EHF) is positive.
12. **HWD(EHF)** Heat wave duration. The length of the longest heat wave as defined by the Excess Heat Factor (EHF)
13. **CWN(ECF)** Cold wave number. The number of individual 'cold waves' that occur each year as defined by the Excess Cold Factor (ECF)
14. **CWD (ECF)** Cold wave duration. The length of the longest 'cold wave' as defined by the Excess Cold Factor (ECF).
15. **R95p** - Total annual precipitation from heavy rain days. Annual sum of daily precipitation > 95th percentile
16. **R99p** Total annual precipitation from very heavy rain days. Annual sum of daily precipitation > 99th percentile
17. **R95pTOT** Contribution from very wet days. (R95p / Annual total wet-day precipitation) x 100 (percentage)
18. **R99pTOT** Contribution from extremely wet days. (R99p / Annual total wet-day precipitation) x 100 (percentage)
19. **CWD** Consecutive wet days. Maximum annual number of consecutive wet days with PR>=1mm (longest wet spell)
20. **TMge10** TM of at least 10^0C. Monthly or annual number of days when TM ≥ 10^0C
21. **TMlt10** TM below 10^0C. Monthly or annual number of days when TM < 10^0C
22. **FD** Frost days. Monthly or annual number of days when TN < 0^0C
23. **PRCP(TOT)** Monthly or annual total wet-day precipitation. PR from wet days (PR ≥ 0.1 mm)
24. **R30mm** Number of heavy precipitation days. Monthly or annual number of days when PR ≥ 30 mm

25. **R50mm** Number of heavy precipitation days. Monthly or Annual number of days when PR ≥ 50 mm
26. **Rx1day**-Maximum 1-day precipitation. Monthly or annual maximum amount of rain that falls in one day
27. **Rx5day-**Maximum 5-day precipitation. Monthly or annual maximum amount of rain that falls in five consecutive days
28. **CDD**-Consecutive dry days. Monthly or annual maximum number of consecutive dry days when PR < 1 mm (longest dry spell)
29. **Wg15**-Number of days with strong wind. Monthly or annual number of days with maximum wind speed ≥ 15 m/sec
30. **Wg25** Number of days with extreme wind. Monthly or annual number of days with maximum wind speed ≥ 25 m/sec
31. **RH80** Amount of humid days. Monthly or annual number of days with afternoon relative humidity ≥ 80%
32. **RH30** Amount of dry days. Monthly or annual number of days with daily minimum relative humidity ≤30%
33. **TXm** Mean TX. Monthly or annual mean daily maximum temperature
34. **TNm** Mean TN. Monthly or annual mean daily minimum temperature
35. **TMm** Mean TM. Monthly or annual mean daily mean temperature
36. **TNn** Minimum TN. Monthly or annual coldest daily TN (coldest day)
37. **TXx** Maximum TX. Monthly or annual warmest daily TX (hottest day)

Table A 1: Mean air temperatures in 1986–2015 and their change between two 30-year periods (1956–1985 and 1986-2015)

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spr	Sum	Aut	Wint	Year
Adjara	Kobuleti	Tmean in 1986-2015, ^{0}C	6	6.3	8.5	12.1	16.1	20.6	23.3	24	20.6	16.3	11	7.6	12.2	22.7	16	6.7	14.4
		□Tmean, ^{0}C	0.33	0.23	0.48	0.27	0.29	0.76	1.21	1.67	1.27	1.37	0.01	0.16	0.35	1.22	0.89	0.24	0.68
	Batumi	Tmean in 1986-2015, ^{0}C	7.2	7.4	9.1	12.6	16.3	20.5	23.1	23.7	20.5	16.8	12.3	9	12.7	22.4	16.5	7.9	14.9
		□Tmean, ^{0}C	0.07	0.14	0.48	0.24	0.13	0.51	0.97	1.51	0.99	1.16	-0.15	-0.15	0.28	1.00	0.67	0.02	0.49
	Khulo	Tmean in 1986-2015, ^{0}C	1.4	1.2	4	9.3	13.6	16.6	18.9	19.5	16.4	12.2	6.8	2.8	9	18.4	11.8	1.8	10.3
		□Tmean, ^{0}C	-0.29	-0.55	-0.43	-0.42	-0.59	0.00	0.59	1.05	0.66	0.57	-0.82	-0.60	-0.48	0.55	0.14	-0.48	-0.05
	Goderdzi Pass	Tmean in 1986-2015, ^{0}C	-7.4	-7.6	-4.6	0.9	5.8	9.5	12.5	12.9	9.3	4.7	-1.3	-5.6	0.7	11.7	4.2	-6.9	2.5
		□Tmean, ^{0}C	0.10	-0.15	-0.36	-0.47	-0.34	0.18	0.55	1.12	0.63	0.65	-0.84	-0.43	-0.39	0.62	0.15	-0.10	0.07
	Average	**□Tmean, ^{0}C**	**0.11**	**-0.08**	**0.04**	**-0.10**	**-0.13**	**0.36**	**0.83**	**1.34**	**0.89**	**0.94**	**-0.45**	**-0.26**	**-0.06**	**0.85**	**0.46**	**-0.08**	**0.30**
Guria	Chokhatauri	Tmean in 1986-2015, ^{0}C	5.5	5.8	8.6	13.4	17	20.7	22.3	23.4	20.3	16	10.8	7.1	13	22.1	15.7	6.2	14.3
		□Tmean, ^{0}C	0.13	0.04	0.45	0.43	-0.03	0.45	0.27	1.38	1.14	0.92	-0.32	-0.43	0.28	0.70	0.58	-0.09	0.37
	Bakhmaro	Tmean in 1986-2015, ^{0}C	-4.5	-5.2	-2.6	2.6	7.1	10.4	13.6	13.9	10.5	6.2	0.8	-3	2.3	12.7	5.8	-4.2	4.2
		□Tmean, ^{0}C	0.14	-0.48	-0.36	-0.38	-0.30	0.09	0.81	1.11	0.80	0.98	-0.53	-0.48	-0.35	0.67	0.42	-0.27	0.12
	Average	**□Tmean, ^{0}C**	**0.14**	**-0.22**	**0.05**	**0.03**	**-0.17**	**0.27**	**0.54**	**1.25**	**0.97**	**0.95**	**-0.43**	**-0.46**	**-0.04**	**0.69**	**0.50**	**-0.18**	**0.25**
Samegreli-Zemo Svaneti	Mestia	Tmean in 1986-2015, ^{0}C	-4.9	-3.5	-3.7	5.9	10.8	14.2	17.5	17.1	12.8	7.9	1.9	-3.1	4.3	16.3	7.5	-3.8	6.1
		□Tmean, ^{0}C	0.02	0.07	0.17	0.18	-0.10	0.58	1.09	1.23	0.98	1.30	-0.04	0.10	0.08	0.97	0.75	0.07	0.47
	Khaishi	Tmean in 1986-2015, ^{0}C	0.2	2	5.8	11.1	15.5	18.7	21.7	22.1	17.6	12.3	6.2	1.8	10.8	20.8	12	1.3	11.3
		□Tmean, ^{0}C	-0.05	0.09	0.49	0.30	0.07	0.54	1.24	1.64	1.22	1.36	-0.10	0.03	0.29	1.15	0.83	0.02	0.57
	Zugdidi	Tmean in 1986-2015, ^{0}C	5.7	6.6	9.1	13.4	17.2	21.1	23.4	24.1	20.5	16	11	7.5	13.2	22.9	15.8	6.6	14.7
		□Tmean, ^{0}C	-0.04	0.28	0.45	0.26	-0.04	0.77	1.23	1.81	1.37	1.42	-0.08	0.07	0.22	1.27	0.91	0.10	0.63
	Poti	Tmean in 1986-2015, ^{0}C	6.3	6.7	9	12.9	16.8	21.1	23.7	24.3	20.8	16.6	11.5	8.1	12.9	23.1	16.3	7.1	14.9
		□Tmean, ^{0}C	0.30	0.20	0.39	0.31	0.30	0.82	1.12	1.58	1.15	1.22	-0.04	0.11	0.34	1.18	0.78	0.20	0.63
	Average	**□Tmean, ^{0}C**	**0.06**	**0.16**	**0.38**	**0.26**	**0.06**	**0.68**	**1.17**	**1.57**	**1.18**	**1.33**	**-0.07**	**0.08**	**0.23**	**1.14**	**0.82**	**0.10**	**0.58**
Imereti	Sachkhere	Tmean in 1986-2015, ^{0}C	1	1.9	5.9	11.6	16	19.5	22.8	23.2	19	12.9	6.7	2.6	11.2	21.9	12.9	1.9	12
		□Tmean, ^{0}C	0.28	0.13	0.19	0.04	-0.25	0.10	1.14	1.55	1.05	0.96	-0.12	0.09	0.00	0.94	0.63	0.17	0.43
	Kutaisi	Tmean in 1986-2015, ^{0}C	5.7	6.2	9.1	13.9	18	21.5	24	24.5	21.2	16.9	11.5	7.7	13.7	23.4	16.6	6.6	15.1
		□Tmean, ^{0}C	0.00	0.12	0.33	0.19	0.05	0.52	1.14	1.56	1.12	1.18	-0.18	-0.13	0.19	1.08	0.72	-0.01	0.50
	Mta Sabueti	Tmean in 1986-2015, ^{0}C	-2.8	-2.6	0.5	6	10.5	14.1	16.9	17.3	13.4	8.6	3	-0.9	5.6	16.1	8.3	-2.1	7
		□Tmean, ^{0}C	0.36	0.17	0.39	0.08	-0.06	0.53	0.99	1.43	0.80	0.84	-0.15	-0.08	0.14	0.99	0.50	0.15	0.45
	Samtredia	Tmean in 1986-2015, ^{0}C	5.6	6.3	9.2	13.9	18.1	21.7	24.1	24.5	21	16.5	11	7.2	13.7	23.5	16.2	6.4	15
		□Tmean, ^{0}C	0.19	0.28	0.36	0.25	0.17	0.59	1.13	1.60	1.10	1.16	-0.19	-0.05	0.26	1.11	0.69	0.13	0.55
	Zestaponi	Tmean in 1986-2015, ^{0}C	4.6	5.2	8.7	13.8	18.2	21.7	24.3	24.8	21.3	16.3	10.4	6.4	13.6	23.6	16	5.4	14.7
		□Tmean, ^{0}C	0.07	0.10	0.28	0.08	0.13	0.54	1.13	1.52	1.12	1.10	-0.27	-0.15	0.17	1.07	0.65	0.00	0.48
	Average	**□Tmean, ^{0}C**	**0.18**	**0.16**	**0.31**	**0.13**	**0.01**	**0.46**	**1.11**	**1.53**	**1.04**	**1.05**	**-0.18**	**-0.06**	**0.15**	**1.04**	**0.64**	**0.09**	**0.48**
Racha Lechkhumi – Kvemo Svaneti	Lentekhi	Tmean in 1986-2015, ^{0}C	-1.3	0.2	4.4	10	14.8	18.4	21.4	21.1	16.5	10.8	4.2	-0.4	9.7	20.3	10.5	-0.5	10.1
		□Tmean, ^{0}C	0.59	0.25	0.48	0.30	0.28	0.88	1.23	1.38	0.96	1.05	-0.32	0.00	0.35	1.17	0.57	0.28	0.59
	Shovi	Tmean in 1986-2015, ^{0}C	-4.7	-3.8	-0.6	4.8	9.7	13.5	16.7	16.3	12.1	7.2	1	-3.6	4.6	15.5	6.8	-4	5.8
		□Tmean, ^{0}C	0.41	0.30	0.37	0.29	0.08	0.89	1.17	1.33	1.11	1.26	-0.31	-0.25	0.25	1.13	0.69	0.15	0.56
	Ambrolauri	Tmean in 1986-2015, ^{0}C	0.1	1.8	5.9	11.3	15.7	19.4	22.4	22.4	18.2	12.6	6.3	1.6	11	21.4	12.4	1.1	11.5
		□Tmean, ^{0}C	0.02	0.15	0.13	-0.04	-0.10	0.48	0.85	1.06	0.81	1.14	-0.14	-0.15	0.00	0.80	0.61	0.00	0.35
	Average	**□Tmean, ^{0}C**	**0.34**	**0.23**	**0.33**	**0.18**	**0.09**	**0.75**	**1.08**	**1.26**	**0.96**	**1.15**	**-0.26**	**-0.13**	**0.20**	**1.03**	**0.62**	**0.14**	**0.50**
Samtskhe-Javakheti	Borjomi	Tmean in 1986-2015, ^{0}C	-0.6	0.2	4.1	9.5	14	17.8	20.9	21.1	16.6	10.9	4.8	0.7	9.2	19.9	10.7	0.1	10.1
		□Tmean, ^{0}C	0.57	0.47	0.84	0.42	0.26	0.90	1.07	1.50	0.98	1.09	0.01	0.17	0.50	1.16	0.70	0.40	0.69
	Bakuriani	Tmean in 1986-2015, ^{0}C	-5.3	-4.7	-1	4.5	9	12.7	15.6	15.9	11.5	6.8	1.1	-3.3	4.2	14.8	6.5	-4.4	5.3
		□Tmean, ^{0}C	0.44	0.34	0.75	0.29	-0.04	0.72	0.89	1.47	0.77	1.15	-0.10	0.15	0.33	1.03	0.62	0.31	0.57

Table A1: Mean air temperatures in 1986–2015 and their change between two 30-year periods (1956–1985 and 1986-2015)

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spr	Sum	Aut	Win	Year
Samtskhe-Javakheti	Akhaltsikhe	Tmean in 1986-2015, ^{0}C	-2.9	-1.4	3.6	9.1	13.6	17.4	20.8	20.8	16.3	10.5	3.9	-1.1	8.8	19.7	10.2	-1.8	9.3
		□Tmean, ^{0}C	0.40	0.16	0.63	0.02	-0.05	0.61	0.78	1.24	0.83	0.95	-0.08	0.14	0.21	0.88	0.57	0.24	0.47
	Tsalka	Tmean in 1986-2015, ^{0}C	-3.9	-3.4	0.4	5.9	10.2	14.3	17	16.7	12.6	7.7	2	-2	5.5	16	7.4	-3.1	6.5
		□Tmean, ^{0}C	0.14	0.33	0.74	0.25	-0.19	0.79	0.66	1.01	0.60	0.69	-0.46	-0.37	0.27	0.82	0.28	0.03	0.35
	Akhalkalaki	Tmean in 1986-2015, ^{0}C	-6	-5.3	-0.9	5.4	9.8	13.2	16.5	16.8	12.8	7.8	1.6	-4	4.8	15.5	7.4	-5.1	5.7
		□Tmean, ^{0}C	0.40	0.16	0.63	0.02	-0.05	0.61	0.78	1.24	0.83	0.95	-0.08	0.14	0.21	0.88	0.57	0.24	0.47
	Paravani	Tmean in 1986-2015, ^{0}C	-7.8	-7.6	-3.7	2.2	7.1	10.9	14.2	13.9	10.3	5.5	-0.3	-5.3	1.8	13	5.2	-6.9	3.3
		□Tmean, ^{0}C	0.27	0.18	0.61	0.30	0.08	0.73	1.02	1.07	0.97	1.00	-0.11	0.01	0.33	0.94	0.62	0.15	0.51
	Average	**□Tmean, ^{0}C**	**0.37**	**0.27**	**0.70**	**0.25**	**-0.01**	**0.71**	**0.87**	**1.25**	**0.83**	**1.00**	**-0.13**	**-0.02**	**0.31**	**0.94**	**0.57**	**0.21**	**0.51**
Shida Kartli	Khashuri	Tmean in 1986-2015, ^{0}C	-0.5	1.1	4.5	10.1	14.5	18.3	21.4	21.6	17.2	11.6	5.3	1	9.7	20.4	11.4	0.5	10.6
		□Tmean, ^{0}C	0.63	1.02	0.62	0.17	-0.05	0.54	0.91	1.38	0.84	1.04	0.04	0.30	0.25	0.95	0.64	0.64	0.62
	Gori	Tmean in 1986-2015, ^{0}C	0.1	1.1	5.5	10.8	15.3	19.3	22.5	22.6	18.2	12.4	5.8	1.5	10.5	21.5	12.1	0.9	11.3
		□Tmean, ^{0}C	0.51	0.36	0.40	-0.11	-0.41	0.34	0.58	1.16	0.61	0.92	-0.13	0.18	-0.04	0.69	0.47	0.35	0.37
	Average	**□Tmean, ^{0}C**	**0.57**	**0.69**	**0.51**	**0.03**	**-0.23**	**0.44**	**0.75**	**1.27**	**0.73**	**0.98**	**-0.05**	**0.24**	**0.11**	**0.82**	**0.56**	**0.50**	**0.50**
Kvemo Kartli	Tbilisi	Tmean in 1986-2015, ^{0}C	2.5	3.4	7.4	12.7	17.4	22	25.1	25	20.3	14.3	7.9	3.8	12.5	24	14.2	3.2	13.5
		□Tmean, ^{0}C	0.51	0.58	0.85	0.18	-0.13	0.88	0.88	1.24	0.74	0.82	-0.20	0.14	0.30	1.00	0.46	0.40	0.54
	Bolnisi	Tmean in 1986-2015, ^{0}C	1.8	2.7	6.9	12.1	16.6	21.3	24.7	24.7	19.9	13.7	7.4	3.2	11.8	23.6	13.7	2.6	13
		□Tmean, ^{0}C	0.49	0.50	0.94	0.05	-0.32	0.83	0.90	1.40	0.88	0.73	-0.22	-0.15	0.22	1.05	0.47	0.27	0.50
	Gardabani	Tmean in 1986-2015, ^{0}C	2	3.2	7.7	13.3	17.9	22.9	26.1	25.9	21	14.6	7.9	3.4	13	25	14.5	2.8	13.9
		□Tmean, ^{0}C	0.61	0.43	0.85	0.23	-0.41	0.94	0.89	1.35	0.86	0.82	-0.10	0.06	0.22	1.06	0.53	0.36	0.54
	Average	**□Tmean, ^{0}C**	**0.54**	**0.50**	**0.88**	**0.15**	**-0.29**	**0.88**	**0.89**	**1.33**	**0.83**	**0.79**	**-0.17**	**0.02**	**0.25**	**1.04**	**0.49**	**0.34**	**0.53**
Mtskheta Mtianeti	Stepantsminda	Tmean in 1986-2015, ^{0}C	-4.4	-4.2	-0.9	4.9	9.2	12.7	15	15.1	11.6	7.2	1.4	-3.1	4.4	14.3	6.7	-3.9	5.4
		□Tmean, ^{0}C	0.33	0.09	0.60	0.28	0.08	0.88	0.79	1.06	0.86	1.22	-0.29	-0.52	0.32	0.91	0.60	-0.04	0.45
	Gudauri	Tmean in 1986-2015, ^{0}C	-6.9	-6.9	-3.9	1.3	5.7	10.1	13	12.9	9.1	4.7	-1.3	-5.3	1	12	4.2	-6.3	2.8
		□Tmean, ^{0}C	0.24	0.10	0.49	0.22	0.04	0.77	0.71	0.91	0.82	1.31	-0.35	-0.40	0.25	0.80	0.60	-0.02	0.41
	Pasanauri	Tmean in 1986-2015, ^{0}C	-2.9	-1.4	2.9	8.6	12.8	16.6	19.4	19.1	15	10	3.8	-1.2	8.1	18.4	9.6	-1.9	8.6
		□Tmean, ^{0}C	0.45	0.49	0.91	0.60	0.31	1.07	1.06	1.10	0.85	1.19	0.01	-0.11	0.60	1.08	0.69	0.27	0.66
	Tianeti	Tmean in 1986-2015, ^{0}C	-2.9	-1.9	2.4	8.3	12.7	16.8	19.6	19.3	15	9.6	3.6	-1.2	7.8	18.6	9.4	-2	8.5
		□Tmean, ^{0}C	0.27	0.52	0.95	0.23	0.05	0.93	1.10	1.53	0.89	0.89	0.09	-0.15	0.41	1.19	0.63	0.20	0.61
	Average	**□Tmean, ^{0}C**	**0.32**	**0.30**	**0.74**	**0.33**	**0.12**	**0.91**	**0.92**	**1.15**	**0.86**	**1.15**	**-0.14**	**-0.30**	**0.40**	**1.00**	**0.63**	**0.10**	**0.53**
Kakheti	Kvareli	Tmean in 1986-2015, ^{0}C	2.2	3.3	7.5	12.7	17.1	21.7	24.4	24.2	19.9	14	7.9	3.2	12.4	23.4	13.9	2.9	13.2
		□Tmean, ^{0}C	0.51	0.53	1.06	0.20	-0.25	0.90	0.69	1.03	0.85	0.95	-0.11	-0.04	0.34	0.87	0.57	0.32	0.53
	Telavi	Tmean in 1986-2015, ^{0}C	1.6	2.6	6.7	12	16.5	21	23.8	23.7	19	13.4	7.3	3.2	11.7	22.8	13.2	2.4	12.6
		□Tmean, ^{0}C	0.40	0.54	1.03	0.13	-0.21	0.89	0.68	1.18	0.78	0.95	-0.25	-0.05	0.32	0.92	0.50	0.29	0.51
	Lagodekhi	Tmean in 1986-2015, ^{0}C	2.1	3.3	7.5	12.8	17.4	22.1	24.9	24.7	20.1	14.3	8	3.6	12.6	23.9	14.1	3	13.5
		□Tmean, ^{0}C	0.37	0.42	0.84	-0.03	-0.36	0.80	0.55	1.07	0.69	0.97	-0.11	-0.20	0.15	0.81	0.52	0.19	0.42
	Gurjaani	Tmean in 1986-2015, ^{0}C	2	3.3	7.5	12.8	17.3	21.9	24.5	24.2	19.7	13.9	7.7	3.3	12.5	23.6	13.8	2.8	13.2
		□Tmean, ^{0}C	0.40	0.51	1.03	0.13	-0.20	0.91	0.62	1.04	0.79	0.93	-0.25	-0.05	0.32	0.85	0.49	0.28	0.49
	Sagarejo	Tmean in 1986-2015, ^{0}C	1.2	1.7	5.5	10.9	15.3	19.9	22.7	22.6	18.1	13.4	6.7	2.8	10.6	21.8	12.7	1.9	11.8
		□Tmean, ^{0}C	0.55	0.60	1.10	0.28	-0.31	0.86	0.62	1.29	0.91	1.36	-0.18	-0.22	0.36	0.92	0.71	0.30	0.57
	Dedoplistskaro	Tmean in 1986-2015, ^{0}C	0.3	0.9	4.8	10.3	15	20.1	22.9	23	18.2	12.1	6	1.9	10.1	22	12.1	1	11.3
		□Tmean, ^{0}C	0.58	0.61	1.10	0.25	-0.19	1.31	0.93	1.60	1.22	1.22	0.00	0.11	0.39	1.28	0.82	0.43	0.73
	Average	**□Tmean, ^{0}C**	**0.47**	**0.54**	**1.03**	**0.16**	**-0.25**	**0.95**	**0.68**	**1.20**	**0.87**	**1.06**	**-0.15**	**-0.08**	**0.31**	**0.94**	**0.60**	**0.30**	**0.54**

Table A 2: Precipitations during 1986–2015 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Adjara	Kobuleti	Precipitation in 1986-2015; mm	226	173	162	93	83	170	176	235	302	310	260	261	338	582	872	660	2452
		□Pr (1986-2015;1956-1985), mm	32	-10	4	-18	2	11	-1	1	7	47	2	24	-12	11	56	46	101
		□Pr (1986-2015;1956-1985), %	16	-5	3	-16	2	7	-1	0	2	18	1	10	-3	2	7	7	4
	Batumi	Precipitation in 1986-2015; mm	241	183	151	94	90	146	160	216	335	322	303	283	335	522	960	707	2523
		□Pr (1986-2015;1956-1985), mm	5	-22	-17	-13	0	-9	-12	11	24	8	12	-3	-30	-10	44	-20	-16
		□Pr (1986-2015;1956-1985), %	2	-11	-10	-12	0	-6	-7	5	8	3	4	-1	-8	-2	5	-3	-1
	Khulo	Precipitation in 1986-2015; mm	182	5	112	4	96	11	77	16	110	14	188	10	296	16	470	17	1589
		□Pr (1986-2015;1956-1985), mm	54	6	13	3	12	10	15	10	21	21	28	24	28	35	70	84	217
		□Pr (1986-2015;1956-1985), %	42	5	13	4	14	11	24	16	24	14	18	10	10	16	18	17	16
Guria	Chokhatauri	Precipitation in 1986-2015; mm	167	133	123	81	83	114	98	113	176	210	179	179	286	325	565	479	1655
		□Pr (1986-2015;1956-1985), mm	-18	-35	-14	-16	6	-9	-10	-16	-2	-11	-27	-52	-24	-35	-40	-105	-204
		□Pr (1986-2015;1956-1985), %	-10	-21	-10	-16	8	-7	-9	-12	-1	-5	-13	-23	-8	-10	-7	-18	-11
Samegrelo - Zemo Svaneti	Zugdidi	Precipitation in 1986-2015; mm	153	134	168	128	142	215	154	147	153	182	162	149	438	517	497	436	1888
		□Pr (1986-2015;1956-1985), mm	25	-4	16	-5	34	29	-29	-31	1	26	22	-11	45	-31	49	10	73
		□Pr (1986-2015;1956-1985), %	20	-3	11	-4	31	16	-16	-17	1	17	16	-7	11	-6	11	2	4
	Poti	Precipitation in 1986-2015; mm	162	122	121	85	86	167	211	261	265	237	179	162	292	639	681	446	2058
		□Pr (1986-2015;1956-1985), mm	29	0	9	0	30	26	7	27	16	51	12	5	39	60	79	34	212
		□Pr (1986-2015;1956-1985), %	22	0	8	0	54	18	3	12	6	27	7	3	15	10	13	8	11
Imereti	Sachkhere	Precipitation in 1986-2015; mm	83	68	76	80	86	96	72	69	84	53	35	24	242	237	171	175	826
		□Pr (1986-2015;1956-1985), mm	18	0	10	2	2	8	-5	-2	5	6	2	2	14	1	13	20	48
		□Pr (1986-2015;1956-1985), %	28	0	15	3	2	9	-6	-3	6	13	6	9	6	0	8	13	6
	Kutaisi	Precipitation in 1986-2015; mm	157	118	130	89	88	110	83	88	117	146	143	150	306	281	407	425	1420
		□Pr (1986-2015;1956-1985), mm	27	-7	13	-9	12	9	-3	-11	5	13	2	-10	16	-5	20	10	41
		□Pr (1986-2015;1956-1985), %	21	-6	11	-9	16	9	-3	-11	4	10	1	-6	6	-2	5	2	3
	Mta Sabueti	Precipitation in 1986-2015; mm	160	128	114	80	92	86	58	57	71	90	131	132	286	201	292	420	1199
		□Pr (1986-2015;1956-1985), mm	46	6	4	-17	-2	-25	-19	-12	-9	-26	10	-9	-15	-56	-25	43	-53
		□Pr (1986-2015;1956-1985), %	40	5	4	-18	-2	-23	-25	-17	-11	-22	8	-6	-5	-22	-8	11	-4
	Zestaponi	Precipitation in 1986-2015; mm	154	119	119	92	78	98	61	62	81	129	145	138	290	220	356	412	1277
		□Pr (1986-2015;1956-1985), mm	27	-10	10	0	8	3	-14	-5	-5	10	17	-28	18	-16	22	-11	13
		□Pr (1986-2015;1956-1985), %	21	-8	9	0	11	3	-19	-7	-6	8	13	-17	7	-7	7	-3	1
Racha - Lechkhumi and Kvemo Svaneti	Shovi	Precipitation in 1986-2015; mm	88	68	95	107	116	128	111	96	93	123	89	74	318	336	305	230	1189
		□Pr (1986-2015;1956-1985), mm	13	-6	3	-5	-2	3	1	-15	-10	27	12	-5	-4	-11	29	2	16
		□Pr (1986-2015;1956-1985), %	17	-8	3	-4	-2	2	1	-14	-10	28	16	-6	-1	-3	11	1	1
	Ambrolauri	Precipitation in 1986-2015; mm	96	66	78	83	99	95	78	78	90	117	100	100	260	251	306	262	1079
		□Pr (1986-2015;1956-1985), mm	20	-9	6	-2	12	-3	0	4	6	13	9	-4	16	1	28	7	52
		□Pr (1986-2015;1956-1985), %	26	-12	8	-2	14	-3	0	5	7	13	10	-4	7	0	10	3	5
Samtskhe - Javakheti	Borjomi	Precipitation in 1986-2015; mm	41	39	46	59	88	73	50	39	48	61	62	39	192	162	171	119	644
		□Pr (1986-2015;1956-1985), mm	5	-2	0	-3	9	-14	-3	-12	-5	0	9	-11	6	-29	4	-8	-27
		□Pr (1986-2015;1956-1985), %	14	-5	0	-5	11	-16	-6	-24	-9	0	17	-22	3	-15	2	-6	-4
	Akhaltsikhe	Precipitation in 1986-2015; mm	25	27	34	50	69	79	62	50	35	44	33	26	153	191	112	77	533
		□Pr (1986-2015;1956-1985), mm	5	1	-2	0	-6	3	10	-2	-1	7	-3	-5	-8	11	3	1	7
		□Pr (1986-2015;1956-1985), %	25	4	-6	0	-8	4	19	-4	-3	19	-8	-16	-5	6	3	1	1

	Tsalka	Precipitation in 1986-2015; mm	20	28	37	76	108	123	56	59	44	53	35	24	222	237	131	72	662
		□Pr (1986-2015;1956-1985), mm	-4	0	-3	6	-17	14	-18	-13	-18	6	2	2	-14	-17	-10	-2	-43
		□Pr (1986-2015;1956-1985), %	-17	0	-8	9	-14	13	-24	-18	-29	13	6	9	-6	-7	-7	-3	-6
	Akhalkalaki	Precipitation in 1986-2015; mm	31	33	38	54	84	85	59	47	36	45	36	30	176	190	116	93	575
		□Pr (1986-2015;1956-1985), mm	9	8	7	3	3	-1	1	-8	1	8	4	5	13	-8	13	22	40
		□Pr (1986-2015;1956-1985), %	41	32	23	6	4	-1	2	-15	3	22	13	20	8	-4	13	31	7
Shida Kartli	Khashuri	Precipitation in 1986-2015; mm	60	46	42	50	63	66	41	36	40	54	68	51	155	143	163	158	618
		□Pr (1986-2015;1956-1985), mm	14	-5	4	-2	1	-3	-6	-4	1	-7	6	-15	3	-13	0	-6	-16
		□Pr (1986-2015;1956-1985), %	30	-10	11	-4	2	-4	-13	-10	3	-11	10	-23	2	-8	0	-4	-3
	Gori	Precipitation in 1986-2015; mm	35	32	34	53	61	62	41	38	32	43	49	33	148	141	125	100	514
		□Pr (1986-2015;1956-1985), mm	9	1	-2	2	2	4	-4	-1	-7	-2	5	-5	2	-1	-4	5	2
		□Pr (1986-2015;1956-1985), %	35	3	-6	4	3	7	-9	-3	-18	-4	11	-13	1	-1	-3	5	0
Kvemo Kartli	Tbilisi	Precipitation in 1986-2015; mm	18	22	30	63	82	80	39	40	32	48	35	21	175	159	115	61	510
		□Pr (1986-2015;1956-1985), mm	-1	-2	-2	12	1	7	-10	-7	-11	11	9	2	11	-10	9	-1	9
		□Pr (1986-2015;1956-1985), %	-5	-8	-6	24	1	10	-20	-15	-26	30	35	11	7	-6	8	-2	2
	Bolnisi	Precipitation in 1986-2015; mm	19	28	41	69	74	64	31	34	38	52	36	21	183	129	127	67	507
		□Pr (1986-2015;1956-1985), mm	-4	-1	-3	12	-8	-11	-17	-5	-5	17	7	3	1	-33	19	-2	-15
		□Pr (1986-2015;1956-1985), %	-17	-3	-7	21	-10	-15	-35	-13	-12	49	24	17	1	-20	18	-3	-3
Mtskheta-Mtianeti	Pasanauri	Precipitation in 1986-2015; mm	50	51	69	102	139	128	95	99	68	85	64	57	310	322	216	158	1005
		□Pr (1986-2015;1956-1985), mm	4	-3	-2	-5	6	5	-14	20	-16	26	11	9	-1	11	21	10	41
		□Pr (1986-2015;1956-1985), %	9	-6	-3	-5	5	4	-13	25	-19	44	21	19	-0.3	4	11	7	4
	Tianeti	Precipitation in 1986-2015; mm	30	37	43	78	93	94	58	66	51	63	45	34	215	218	159	101	694
		□Pr (1986-2015;1956-1985), mm	0	-4	-12	-12	-41	-25	-28	-17	-23	9	1	3	-65	-70	-13	-1	-149
		□Pr (1986-2015;1956-1985), %	0	-10	-22	-13	-31	-21	-33	-20	-31	17	2	10	-23	-24	-8	-1	-18
Kakheti	Telavi	Precipitation in 1986-2015; mm	27	35	50	88	123	99	62	69	66	67	47	31	261	230	180	93	765
		□Pr (1986-2015;1956-1985), mm	1	0	0	9	12	-24	-16	-4	-2	14	7	2	21	-44	19	3	-1
		□Pr (1986-2015;1956-1985), %	4	0	0	11	11	-20	-21	-5	-3	26	18	7	9	-16	12	3	-0.1
	Lagodekhi	Precipitation in 1986-2015; mm	47	59	85	115	135	125	105	113	110	113	80	47	334	343	303	154	1134
		□Pr (1986-2015;1956-1985), mm	9	11	7	14	8	2	8	26	4	19	17	9	29	36	40	29	134
		□Pr (1986-2015;1956-1985), %	24	23	9	14	6	2	8	30	4	20	27	24	10	12	15	23	13
	Sagarejo	Precipitation in 1986-2015; mm	27	38	57	95	104	87	56	52	60	82	49	32	256	196	191	97	741
		□Pr (1986-2015;1956-1985), mm	-5	-3	-6	5	-6	-21	-25	-16	-10	20	6	4	-7	-62	16	-4	-57
		□Pr (1986-2015;1956-1985), %	-16	-7	-10	6	-5	-19	-31	-24	-14	32	14	14	-3	-24	9	-4	-7
	Dedoplistskaro	Precipitation in 1986-2015; mm	29	31	46	66	95	75	50	39	55	57	40	21	208	163	153	81	604
		□Pr (1986-2015;1956-1985), mm	6	2	1	3	9	-30	-4	-6	9	7	10	-2	13	-40	26	6	5
		□Pr (1986-2015;1956-1985), %	26	7	2	5	10	-29	-7	-13	20	14	33	-9	7	-20	20	8	1

Table A 3: Relative humiditytes during 1956–1985 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Adjara	Kobuleti	RH in 1986-2015; %	83	81	81	83	84	83	84	84	84	85	83	83	83	84	84	82	83
		□RH value (1986-2015;1956-1985)	1	1	-1	1	0	1	0	0	-1	0	0	1	0	0	0	1	0
		□RH percent (1986-2015;1956-1985)	1	1	-1	1	0	1	0	0	-1	1	0	1	0	0	0	1	0
	Khulo	RH in 1986-2015; %	73	71	68	65	68	74	79	78	74	73	69	71	68	79	74	71	79
		□RH value (1986-2015;1956-1985)	4	3	-1	0	1	1	1	1	-2	3	2	2	0	1	1	3	1
		□RH percent (1986-2015;1956-1985)	6	4	-2	0	1	2	1	1	-3	5	3	3	0	1	1	4	2
Guria	Chokhatauri	RH in 1986-2015; %	77	75	73	70	73	75	80	81	79	78	76	77	72	79	77	76	76
		□RH value (1986-2015;1956-1985)	7	6	2	0	0	0	-1	0	-1	3	4	7	1	0	2	7	2
		□RH percent (1986-2015;1956-1985)	10	8	3	0	-1	0	-1	0	-1	4	5	10	1	0	2	9	3
	Bakhmaro	RH in 1986-2015; %	77	76	74	70	72	77	80	77	75	72	72	75	72	78	73	76	75
		□RH value (1986-2015;1956-1985)	6	5	2	3	2	1	0	-1	0	1	1	4	2	0	1	5	2
		□RH percent (1986-2015;1956-1985)	9	7	3	4	3	2	0	-2	-1	2	1	5	3	0	1	7	3
Samegrelo-Zemo Svaneti	Zugdidi	RH in 1986-2015; %	79	75	74	74	78	81	83	82	81	80	79	77	75	82	80	77	79
		□RH value (1986-2015;1956-1985)	4	2	2	2	2	2	0	-1	-1	0	3	3	2	0	1	3	1
		□RH percent (1986-2015;1956-1985)	6	3	3	2	3	2	0	-1	-2	0	4	4	2	0	1	4	2
	Poti	RH in 1986-2015; %	80	78	79	81	85	86	88	87	86	84	81	79	82	87	84	79	83
		□RH value (1986-2015;1956-1985)	7	6	4	4	3	4	4	3	2	4	5	6	4	4	4	6	4
		□RH percent (1986-2015;1956-1985)	10	8	6	5	4	5	4	4	3	5	7	9	5	4	5	9	6
Imereti	Sachkhere	RH in 1986-2015; %	81	78	72	68	69	72	72	70	72	77	79	82	70	71	76	80	74
		□RH value (1986-2015;1956-1985)	-1	-1	-2	-2	-1	0	-3	-4	-4	-2	-2	-2	-2	-2	-3	-2	-2
		□RH percent (1986-2015;1956-1985)	-2	-1	-3	-3	-2	0	-4	-6	-5	-2	-2	-3	-3	-3	-3	-2	-3
	Kutaisi	RH in 1986-2015; %	72	70	70	70	71	74	75	74	73	71	71	71	70	74	71	71	72
		□RH value (1986-2015;1956-1985)	3	2	2	1	1	0	-4	-5	-4	-2	1	2	1	-3	-2	2	0
		□RH percent (1986-2015;1956-1985)	5	3	2	1	1	-1	-5	-6	-5	-3	1	2	2	-4	-3	3	-1
	Mta Sabueti	RH in 1986-2015; %	88	89	86	81	84	86	86	84	85	87	87	88	86	86	87	88	89
		□RH value (1986-2015;1956-1985)	2	2	1	2	3	3	0	0	-1	3	2	3	2	1	1	2	2
		□RH percent (1986-2015;1956-1985)	2	3	1	2	4	3	0	0	-1	3	3	4	2	1	2	3	2
	Samtredia	RH in 1986-2015; %	75	73	70	70	73	77	78	79	78	77	75	76	71	78	77	75	75
		□RH value (1986-2015;1956-1985)	3	2	0	0	1	3	-1	0	-1	1	3	4	0	0	1	3	1
		□RH percent (1986-2015;1956-1985)	5	3	1	-1	2	3	-1	0	-2	1	4	5	1	1	1	4	2
Racha Lechkhumi – Kvemo Svaneti	Lentekhi	RH in 1986-2015; %	92	88	83	77	76	78	77	78	83	87	91	93	79	78	87	91	84
		□RH value (1986-2015;1956-1985)	5	5	5	4	3	4	2	2	2	4	5	3	4	3	4	4	4
		□RH percent (1986-2015;1956-1985)	5	6	6	6	3	5	2	3	3	5	6	4	5	3	5	5	5
	Ambrolauri	RH in 1986-2015; %	83	76	70	69	72	73	72	71	73	77	80	83	70	72	77	81	75
		□RH value (1986-2015;1956-1985)	3	0	-1	-1	-1	-1	-4	-3	-3	-1	0	1	-1	-3	-1	1	-1
		□RH percent (1986-2015;1956-1985)	3	0	-1	-1	-1	-1	-5	-4	-4	-2	0	1	-1	-3	-2	1	-1
Samtskhe-Javakheti	Paravani	RH in 1986-2015; %	76	76	76	74	74	75	76	74	73	73	73	75	75	75	73	76	75
		□RH value (1986-2015;1956-1985)	1	0	1	0	0	0	0	0	0	2	0	1	0	0	1	1	0
		□RH percent (1986-2015;1956-1985)	2	0	1	0	1	0	0	0	0	3	0	1	1	0	1	1	1

Table A3: Relative humidityes during 1956–1985 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Samtskhe-Javakheti	Akhaltsikhe	RH in 1986-2015; %	82	79	73	72	73	74	71	69	72	77	81	83	73	71	77	81	75
		ΔRH value (1986-2015;1956-1985)	6	5	4	6	5	5	4	3	3	6	4	4	5	4	5	5	5
		ΔRH percent (1986-2015;1956-1985)	7	7	6	10	7	7	5	5	4	9	5	5	7	6	6	6	6
	Tsalka	RH in 1986-2015; %	74	73	74	74	76	76	76	76	77	80	77	75	75	76	78	74	76
		ΔRH value (1986-2015;1956-1985)	-1	-3	-4	-3	-3	-3	-2	-2	-3	1	-1	0	-4	-2	-1	-1	-2
		ΔRH percent (1986-2015;1956-1985)	-2	-4	-6	-4	-4	-4	-2	-3	-4	1	-1	0	-5	-3	-1	-2	-3
	Akhalkalaki	RH in 1986-2015; %	84	84	81	76	77	78	78	76	75	79	81	85	78	77	78	84	79
		ΔRH value (1986-2015;1956-1985)	9	9	6	7	8	6	6	7	7	9	8	10	7	6	8	9	8
		ΔRH percent (1986-2015;1956-1985)	12	12	9	11	12	8	9	10	10	13	10	13	10	9	11	12	11
Shida Qartli	Khashuri	RH in 1986-2015; %	84	82	76	71	74	75	74	73	75	80	83	85	74	74	79	83	77
		ΔRH value (1986-2015;1956-1985)	3	2	0	1	1	1	0	1	0	1	1	2	1	1	1	2	1
		ΔRH percent (1986-2015;1956-1985)	3	2	0	1	2	2	0	1	0	2	1	2	1	1	1	3	1
	Gori	RH in 1986-2015; %	81	77	71	70	72	71	68	68	71	77	82	83	71	69	77	80	74
		ΔRH value (1986-2015;1956-1985)	0	-1	-1	3	3	3	1	1	0	2	1	1	2	2	1	0	1
		ΔRH percent (1986-2015;1956-1985)	1	-1	-1	4	4	4	1	2	0	2	1	1	3	2	1	0	2
Kvemo Qartli	Tbilisi	RH in 1986-2015; %	75	73	68	68	69	65	63	64	68	76	78	77	68	64	74	75	70
		ΔRH value (1986-2015;1956-1985)	1	2	1	6	6	3	4	4	3	5	4	2	4	4	4	2	3
		ΔRH percent (1986-2015;1956-1985)	2	3	2	9	9	5	6	7	5	7	5	3	6	6	6	3	5
	Bolnisi	RH in 1986-2015; %	71	71	68	70	70	66	60	58	64	73	75	73	69	61	70	72	68
		ΔRH value (1986-2015;1956-1985)	-2	-1	-2	2	2	1	-1	-3	-3	1	0	-2	1	-1	-1	-2	-1
		ΔRH percent (1986-2015;1956-1985)	-3	-1	-3	3	3	2	-2	-5	-5	1	-1	-2	1	-2	-1	-2	-1
Mtskheta-Mtoaneti	Pasanauri	RH in 1986-2015; %	79	76	73	72	75	75	75	75	76	78	77	79	73	75	77	78	76
		ΔRH value (1986-2015;1956-1985)	4	3	1	2	0	0	0	1	-1	2	1	2	1	0	1	3	1
		ΔRH percent (1986-2015;1956-1985)	6	4	2	3	0	0	0	1	-1	2	1	3	2	0	1	4	2
	Tianeti	RH in 1986-2015; %	85	84	82	79	80	78	77	77	80	83	84	86	80	77	82	85	81
		ΔRH value (1986-2015;1956-1985)	3	3	3	4	3	2	2	2	0	2	3	4	3	2	2	3	3
		ΔRH percent (1986-2015;1956-1985)	3	3	4	6	4	3	3	3	0	3	4	4	4	3	2	4	3
Kakheti	Kvareli	RH in 1986-2015; %	83	81	78	76	77	72	70	72	76	82	84	85	77	71	80	83	78
		ΔRH value (1986-2015;1956-1985)	5	6	4	5	7	4	4	5	3	4	5	5	5	5	4	5	5
		ΔRH percent (1986-2015;1956-1985)	7	7	6	7	10	6	6	8	5	5	6	6	7	7	5	7	7
	Telavi	RH in 1986-2015; %	74	72	67	68	69	66	64	64	69	77	76	75	68	65	74	74	70
		ΔRH value (1986-2015;1956-1985)	1	0	-4	-1	0	-2	-1	0	-1	2	3	1	-2	-1	1	1	0
		ΔRH percent (1986-2015;1956-1985)	1	0	-6	-1	1	-3	-1	0	-2	3	4	2	-2	-1	2	1	0
	Gurjaani	RH in 1986-2015; %	78	73	70	71	73	68	67	67	72	80	81	79	71	67	78	77	73
		ΔRH value (1986-2015;1956-1985)	-1	-3	-5	-2	1	-2	-1	-1	-2	1	0	-2	-2	-1	0	-2	-1
		ΔRH percent (1986-2015;1956-1985)	-1	-4	-7	-3	2	-3	-2	-2	-3	1	1	-2	-3	-2	0	-2	-2
	Sagarejo	RH in 1986-2015; %	68	66	65	65	66	62	61	61	66	72	70	69	65	61	69	68	66
		ΔRH value (1986-2015;1956-1985)	-2	-4	-6	-3	-2	-4	-3	-2	-4	-1	-2	-1	-3	-3	-2	-2	-3
		ΔRH percent (1986-2015;1956-1985)	-3	-6	-8	-4	-3	-6	-4	-4	-5	-2	-3	-2	-5	-5	-3	-3	-4
	Dedoplistskaro	RH in 1986-2015; %	83	82	80	80	81	75	72	71	77	84	85	84	80	72	82	83	79
		ΔRH value (1986-2015;1956-1985)	3	3	1	5	6	3	3	3	2	3	5	4	4	3	3	4	3
		ΔRH percent (1986-2015;1956-1985)	4	4	1	7	8	4	4	4	2	4	6	5	5	4	4	5	4

Table A 4: Wind speeds during 1986–2015 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Adjara	Kobuleti	Wind in 1986-2015; m/sec	3.3	3.6	3.5	3.0	3.0	2.9	2.6	2.4	2.5	2.6	3.0	2.9	3.3	3.2	2.7	2.7	2.9
		ΔWind, m/sec	0.3	0.0	0.2	-0.1	0.0	-0.1	-0.5	-0.5	-0.2	-0.3	0.2	-0.1	0.1	0.0	-0.3	0.0	-0.1
		ΔWind, %	9	1	5	-3	0	-4	-16	-18	-7	-9	6	-3	2	1	-10	-1	-3
	Batumi	Wind in 1986-2015; m/sec	5.8	4.8	4.2	3.7	3.2	3.4	3.4	3.6	4.0	4.3	5.1	5.7	5.5	3.7	3.5	4.5	4.3
		ΔWind, m/sec	-0.5	-1.0	-0.4	-0.3	0.1	0.1	0.3	0.3	0.5	-0.2	-0.4	-1.1	-0.8	-0.2	0.2	-0.1	-0.2
		ΔWind, %	-8	-18	-8	-7	2	3	10	8	15	-5	-8	-16	-12	-4	7	-1	-5
	Khulo	Wind in 1986-2015; m/sec	1.8	1.8	1.8	1.7	1.4	1.2	1.1	1.1	1.2	1.3	1.6	1.7	1.8	1.7	1.2	1.4	1.5
		ΔWind, m/sec	-0.9	-0.9	-0.8	-0.8	-0.8	-0.9	-0.8	-0.8	-0.7	-0.8	-0.6	-0.9	-0.9	-0.8	-0.8	-0.8	-0.8
		ΔWind, %	-32	-34	-29	-31	-36	-42	-41	-43	-38	-39	-29	-35	-33	-31	-42	-36	-35
	Goderdzi Pass	Wind in 1986-2015; m/sec	6.0	5.4	4.8	3.9	4.4	4.2	3.9	3.9	4.1	4.3	4.6	5.1	5.5	4.3	3.9	4.3	4.5
		ΔWind, m/sec	-0.7	-1.1	-0.8	-0.8	-0.1	-0.3	-0.1	-0.5	-0.3	-0.4	-0.2	-1.1	-1.1	-0.6	-0.3	-0.5	-0.5
		ΔWind, %	-10	-17	-14	-17	-3	-6	-3	-10	-7	-9	-5	-17	-16	-13	-8	-10	-10
Guria	Chokhatauri	Wind in 1986-2015; m/sec	2.0	2.3	2.4	2.2	1.8	1.5	1.2	1.2	1.4	1.8	2.1	2.1	2.1	2.1	1.3	1.7	1.8
		ΔWind, m/sec	-0.3	-0.4	-0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.0	0.2	-0.2	-0.3	0.0	0.2	0.0	0.0
		ΔWind, %	-15	-15	-6	6	16	25	23	12	19	-3	9	-8	-11	-1	16	0	1
	bakhmaro	Wind in 1986-2015; m/sec	3.2	2.5	3.0	2.1	2.1	1.6	1.1	1.1	1.1	1.8	2.2	2.3	2.7	2.4	1.2	1.7	2.0
		ΔWind, m/sec	0.9	-0.1	0.7	0.2	0.6	0.4	0.1	0.2	0.1	0.4	0.3	0.1	0.4	0.5	0.2	0.2	0.3
		ΔWind, %	39	-4	32	12	37	32	8	17	5	26	17	5	16	24	17	17	19
Samegrelo - Zemo Svaneti	Zugdidi	Wind in 1986-2015; m/sec	0.9	1.2	1.3	1.2	1.1	1.0	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.2	0.9	0.9	1.0
		ΔWind, m/sec	-0.5	-0.6	-0.5	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.0	-0.2	-0.3	-0.5	-0.5	-0.2	0.0	-0.3
		ΔWind, %	-33	-34	-29	-27	-27	-22	-15	-8	4	0	-17	-25	-33	-28	-17	-5	-22
	Poti	Wind in 1986-2015; m/sec	2.1	2.5	2.2	2.0	1.5	1.4	1.1	1.1	1.4	1.7	2.1	2.2	2.2	1.9	1.2	1.7	1.8
		ΔWind, m/sec	-1.8	-1.9	-1.8	-1.7	-1.5	-1.4	-1.5	-1.4	-1.1	-1.3	-1.3	-1.6	-1.8	-1.7	-1.4	-1.2	-1.5
		ΔWind, %	-46	-44	-46	-46	-51	-51	-58	-56	-43	-43	-37	-43	-45	-47	-54	-41	-46
Imereti	Sachkhere	Wind in 1986-2015; m/sec	0.6	0.8	1.5	1.7	1.7	1.5	1.6	1.6	1.2	1.0	0.6	0.5	0.6	1.6	1.6	1.0	1.2
		ΔWind, m/sec	-0.3	-0.4	-0.5	-0.6	-0.5	-0.5	-0.3	-0.2	-0.3	-0.1	-0.2	-0.2	-0.3	-0.6	-0.3	-0.2	-0.3
		ΔWind, %	-31	-34	-24	-27	-22	-25	-15	-9	-17	-9	-23	-33	-33	-26	-17	-18	-22
	Kutaisi	Wind in 1986-2015; m/sec	5.1	5.6	5.6	5.2	4.5	3.8	3.4	3.5	4.2	5.1	5.2	5.3	5.3	5.2	3.6	4.8	4.7
		ΔWind, m/sec	-1.8	-1.8	-1.4	-0.9	-1.1	-0.6	-0.3	-0.4	-0.4	-0.5	-1.3	-1.2	-1.7	-1.1	-0.4	-0.8	-1.0
		ΔWind, %	-26	-25	-19	-15	-19	-13	-9	-10	-10	-9	-20	-19	-24	-18	-10	-15	-17
	Mta Sabueti	Wind in 1986-2015; m/sec	5.1	5.7	5.8	5.7	5.4	4.7	4.9	5.1	5.3	5.7	5.2	4.9	5.2	5.6	4.9	5.3	5.3
		ΔWind, m/sec	-1.9	-1.7	-1.6	-2.1	-2.0	-1.6	-1.3	-2.2	-2.2	-1.8	-1.8	-1.1	-1.6	-2.1	-1.8	-2.1	-1.8
		ΔWind, %	-27	-23	-22	-27	-27	-25	-21	-30	-29	-24	-25	-18	-23	-28	-28	-29	-25
	Zestaponi	Wind in 1986-2015; m/sec	0.4	0.6	0.8	0.8	0.9	0.6	0.6	0.7	0.7	0.7	0.6	0.4	0.5	0.8	0.6	0.7	0.6
		ΔWind, m/sec	-1.3	-1.5	-1.6	-1.6	-1.4	-1.1	-1.0	-1.1	-1.0	-0.7	-1.0	-1.0	-1.3	-1.6	-1.1	-0.9	-1.2
		ΔWind, %	-77	-73	-67	-66	-61	-64	-65	-62	-58	-49	-64	-72	-74	-65	-63	-58	-65

Table A4: Wind speeds during 1986–2015 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Imereti	Samtredia	Wind in 1986-2015; m/sec	1.4	1.5	1.9	1.8	1.9	1.4	1.3	1.2	1.4	1.6	1.5	1.3	1.4	1.9	1.3	1.5	1.5
		ΔWind, m/sec	-1.9	-2.3	-1.8	-1.4	-1.0	-0.9	-0.6	-0.6	-0.7	-0.9	-1.4	-1.7	-2.0	-1.5	-0.7	-1.1	-1.3
		ΔWind, %	-58	-60	-50	-45	-35	-39	-31	-35	-33	-37	-49	-56	-59	-44	-35	-42	-46
Racha - Lechkhumi and Kvemo Svaneti	Shovi	Wind in 1986-2015; m/sec	1.5	1.6	2.1	2.0	1.9	1.7	1.8	1.8	1.8	1.8	1.5	1.6	1.6	1.9	1.7	1.6	1.8
		ΔWind, m/sec	0.4	0.3	0.1	0.7	0.6	0.5	0.6	0.7	0.6	0.6	0.4	0.5	0.5	0.4	0.6	0.5	0.5
		ΔWind, %	39	20	3	49	45	40	53	70	53	51	41	49	39	23	53	43	40
	Ambrolauri	Wind in 1986-2015; m/sec	0.7	1.1	1.6	1.6	1.5	1.4	1.4	1.5	1.3	1.1	0.8	0.7	0.8	1.6	1.5	1.1	1.2
		ΔWind, m/sec	-1.0	-1.0	-1.2	-1.3	-1.1	-0.9	-0.9	-0.8	-1.3	-0.7	-0.9	-0.8	-0.9	-1.1	-0.8	-1.0	-1.0
		ΔWind, %	-59	-46	-42	-45	-41	-39	-39	-33	-49	-41	-53	-54	-53	-42	-37	-48	-44
	Lentekhi	Wind in 1986-2015; m/sec	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1
		ΔWind, m/sec	-0.2	-0.3	-0.4	-0.5	-0.5	-0.6	-0.7	-0.5	-0.5	-0.3	-0.3	-0.2	-0.2	-0.5	-0.6	-0.4	-0.4
		ΔWind, %	-93	-94	-94	-88	-87	-88	-88	-86	-86	-84	-89	-88	-91	-88	-86	-85	-88
Samtskhe - Javakheti	Borjomi	Wind in 1986-2015; m/sec	0.6	0.8	0.8	0.8	0.9	0.9	0.9	0.8	0.7	0.5	0.4	0.4	0.6	0.9	1.0	0.6	0.7
		ΔWind, m/sec	-0.2	-0.1	-0.1	0.0	-0.1	0.0	-0.1	-0.2	-0.1	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	-0.1
		ΔWind, %	-21	-13	-9	-4	-11	-5	-12	-19	-12	-9	-9	-29	-12	5	1	2	-12
	Akhaltsikhe	Wind in 1986-2015; m/sec	0.4	0.5	0.8	0.7	0.7	0.7	0.7	0.7	0.5	0.4	0.4	0.3	0.4	0.8	0.7	0.4	0.6
		ΔWind, m/sec	-0.8	-0.9	-0.8	-1.0	-0.9	-0.7	-0.9	-0.8	-0.8	-0.7	-0.6	-0.7	-0.8	-0.9	-0.8	-0.7	-0.8
		ΔWind, %	-67	-64	-50	-58	-56	-52	-55	-55	-59	-65	-59	-66	-64	-54	-53	-60	-58
	Bakuriani	Wind in 1986-2015; m/sec	0.6	0.6	1.0	1.1	1.2	0.8	1.0	0.9	0.7	0.8	0.6	0.7	0.6	1.0	0.9	0.6	0.8
		ΔWind, m/sec	-1.0	-1.0	-0.7	-1.1	-0.9	-0.8	-1.0	-1.3	-0.8	-0.2	-0.5	-0.6	-0.9	-1.0	-1.1	-0.6	-0.8
		ΔWind, %	-65	-62	-39	-51	-42	-49	-51	-60	-56	-18	-49	-48	-62	-49	-54	-48	-50
	Akhalkalaki	Wind in 1986-2015; m/sec	2.1	2.3	2.4	2.4	2.2	2.0	1.8	1.7	1.6	1.7	2.0	2.1	2.2	2.3	1.8	1.8	2.0
		ΔWind, m/sec	-0.9	-1.1	-0.9	-0.9	-0.8	-0.5	-0.6	-0.7	-0.5	-0.3	-0.4	-0.8	-0.9	-0.9	-0.6	-0.4	-0.7
		ΔWind, %	-30	-33	-26	-28	-27	-19	-27	-29	-24	-16	-18	-28	-29	-28	-25	-19	-26
	Paravani	Wind in 1986-2015; m/sec	4.2	4.0	3.7	3.6	3.7	3.4	3.6	3.4	3.2	3.4	3.7	4.3	4.2	3.7	3.6	3.5	3.7
		ΔWind, m/sec	-0.6	-0.7	-0.6	-0.2	0.1	0.0	-0.2	-0.4	-0.1	0.0	-0.4	-0.5	-0.5	-0.2	-0.1	0.0	-0.3
		ΔWind, %	-12	-15	-13	-5	2	0	-4	-11	-2	0	-10	-10	-11	-4	-2	-1	-7
Shida Kartli	Khashuri	Wind in 1986-2015; m/sec	1.2	1.3	1.6	1.8	1.7	1.4	1.5	1.4	1.2	1.2	1.0	1.1	1.2	1.6	1.4	1.1	1.4
		ΔWind, m/sec	-0.8	-1.0	-1.2	-1.5	-1.0	-1.3	-1.5	-1.5	-1.4	-0.8	-0.8	-0.4	-0.7	-1.4	-1.5	-1.1	-1.1
		ΔWind, %	-42	-45	-44	-45	-38	-49	-51	-51	-53	-41	-46	-24	-39	-46	-51	-49	-45
	Gori	Wind in 1986-2015; m/sec	1.3	1.5	1.8	1.7	1.6	1.5	1.6	1.6	1.6	1.3	1.1	1.1	1.3	1.7	1.6	1.3	1.5
		ΔWind, m/sec	-1.3	-1.7	-2.3	-2.2	-2.0	-2.0	-2.0	-1.9	-1.6	-1.4	-1.2	-1.0	-1.3	-2.3	-2.0	-1.5	-1.7
		ΔWind, %	-50	-53	-56	-56	-57	-57	-54	-54	-51	-51	-53	-49	-51	-57	-56	-53	-54
Kvemo Kartli	Tbilisi	Wind in 1986-2015; m/sec	1.3	1.6	2.0	1.8	1.8	2.0	1.8	1.8	1.7	1.3	1.2	1.2	1.4	1.8	1.8	1.4	1.6
		ΔWind, m/sec	-0.1	-0.1	-0.3	-0.4	0.0	0.0	-0.1	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.3	-0.1	-0.1	-0.1
		ΔWind, %	-10	-3	-14	-17	-2	-1	-5	-2	1	-9	-11	-9	-5	-14	-6	-8	-7

Table A4: Wind speeds during 1986–2015 years and their change between two 30-year periods (1956–1985 and 1986–2015)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Kvemo Kartli	Bolnisi	Wind in 1986-2015; m/sec	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.4	0.4	0.5	0.7	0.7	0.5	0.6
		ΔWind, m/sec	-1.0	-1.0	-1.0	-1.2	-1.1	-1.1	-1.0	-1.0	-0.9	-1.0	-0.9	-0.9	-1.0	-1.1	-1.1	-1.0	-1.0
		ΔWind, %	-67	-62	-58	-63	-63	-59	-60	-60	-62	-68	-67	-70	-66	-62	-61	-66	-63
	Tsalka	Wind in 1986-2015; m/sec	1.4	1.2	1.2	1.1	1.1	1.0	0.8	0.8	0.9	0.8	1.0	1.1	1.2	1.1	0.9	0.9	1.0
		ΔWind, m/sec	-0.6	-0.7	-0.6	-0.5	-0.2	-0.3	-0.4	-0.4	-0.3	-0.6	-0.6	-0.7	-0.7	-0.5	-0.4	-0.5	-0.5
		ΔWind, %	-32	-37	-32	-32	-17	-25	-32	-35	-26	-41	-38	-40	-35	-29	-30	-35	-33
	Gardabani	Wind in 1986-2015; m/sec	0.7	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.5	0.5	0.4	0.7	0.9	0.8	0.6	0.7
		ΔWind, m/sec	-0.3	-0.5	-0.9	-1.1	-1.0	-1.2	-1.4	-1.2	-0.8	-0.7	-0.4	-0.5	-0.4	-1.0	-1.3	-0.6	-0.8
		ΔWind, %	-31	-41	-48	-56	-56	-62	-63	-61	-50	-56	-46	-55	-36	-53	-61	-49	-54
Mtskheta-Mtianeti	Pasanauri	Wind in 1986-2015; m/sec	0.6	0.7	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.6	0.9	0.8	0.6	0.7
		ΔWind, m/sec	-0.9	-1.0	-1.0	-0.9	-0.8	-0.8	-0.8	-0.7	-0.7	-0.7	-0.7	-0.8	-0.9	-0.9	-0.7	-0.7	-0.8
		ΔWind, %	-63	-58	-55	-49	-46	-50	-51	-51	-51	-54	-60	-66	-62	-49	-49	-53	-54
	Tianeti	Wind in 1986-2015; m/sec	0.8	0.8	0.9	0.8	0.9	1.0	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.9	0.8	0.7	0.8
		ΔWind, m/sec	-0.6	-1.0	-1.2	-1.2	-0.8	-0.8	-0.7	-0.7	-0.7	-0.9	-0.6	-0.7	-0.8	-1.1	-0.7	-0.8	-0.8
		ΔWind, %	-45	-55	-58	-61	-46	-46	-51	-50	-50	-55	-47	-53	-51	-55	-48	-51	-52
	Stepantsminda	Wind in 1986-2015; m/sec	2.1	1.9	1.9	2.0	2.3	1.8	1.6	1.6	2.0	2.0	2.1	2.1	2.0	2.1	1.8	2.1	1.9
		ΔWind, m/sec	-0.8	-1.1	-0.7	-0.4	0.1	-0.3	-0.3	-0.4	-0.3	-0.3	-0.5	-0.8	-0.9	-0.3	-0.2	-0.2	-0.5
		ΔWind, %	-27	-36	-26	-17	6	-14	-14	-21	-13	-15	-20	-27	-31	-12	-10	-10	-20
Kakheti	Telavi	Wind in 1986-2015; m/sec	1.0	1.1	1.3	1.3	1.2	1.2	1.1	1.0	1.0	1.0	1.0	0.9	1.0	1.3	1.1	1.0	1.1
		ΔWind, m/sec	-0.6	-0.7	-0.7	-0.9	-0.7	-0.7	-0.6	-0.7	-0.7	-0.8	-0.7	-0.6	-0.6	-0.8	-0.7	-0.7	-0.7
		ΔWind, %	-36	-38	-35	-42	-37	-39	-37	-40	-41	-45	-42	-40	-39	-38	-37	-42	-39
	Gurgaani	Wind in 1986-2015; m/sec	0.7	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.9	0.8	0.7	0.8
		ΔWind, m/sec	-0.3	-0.5	-0.5	-0.4	-0.5	-0.4	-0.4	-0.4	-0.3	-0.4	-0.4	-0.3	-0.4	-0.5	-0.4	-0.4	-0.4
		ΔWind, %	-33	-38	-34	-32	-34	-33	-30	-31	-30	-38	-35	-29	-34	-34	-33	-35	-33
	Lagodekhi	Wind in 1986-2015; m/sec	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.2	0.2	0.2	0.4	0.4	0.3	0.4
		ΔWind, m/sec	-0.1	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2
		ΔWind, %	-27	-40	-44	-41	-38	-36	-28	-26	-19	-30	-51	-59	-64	-46	-38	-47	-36
	Sagarejo	Wind in 1986-2015; m/sec	1.5	1.4	1.4	1.3	1.4	1.4	1.2	1.2	1.3	1.2	1.3	1.4	1.4	1.4	1.3	1.3	1.3
		ΔWind, m/sec	-0.5	-0.6	-0.6	-0.7	-0.5	-0.4	-0.4	-0.5	-0.5	-0.7	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6
		ΔWind, %	-25	-32	-29	-34	-25	-24	-27	-29	-27	-37	-31	-31	-28	-29	-25	-30	-29
	Kvareli	Wind in 1986-2015; m/sec	0.6	0.8	0.9	0.9	0.9	0.8	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.9	0.7	0.7	0.7
		ΔWind, m/sec	-0.3	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5	-0.8	-0.4	-0.4	-0.4	-0.3	-0.4	-0.5	-0.6	-0.4	-0.4
		ΔWind, %	-33	-33	-31	-36	-36	-40	-44	-56	-36	-37	-36	-33	-36	-35	-47	-36	-38
	Dedoplistskaro	Wind in 1986-2015; m/sec	1.6	1.6	1.6	1.4	1.5	1.2	1.0	1.1	1.1	1.1	1.3	1.5	1.5	1.5	1.1	1.2	1.3
		ΔWind, m/sec	-0.1	-0.4	-0.3	-0.7	-0.4	-0.6	-0.6	-0.5	-0.4	-0.4	-0.2	0.0	-0.2	-0.5	-0.6	-0.4	-0.4
		ΔWind, %	-7	-22	-16	-33	-22	-35	-38	-34	-29	-28	-14	0	-12	-25	-36	-23	-23

Table B 1: Projected mean air temperatures in 2071–2100 and their change relative to 1971–2000

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spr	Sum	Aut	Win	Year
Adjara	Kobuleti	Tmean in 2071-2100, °C	7.7	8.4	10.8	15.5	19.8	22.6	24.8	25.2	22.3	18.6	13.5	9.9	15.4	24.2	18.1	8.7	16.6
		ΔTmean, °C	2.3	2.6	2.9	3.4	4.0	2.4	2.1	2.4	2.4	3.0	2.9	2.7	3.4	2.3	2.7	2.5	2.7
	Batumi	Tmean in 2071-2100, °C	8.5	9.4	11.4	15.5	20.6	22.9	24.9	25.2	22.8	20.0	14.9	11.0	15.9	24.3	19.2	9.7	17.3
		ΔTmean, °C	2.2	2.6	2.9	2.9	4.7	2.8	2.4	2.6	3.0	3.9	3.1	2.6	3.5	2.6	3.3	2.4	2.9
	Khulo	Tmean in 2071-2100, °C	3.0	3.9	7.5	13.5	18.7	20.4	21.4	21.9	19.5	16.5	10.4	5.6	13.2	21.2	15.5	4.2	13.5
		ΔTmean, °C	2.2	2.7	3.0	3.5	4.8	3.8	2.7	3.2	3.4	4.4	3.4	2.7	3.8	3.2	3.7	2.5	3.3
	Goderdzi Pass	Tmean in 2071-2100, °C	-6.6	-5.7	-1.7	4.2	9.9	12.2	14.9	15.0	12.0	7.9	1.0	-3.8	4.1	14.1	7.0	-5.4	4.9
		ΔTmean, °C	1.4	2.0	2.6	2.6	4.1	2.9	2.6	2.8	2.9	3.4	2.2	1.8	3.1	2.8	2.8	1.7	2.5
	Average	**ΔTmean, °C**	**2.0**	**2.5**	**2.9**	**3.1**	**4.4**	**3.0**	**2.5**	**2.7**	**2.9**	**3.6**	**2.9**	**2.4**	**3.4**	**2.7**	**3.1**	**2.3**	**2.9**
Guria	Chokhatauri	Tmean in 2071-2100, °C	6.8	7.7	11.3	17.0	21.2	24.0	24.9	25.1	22.4	19.4	13.3	9.2	16.5	24.7	18.4	7.9	16.9
		ΔTmean, °C	2.2	2.6	3.3	3.7	4.4	3.6	2.6	2.7	3.0	4.2	2.9	2.7	3.8	3.0	3.4	2.5	3.1
	Bakhmaro	Tmean in 2071-2100, °C	-3.2	-3.3	0.4	5.8	11.0	12.7	15.4	15.6	12.9	8.3	3.8	-1.2	5.8	14.6	8.4	-2.6	6.5
		ΔTmean, °C	2.0	1.9	2.7	2.5	3.9	2.4	2.1	2.5	2.7	2.3	3.0	1.9	3.1	2.3	2.7	1.9	2.4
	Average	**ΔTmean, °C**	**2.1**	**2.2**	**3.0**	**3.1**	**4.2**	**3.0**	**2.4**	**2.6**	**2.8**	**3.3**	**2.9**	**2.3**	**3.4**	**2.6**	**3.0**	**2.2**	**2.8**
Samegreli-Zemo Svaneti	Mestia	Tmean in 2071-2100, °C	-2.8	-1.3	0.9	8.7	14.3	17.1	20.4	19.4	15.9	11.8	3.6	-0.5	8.0	19.0	10.4	-1.5	9.0
		ΔTmean, °C	3.2	3.0	5.0	2.7	3.8	3.5	3.5	3.1	3.7	4.6	2.5	3.5	3.9	3.4	3.6	3.2	3.5
	Khaishi	Tmean in 2071-2100, °C	1.8	4.1	7.9	13.8	18.5	21.0	24.5	23.7	20.1	16.2	7.8	3.6	13.4	23.0	14.7	3.2	13.6
		ΔTmean, °C	2.6	2.9	2.5	2.8	3.4	2.9	3.5	2.8	3.2	4.6	2.4	2.6	2.9	3.0	3.4	2.7	3.0
	Zugdidi	Tmean in 2071-2100, °C	7.2	8.7	10.8	15.5	19.9	22.3	25.3	25.3	22.7	19.0	13.1	9.9	15.4	24.3	18.3	8.6	16.6
		ΔTmean, °C	2.5	3.0	2.2	2.2	3.2	1.9	2.5	2.4	3.0	3.8	2.8	3.4	2.5	2.2	3.2	3.0	2.7
	Poti	Tmean in 2071-2100, °C	7.9	8.4	11.3	16.4	19.8	22.9	25.2	25.2	22.4	19.4	13.9	10.1	15.8	24.5	18.5	8.8	16.9
		ΔTmean, °C	2.2	2.3	2.6	3.5	3.3	2.4	2.2	2.1	2.3	3.4	2.7	2.4	3.1	2.2	2.8	2.3	2.6
	Average	**ΔTmean, °C**	**2.6**	**2.8**	**3.1**	**2.8**	**3.4**	**2.7**	**2.9**	**2.6**	**3.1**	**4.1**	**2.6**	**3.0**	**3.1**	**2.7**	**3.2**	**2.8**	**2.9**
Imereti	Sachkhere	Tmean in 2071-2100, °C	2.8	4.4	8.9	15.6	19.7	22.2	25.0	25.1	21.1	15.7	9.7	5.2	14.7	24.1	15.5	4.1	14.6
		ΔTmean, °C	2.5	3.1	3.3	3.8	4.0	3.2	3.2	3.2	3.0	3.5	3.4	3.0	3.7	3.2	3.3	2.9	3.2
	Kutaisi	Tmean in 2071-2100, °C	7.5	8.3	12.3	18.4	22.3	24.1	26.1	26.3	23.6	20.0	14.2	9.9	17.7	25.5	19.3	8.6	17.8
		ΔTmean, °C	2.4	2.7	3.4	4.3	4.6	3.1	3.0	3.0	3.2	3.8	3.1	2.6	4.1	3.0	3.3	2.6	3.2
	Mta Sabueti	Tmean in 2071-2100, °C	-1.3	-0.6	3.2	10.5	14.6	16.7	19.2	19.3	15.8	11.5	6.2	1.6	9.4	18.4	11.2	-0.1	9.7
		ΔTmean, °C	2.1	2.6	3.1	4.1	4.3	3.0	2.9	3.0	3.0	3.5	3.6	2.7	3.9	2.9	3.3	2.4	3.1
	Samtredia	Tmean in 2071-2100, °C	7.2	8.3	12.2	18.2	22.2	24.8	26.5	26.7	23.6	19.6	13.6	9.4	17.5	26.0	18.9	8.3	17.7
		ΔTmean, °C	2.3	2.6	3.3	4.3	4.4	3.6	3.2	3.4	3.3	3.7	2.9	2.6	4.0	3.4	3.3	2.5	3.2
	Zestaponi	Tmean in 2071-2100, °C	6.1	7.6	11.7	17.6	21.7	24.5	26.6	26.9	23.8	19.7	13.2	8.9	17.0	26.0	18.9	7.5	17.3
		ΔTmean, °C	2.1	2.9	3.3	3.6	3.8	3.3	3.1	3.2	3.2	4.0	3.0	2.9	3.5	3.2	3.4	2.6	3.1
	Average	**ΔTmean, °C**	**2.3**	**2.8**	**3.3**	**4.0**	**4.2**	**3.3**	**3.1**	**3.1**	**3.1**	**3.7**	**3.2**	**2.7**	**3.8**	**3.1**	**3.3**	**2.6**	**3.2**
Racha Lechkhumi – Kvemo Svaneti	Lentekhi	Tmean in 2071-2100, °C	0.1	1.1	7.9	13.7	16.7	20.8	23.4	22.3	17.2	12.0	5.2	0.5	12.8	22.2	11.5	0.5	11.8
		ΔTmean, °C	2.3	1.4	3.8	3.6	2.2	3.1	2.7	2.0	1.2	1.8	1.2	1.0	3.2	2.6	1.4	1.6	2.1
	Shovi	Tmean in 2071-2100, °C	-2.7	-1.2	2.8	8.7	14.0	16.7	19.4	18.8	14.9	10.7	4.5	-0.4	8.5	18.3	10.0	-1.4	8.8
		ΔTmean, °C	2.9	3.2	3.6	3.6	4.4	3.8	3.2	3.1	3.2	4.0	3.7	3.4	3.9	3.4	3.6	3.2	3.5
	Ambrolauri	Tmean in 2071-2100, °C	2.0	4.2	9.3	15.8	20.0	22.7	24.8	24.8	21.1	16.3	9.4	4.3	15.0	24.1	15.6	3.5	14.6
		ΔTmean, °C	2.5	2.9	3.5	4.2	4.5	3.9	3.0	3.2	3.5	4.4	3.3	3.0	4.1	3.4	3.8	2.8	3.4
	Average	**ΔTmean, °C**	**2.6**	**2.5**	**3.6**	**3.8**	**3.7**	**3.6**	**3.0**	**2.8**	**2.6**	**3.4**	**2.7**	**2.5**	**3.7**	**3.1**	**2.9**	**2.5**	**3.0**
Region	**Station**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Spr**	**Sum**	**Aut**	**Win**	**Year**
Samtskhe-Javakheti	Borjomi	Tmean in 2071-2100, °C	1.1	2.4	7.0	12.2	15.1	20.8	23.0	22.9	19.4	14.5	8.2	3.4	11.4	22.2	14.0	2.3	12.5
		ΔTmean, °C	2.4	2.8	3.4	2.6	1.5	3.7	2.8	2.9	3.5	4.3	3.7	2.9	2.5	3.1	3.8	2.7	3.0
	Bakuriani	Tmean in 2071-2100, °C	-4.2	-2.9	1.0	7.9	12.0	14.9	17.3	17.4	13.7	9.7	4.0	-1.3	7.0	16.5	9.1	-2.8	7.4
		ΔTmean, °C	1.8	2.5	2.7	3.3	3.5	2.9	2.4	2.6	2.9	3.6	3.2	2.5	3.2	2.6	3.2	2.2	2.8

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spr	Sum	Aut	Win	Year
	Akhaltsikhe	Tmean in 2071-2100, ^{0}C	-1.2	0.7	6.2	13.0	16.7	20.7	23.1	23.0	19.0	13.7	7.0	1.4	12.0	22.3	13.2	0.3	11.9
		ΔTmean, ^{0}C	2.5	2.9	3.3	3.7	3.3	4.0	2.9	3.2	3.3	3.8	3.4	2.9	3.4	3.3	3.5	2.8	3.2
	Tsalka	Tmean in 2071-2100, ^{0}C	-2.3	-1.6	2.3	9.1	12.4	16.0	18.8	18.3	14.9	10.4	4.9	0.2	7.9	17.7	10.1	-1.2	8.6
		ΔTmean, ^{0}C	2.1	2.7	2.6	3.0	2.4	2.4	2.2	2.3	2.6	3.2	3.0	2.3	2.7	2.3	2.9	2.3	2.5
	Akhalkalaki	Tmean in 2071-2100, ^{0}C	-4.8	-3.8	1.1	8.8	13.1	15.3	18.6	18.8	15.2	10.9	4.2	-1.9	7.7	17.6	10.1	-3.5	7.9
		ΔTmean, ^{0}C	2.5	2.9	3.3	3.7	3.3	4.0	2.9	3.2	3.3	3.8	3.4	2.9	3.4	3.3	3.5	2.8	3.2
	Paravani	Tmean in 2071-2100, ^{0}C	-6.8	-6.2	-2.5	5.7	10.2	13.6	15.9	16.3	12.6	8.7	1.6	-3.4	4.5	15.3	7.6	-5.4	5.5
		ΔTmean, ^{0}C	1.6	2.2	2.1	3.4	3.3	3.2	2.2	3.1	2.8	3.7	2.1	2.2	3.0	2.8	2.9	1.9	2.6
	Average	**ΔTmean, ^{0}C**	**2.1**	**2.6**	**2.8**	**3.2**	**2.9**	**3.1**	**2.5**	**2.8**	**3.0**	**3.7**	**3.0**	**2.5**	**3.0**	**2.8**	**3.2**	**2.4**	**2.8**
Shida Kartli	Khashuri	Tmean in 2071-2100, ^{0}C	0.6	1.7	7.1	13.9	17.5	21.8	23.4	23.2	20.6	13.6	7.8	3.1	12.8	22.8	14.0	1.8	12.9
		ΔTmean, ^{0}C	1.9	1.3	3.0	3.5	3.2	4.0	2.6	2.6	3.9	2.6	2.8	2.3	3.2	3.0	3.1	1.9	2.8
	Gori	Tmean in 2071-2100, ^{0}C	1.5	2.8	8.0	14.9	17.7	22.4	24.6	24.1	19.9	14.9	8.2	3.5	13.5	23.7	14.3	2.6	13.5
		ΔTmean, ^{0}C	2.1	2.5	2.9	3.7	2.6	3.6	2.6	2.3	2.3	3.2	2.7	2.3	3.1	2.8	2.7	2.3	2.7
	Average	**ΔTmean, ^{0}C**	**2.0**	**1.9**	**3.0**	**3.6**	**2.9**	**3.8**	**2.6**	**2.5**	**3.1**	**2.9**	**2.8**	**2.3**	**3.2**	**2.9**	**2.9**	**2.1**	**2.7**
Kvemo Kartli	Tbilisi	Tmean in 2071-2100, ^{0}C	4.8	6.4	10.8	15.5	21.7	24.7	28.3	27.9	22.2	17.6	10.9	6.6	16.0	27.0	16.9	5.9	16.4
		ΔTmean, ^{0}C	3.0	3.8	4.0	2.5	4.5	3.4	3.7	3.9	2.4	3.9	3.2	3.0	3.7	3.6	3.2	3.1	3.4
	Bolnisi	Tmean in 2071-2100, ^{0}C	3.8	4.9	9.2	15.4	19.2	24.1	27.4	26.1	21.9	16.1	10.2	5.7	14.6	25.9	16.1	4.8	15.3
		ΔTmean, ^{0}C	2.6	2.9	3.1	2.9	2.7	3.5	3.1	2.4	2.5	2.9	3.0	2.5	2.9	3.0	2.8	2.7	2.8
	Gardabani	Tmean in 2071-2100, ^{0}C	3.9	5.7	10.1	16.8	20.9	25.7	28.3	28.3	23.2	17.0	10.7	5.9	15.9	27.4	17.0	5.2	16.4
		ΔTmean, ^{0}C	2.5	3.0	2.9	3.2	3.0	3.3	2.6	3.3	2.6	3.0	3.0	2.6	3.0	3.0	2.9	2.7	2.9
	Average	**ΔTmean, ^{0}C**	**2.7**	**3.3**	**3.3**	**2.9**	**3.4**	**3.4**	**3.1**	**3.2**	**2.5**	**3.3**	**3.1**	**2.7**	**3.2**	**3.2**	**2.9**	**2.8**	**3.0**
Mtskheta Mtianeti	Stepantsminda	Tmean in 2071-2100, ^{0}C	-2.9	-1.6	1.8	8.2	13.1	16.6	18.4	18.0	14.9	9.9	5.1	-0.8	7.7	17.7	10.0	-1.8	8.4
		ΔTmean, ^{0}C	2.5	3.3	3.3	3.3	4.3	4.7	3.8	3.7	3.8	3.6	4.1	2.5	3.7	4.1	3.8	2.7	3.5
	Gudauri	Tmean in 2071-2100, ^{0}C	-3.9	-4.0	-1.2	4.4	9.8	13.8	16.2	16.1	11.6	7.3	2.2	-1.9	4.3	15.4	7.1	-3.3	5.9
		ΔTmean, ^{0}C	3.7	3.4	3.2	3.0	4.5	4.5	3.5	4.0	3.0	3.6	3.8	3.5	3.6	4.0	3.5	3.5	3.6
	Pasanauri	Tmean in 2071-2100, ^{0}C	-1.0	1.0	5.6	11.7	16.0	19.4	22.2	21.6	17.8	12.9	6.8	1.3	11.1	21.1	12.5	0.4	11.3
		ΔTmean, ^{0}C	2.6	3.0	3.3	3.0	3.5	3.6	3.2	3.2	3.2	3.5	3.3	2.6	3.3	3.3	3.3	2.8	3.1
	Tianeti	Tmean in 2071-2100, ^{0}C	-0.9	0.5	5.0	11.6	15.3	19.5	21.7	21.2	17.3	12.3	6.7	1.2	10.6	20.8	12.1	0.3	10.9
		ΔTmean, ^{0}C	2.8	3.1	3.2	3.2	2.9	3.4	2.6	2.7	2.9	3.4	3.4	2.6	3.1	2.9	3.2	2.8	3.0
	Average	**ΔTmean, ^{0}C**	**2.9**	**3.2**	**3.2**	**3.1**	**3.8**	**4.1**	**3.3**	**3.4**	**3.2**	**3.5**	**3.7**	**2.8**	**3.4**	**3.6**	**3.5**	**3.0**	**3.3**
Kakheti	Kvareli	Tmean in 2071-2100, ^{0}C	4.2	5.1	8.9	16.1	21.9	24.6	28.4	27.2	23.3	17.3	10.9	7.0	15.6	26.7	17.2	5.4	16.2
		ΔTmean, ^{0}C	2.7	2.6	2.2	3.1	4.8	3.5	4.1	3.7	3.9	3.9	3.2	3.9	3.4	3.8	3.7	3.1	3.4
	Telavi	Tmean in 2071-2100, ^{0}C	4.0	4.9	9.2	16.0	20.7	23.7	27.5	26.7	22.7	16.6	11.0	6.9	15.3	26.0	16.8	5.3	15.8
		ΔTmean, ^{0}C	3.1	3.1	3.2	3.5	4.3	3.3	3.9	3.8	4.1	3.8	3.8	3.8	3.7	3.7	3.9	3.3	3.6
	Lagodekhi	Tmean in 2071-2100, ^{0}C	4.1	5.2	10.1	16.4	22.5	25.4	28.7	27.5	23.5	17.8	11.0	7.0	16.3	27.2	17.5	5.4	16.6
		ΔTmean, ^{0}C	2.7	2.6	3.2	3.1	5.2	3.9	3.9	3.5	3.8	4.2	3.2	3.5	3.9	3.7	3.7	2.9	3.5
	Gurjaani	Tmean in 2071-2100, ^{0}C	3.9	4.8	10.3	15.5	22.2	24.8	28.2	27.4	23.8	17.6	11.7	6.8	16.0	26.8	17.7	5.2	16.4
		ΔTmean, ^{0}C	2.6	2.3	3.6	2.3	5.0	3.5	3.9	3.9	4.6	4.3	4.2	3.6	3.6	3.8	4.4	2.8	3.6
	Sagarejo	Tmean in 2071-2100, ^{0}C	3.3	4.2	7.8	13.8	19.9	22.9	26.5	26.1	22.5	15.9	10.5	6.8	13.9	25.2	16.3	4.8	15.0
		ΔTmean, ^{0}C	2.8	3.3	3.1	2.6	4.8	3.6	4.0	4.4	4.9	3.2	4.0	4.0	3.5	4.0	4.0	3.4	3.7
	Dedoplistskaro	Tmean in 2071-2100, ^{0}C	2.6	3.8	7.4	13.4	19.3	23.1	25.3	25.3	21.8	16.0	10.1	6.0	13.4	24.6	15.9	4.1	14.5
		ΔTmean, ^{0}C	3.1	3.6	3.4	2.6	4.4	3.8	2.7	3.3	4.2	4.6	4.3	4.2	3.5	3.3	4.4	3.6	3.6
	Average	**ΔTmean, ^{0}C**	**2.8**	**2.9**	**3.1**	**2.9**	**4.8**	**3.6**	**3.7**	**3.8**	**4.2**	**4.0**	**3.8**	**3.8**	**3.6**	**3.7**	**4.0**	**3.2**	**3.6**

Table B 2: Projected precipitations during 2071-2100 years and their change between 2 periods (2071-2100 and 1971-2000)

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Summ	Aut	Wint	Year
Adjara	Kobuleti	Precipitation in 1971-2000; mm	204	147	152	91	76	166	161	213	223	203	253	233	319	540	679	583	2121
		ΔPr (2071-2100;1971-2000), mm	3	-20	13	-13	-11	0	0	-11	-30	-52	0	-12	-10	-11	-82	-29	-133
		ΔPr (1986-2015;1956-1985), %	1	-12	9	-12	-12	0	0	-5	-12	-20	0	-5	-3	-2	-11	-5	-6
	Batumi	Precipitation in 1971-2000; mm	229	178	134	75	101	150	133	213	282	276	257	294	310	495	814	702	2322
		ΔPr (2071-2100;1971-2000), mm	-22	-4	-11	-21	10	-2	-25	-10	2	-32	-48	3	-22	-37	-78	-23	-160
		ΔPr (1986-2015;1956-1985), %	-9	-2	-8	-22	11	-1	-16	-4	1	-10	-16	1	-7	-7	-9	-3	-6
	Khulo	Precipitation in 1971-2000; mm	177	-7	96	-27	77	-1	61	-14	85	-14	150	-26	237	-5	356	-15	1296
		ΔPr (2071-2100;1971-2000), mm	-14	-10	-1	-24	-13	-1	-1	-9	-5	-20	-22	-62	-38	-11	-48	-87	-184
		ΔPr (1986-2015;1956-1985), %	-7	-7	-1	-27	-14	-1	-1	-14	-6	-14	-13	-26	-14	-5	-12	-15	-12
Guria	Chokhatauri	Precipitation in 1971-2000; mm	176	135	108	72	81	118	88	111	154	186	162	221	261	316	502	532	1612
		ΔPr (2071-2100;1971-2000), mm	-8	-8	7	-15	-2	1	-3	-8	-8	-3	-24	5	-11	-11	-35	-11	-67
		ΔPr (1986-2015;1956-1985), %	-4	-5	7	-18	-2	1	-4	-7	-5	-1	-13	2	-4	-3	-6	-2	-4
Samegrelo - Zemo Svaneti	Zugdidi	Precipitation in 1971-2000; mm	106	151	144	162	94	156	150	197	103	106	184	172	400	503	394	428	1725
		ΔPr (2071-2100;1971-2000), mm	-37	16	7	30	-33	-49	-27	22	-38	-67	28	9	4	-54	-78	-11	-139
		ΔPr (1986-2015;1956-1985), %	-26	12	5	23	-26	-24	-15	13	-27	-39	18	6	1	-10	-16	-3	-7
	Poti	Precipitation in 1971-2000; mm	136	143	93	92	83	137	162	239	211	235	180	182	268	538	626	461	1893
		ΔPr (2071-2100;1971-2000), mm	-16	17	-12	8	13	-16	-39	-4	-21	37	0	12	9	-59	16	14	-20
		ΔPr (1986-2015;1956-1985), %	-10	13	-11	9	19	-10	-19	-2	-9	19	0	7	4	-10	3	3	-1
Imereti	Sachkhere	Precipitation in 1971-2000; mm	68	54	65	64	74	79	53	53	59	88	70	85	203	185	203	206	797
		ΔPr (2071-2100;1971-2000), mm	-13	-10	6	-15	-19	-14	-27	-19	-18	-14	-16	-7	-28	-60	-47	-29	-164
		ΔPr (1986-2015;1956-1985), %	-16	-15	10	-19	-20	-15	-34	-26	-23	-16	-18	-8	-12	-24	-19	-13	-17
	Kutaisi	Precipitation in 1971-2000; mm	145	106	116	79	69	85	87	81	81	116	110	161	264	253	307	412	1236
		ΔPr (2071-2100;1971-2000), mm	-22	-15	8	-12	-12	-16	0	-21	-19	-21	-29	-9	-17	-37	-70	-46	-169
		ΔPr (1986-2015;1956-1985), %	-13	-12	7	-14	-15	-16	0	-21	-19	-16	-21	-5	-6	-13	-19	-10	-12
	Mta Sabueti	Precipitation in 1971-2000; mm	118	106	94	77	69	70	80	83	78	100	108	120	240	233	286	344	1103
		ΔPr (2071-2100;1971-2000), mm	-34	-23	2	-10	-28	-31	13	22	6	0	-13	-21	-36	5	-7	-78	-117
		ΔPr (1986-2015;1956-1985), %	-22	-18	2	-12	-29	-31	20	37	8	0	-11	-15	-13	2	-2	-19	-10
	Zestaponi	Precipitation in 1971-2000; mm	135	107	111	80	59	84	54	59	61	100	117	167	250	197	279	409	1134
		ΔPr (2071-2100;1971-2000), mm	-22	-22	8	-12	-19	-14	-15	-11	-20	-21	-16	4	-23	-40	-56	-41	-160
		ΔPr (1986-2015;1956-1985), %	-14	-17	8	-13	-24	-14	-22	-16	-24	-17	-12	2	-8	-17	-17	-9	-12
Racha - Lechkhumi and Kvemo Svaneti	Shovi	Precipitation in 1971-2000; mm	78	54	73	96	114	132	115	113	88	93	76	76	283	359	257	207	1106
		ΔPr (2071-2100;1971-2000), mm	-5	-10	-1	-17	-7	3	1	10	-10	-18	-16	0	-25	13	-43	-16	-71
		ΔPr (1986-2015;1956-1985), %	-6	-16	-1	-15	-6	2	1	9	-10	-16	-17	0	-8	4	-14	-7	-6
	Ambrolauri	Precipitation in 1971-2000; mm	75	56	30	65	83	95	72	70	65	97	86	112	178	237	248	242	906
		ΔPr (2071-2100;1971-2000), mm	-16	-12	-31	-24	-14	-7	-9.1	-8	-14	-19	-17	0	-70	-25	-50	-28	-172
		ΔPr (1986-2015;1956-1985), %	-17	-18	-51	-27	-15	-7	-11	-11	-18	-16	-16	0	-28	-9	-17	-10	-16

Table B2: Projected precipitations during 2071-2100 years and their change between 2 periods (2071-2100 and 1971-2000)

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Summ	Aut	Wint	Year
Samtskhe - Javakheti	Borjomi	Precipitation in 1971-2000; mm	44	35	43	48	77	84	52	42	43	46	51	49	168	178	140	128	614
		ΔPr (2071-2100;1971-2000), mm	1	-6	2	-16	-13	-4	0	1	-4	-10	-9	1	-27	-3	-22	-4	-56
		ΔPr (1986-2015;1956-1985), %	3	-15	4	-26	-14	-5	0	4	-8	-18	-14	2	-14	-1	-14	-3	-8
	Akhaltsikhe	Precipitation in 1971-2000; mm	18	20	15	34	62	75	46	40	25	28	31	31	111	161	84	68	424
		ΔPr (2071-2100;1971-2000), mm	-6	-5	-17	-14	-10	-5	-6	-8	-7	-6	-6	-1	-42	-19	-19	-12	-92
		ΔPr (1986-2015;1956-1985), %	-23	-22	-53	-29	-14	-7	-12	-17	-21	-18	-16	-3	-27	-11	-18	-15	-18
	Tsalka	Precipitation in 1971-2000; mm	21	31	41	52	102	126	70	64	41	39	38	21	195	260	118	74	647
		ΔPr (2071-2100;1971-2000), mm	0	1	1	-15	-18	6	5	0	-6	-10	-2	-4	-32	11	-18	-3	-42
		ΔPr (1986-2015;1956-1985), %	0	2	2	-22	-15	5	8	0	-13	-20	-5	-14	-14	4	-13	-4	-6
	Akhalkalaki	Precipitation in 1971-2000; mm	21	22	24	35	70	84	40	44	30	32	35	20	129	168	97	63	457
		ΔPr (2071-2100;1971-2000), mm	-5	-10	-7	-15	-14	-9	-9	-3	-3	-5	-5	-9	-35	-20	-13	-24	-93
		ΔPr (1986-2015;1956-1985), %	-21	-31	-22	-30	-16	-9	-18	-6	-9	-14	-13	-31	-21	-11	-12	-28	-17
Shida Kartli	Khashuri	Precipitation in 1971-2000; mm	69	45	35	39	55	81	48	40	31	38	69	56	129	169	139	171	608
		ΔPr (2071-2100;1971-2000), mm	5	-2	1	-9	-8	12	5	1	-7	-14	7	-7	-16	18	-15	-3	-17
		ΔPr (1986-2015;1956-1985), %	8	-4	2	-18	-13	17	11	2	-18	-27	11	-11	-11	12	-10	-2	-3
	Gori	Precipitation in 1971-2000; mm	34	29	26	36	53	70	50	32	21	32	49	35	115	152	103	98	467
		ΔPr (2071-2100;1971-2000), mm	-1	-2	-3	-13	-8	6	6	-2	-8	-10	1	-2	-24	11	-18	-5	-36
		ΔPr (1986-2015;1956-1985), %	-2	-5	-11	-27	-13	9	15	-5	-28	-25	3	-6	-17	8	-15	-5	-7
Kvemo Kartli	Tbilisi	Precipitation in 1971-2000; mm	18	14	15	37	48	67	46	44	28	36	37	19	100	157	101	52	409
		ΔPr (2071-2100;1971-2000), mm	0	-11	-14	-19	-30	-13	9	-2	-6	-5	3	-4	-64	-7	-9	-15	-94
		ΔPr (1986-2015;1956-1985), %	-1	-44	-48	-34	-39	-17	24	-5	-17	-13	8	-17	-39	-4	-8	-23	-19
	Bolnisi	Precipitation in 1971-2000; mm	19	31	42	44	66	71	39	35	28	33	33	18	152	145	94	68	459
		ΔPr (2071-2100;1971-2000), mm	0	1	1	-12	-12	6	3	1	-7	-8	-3	-3	-23	10	-18	-3	-33
		ΔPr (1986-2015;1956-1985), %	0	2	2	-22	-15	9	9	3	-19	-19	-9	-16	-13	8	-16	-4	-7
Mtskheta-Mtianeti	Pasanauri	Precipitation in 1971-2000; mm	39	43	64	79	123	120	107	89	56	48	59	60	266	316	163	142	887
		ΔPr (2071-2100;1971-2000), mm	-6	-6	4	-32	-13	-8	4	-4	-12	-17	-8	-1	-41	-8	-37	-13	-100
		ΔPr (1986-2015;1956-1985), %	-13	-13	6	-29	-10	-7	4	-4	-18	-27	-12	-2	-13	-3	-19	-8	-10
	Tianeti	Precipitation in 1971-2000; mm	32	38	53	71	122	127	86	79	46	36	74	36	247	292	156	106	800
		ΔPr (2071-2100;1971-2000), mm	1	-3	2	-18	-6	13	16	7	-15	-16	23	-1	-21	36	-7	-4	4
		ΔPr (1986-2015;1956-1985), %	3	-8	5	-20	-4	12	23	10	-25	-31	46	-4	-8	14	-5	-4	1
Kakheti	Telavi	Precipitation in 1971-2000; mm	18	24	32	63	79	98	56	52	55	35	69	26	174	207	159	69	609
		ΔPr (2071-2100;1971-2000), mm	-6	-14	-16	-11	-37	-16	-10	-22	-5	-23	18	-9	-64	-48	-10	-29	-151
		ΔPr (1986-2015;1956-1985), %	-26	-36	-34	-15	-32	-14	-15	-30	-8	-39	35	-25	-27	-19	-6	-30	-20
	Lagodekhi	Precipitation in 1971-2000; mm	48	65	91	82	81	74	61	85	67	78	41	37	254	221	186	150	810
		ΔPr (2071-2100;1971-2000), mm	13	15	17	-10	-39	-52	-16	-3	-27	-13	-33	-3	-33	-70	-72	25	-150
		ΔPr (1986-2015;1956-1985), %	37	30	23	-11	-33	-41	-20	-3	-28	-14	-45	-7	-11	-24	-28	20	-16
	Sagarejo	Precipitation in 1971-2000; mm	56	47	49	45	69	56	48	59	44	65	45	46	162	163	155	149	628
		ΔPr (2071-2100;1971-2000), mm	27	5	-11	-37	-41	-48	-19	-1	-15	-2	-7	13	-89	-69	-24	45	-137
		ΔPr (1986-2015;1956-1985), %	96	11	-18	-46	-37	-46	-28	-2	-26	-2	-13	37	-36	-30	-13	43	-18
	Dedoplistskaro	Precipitation in 1971-2000; mm	25	25	27	42	54	99	41	37	41	41	36	21	123	176	118	71	488
		ΔPr (2071-2100;1971-2000), mm	2	-6	-22	-19	-36	-10	-7	-1	-4	-11	-7	-2	-77	-18	-23	-6	-125
		ΔPr (1986-2015;1956-1985), %	8	-20	-45	-31	-40	-9	-15	-3	-10	-22	-16	-9	-39	-9	-16	-8	-20

Table B 3: Projected relative humiditіyes during 2071–2100 years and their change between two 30-year periods (1971–2000 and 2071–2100)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Adjara	Kobuleti	RH in 2071-2100; %	82	81	82	87	88	90	93	95	90	87	85	82	86	93	87	82	87
		ΔRH value (2071-2100;1971-2000)	-1	0	1	5	4	8	9	11	6	3	2	0	4	9	4	-0.4	4
		ΔRH percent (2071-2100;1971-2000)	-1	0	1	7	5	9	11	14	7	4	2	-1	4	11	4	-0.4	5
	Khulo	RH in 2071-2100; %	66	66	63	69	71	79	82	81	73	69	65	71	68	81	69	68	71
		ΔRH value (2071-2100;1971-2000)	-5	-4	-5	4	3	5	2	2	-2	-2	-4	0	1	3	-2	-3	0
		ΔRH percent (2071-2100;1971-2000)	-7	-5	-7	6	4	7	3	3	-2	-2	-5	0	1	4	-3	-4	0
Guria	Chokhatauri	RH in 2071-2100; %	74	73	71	73	73	80	85	88	82	80	76	77	72	85	79	75	78
		ΔRH value (2071-2100;1971-2000)	-2	-1	-1	3	0	4	4	7	1	1	0	1	0	5	1	-1	1
		ΔRH percent (2071-2100;1971-2000)	-2	-1	-2	5	0	5	5	8	2	2	-1	1	1	6	1	-1	2
	Bakhmaro	RH in 2071-2100; %	71	71	67	71	71	80	85	87	74	72	71	73	70	84	72	72	74
		ΔRH value (2071-2100;1971-2000)	-3	-1	-3	4	0	4	5	8	1	1	0	1	1	5	1	-1	1
		ΔRH percent (2071-2100;1971-2000)	-4	-2	-4	6	1	5	6	10	1	2	-1	1	1	7	1	-2	2
Samegrelo-Zemo Svaneti	Zugdidi	RH in 2071-2100; %	74	73	72	79	79	86	89	90	86	80	78	77	76	88	82	74	80
		ΔRH value (2071-2100;1971-2000)	-3	-1	0	7	2	6	6	7	5	2	1	-1	3	6	3	-2	3
		ΔRH percent (2071-2100;1971-2000)	-4	-1	0	9	3	8	7	8	6	2	2	-1	4	8	3	-2	3
	Poti	RH in 2071-2100; %	74	73	77	83	86	91	94	95	89	83	78	76	82	93	83	74	83
		ΔRH value (2071-2100;1971-2000)	-1	-1	2	5	4	8	9	10	5	2	0	-1	4	9	3	-1	3
		ΔRH percent (2071-2100;1971-2000)	-2	-1	2	7	5	10	10	12	7	3	0	-1	5	10	3	-1	4
Imereti	Sachkhere	RH in 2071-2100; %	79	77	71	74	72	76	77	76	77	80	80	82	72	76	79	80	77
		ΔRH value (2071-2100;1971-2000)	-3	-1	-2	5	0	3	1	2	2	1	-1	-1	1	2	1	-2	1
		ΔRH percent (2071-2100;1971-2000)	-4	-2	-2	7	0	4	2	3	3	2	-1	-1	1	3	1	-2	1
	Kutaisi	RH in 2071-2100; %	69	69	67	73	72	79	81	81	78	72	72	71	71	80	74	70	74
		ΔRH value (2071-2100;1971-2000)	-3	-1	-2	4	0	4	3	4	3	1	0	-1	1	4	2	-2	1
		ΔRH percent (2071-2100;1971-2000)	-4	-2	-2	6	0	6	4	5	4	2	1	-2	1	5	2	-3	1
	Mta Sabueti	RH in 2071-2100; %	85	86	84	82	83	88	90	88	87	85	82	87	83	89	85	86	86
		ΔRH value (2071-2100;1971-2000)	-4	-2	-2	2	0	2	3	2	0	0	-4	0	0	2	-1	-2	0
		ΔRH percent (2071-2100;1971-2000)	-4	-3	-3	3	0	3	3	3	1	0	-5	0	0	3	-2	-2	0
	Samtredia	RH in 2071-2100; %	71	70	68	73	73	81	84	86	82	78	75	74	72	83	78	72	76
		ΔRH value (2071-2100;1971-2000)	-3	-1	0	3	1	4	4	6	4	2	0	-1	1	5	2	-2	2
		ΔRH percent (2071-2100;1971-2000)	-3	-2	-1	5	1	6	6	8	4	2	0	-1	2	6	2	-2	2
Racha Lechkhumi – Kvemo Svaneti	Lentekhi	RH in 2071-2100; %	84	83	75	79	80	86	81	82	84	88	87	90	78	83	86	86	83
		ΔRH value (2071-2100;1971-2000)	-5	-2	-5	4	6	9	5	4	2	3	-3	-2	1	6	1	-3	1
		ΔRH percent (2071-2100;1971-2000)	-6	-2	-6	5	7	12	6	5	3	4	-3	-2	2	8	1	-3	2
	Ambrolauri	RH in 2071-2100; %	78	76	69	76	74	79	77	77	78	79	80	84	73	78	79	79	77
		ΔRH value (2071-2100;1971-2000)	-4	-2	-2	6	0	4	1	2	1	0	-1	-1	1	2	0	-2	0
		ΔRH percent (2071-2100;1971-2000)	-5	-2	-3	9	1	5	2	2	2	0	-2	-1	2	3	0	-3	0
Samtskhe-Javakheti	Akhaltsikhe	RH in 2071-2100; %	78	75	66	70	70	74	71	72	68	72	77	83	69	72	73	79	73
		ΔRH value (2071-2100;1971-2000)	-2	-2	-5	2	-1	2	2	3	-1	0	-2	1	-1	2	-1	-1	0
		ΔRH percent (2071-2100;1971-2000)	-3	-2	-7	2	-2	3	3	5	-2	-1	-2	1	-2	3	-2	-1	0

Table B3: Projected relative humiditsupport during 2071–2100 years and their change between two 30-year periods (1971–2000 and 2071–2100)

Region	Station		1	2	3	4	5	6	7	8	9	10	11	12	Spring	Summer	Autumn	Winter	Year
Samtskhe-Javakheti	Tsalka	RH in 2071-2100; %	74	75	75	73	81	81	79	82	80	82	75	76					
		ΔRH value (2071-2100;1971-2000)	-1	0	-2	-2	3	3	3	6	2	3	-3	0	0	4	1	0	1
		ΔRH percent (2071-2100;1971-2000)	-2	-1	-2	-2	3	4	4	7	3	4	-4	0	0	5	1	-1	1
	Akhalkalaki	RH in 2071-2100; %	75	74	68	70	72	75	74	73	67	71	74	78	70	74	71	76	72
		ΔRH value (2071-2100;1971-2000)	-3	-3	-7	0	0	1	0	1	-3	-1	-2	0	-2	1	-2	-2	-1
		ΔRH percent (2071-2100;1971-2000)	-4	-4	-9	1	0	1	0	2	-4	-1	-3	0	-3	1	-3	-3	-2
	Paravani	RH in 2071-2100; %	69	70	68	67	73	77	78	78	72	69	65	70	69	78	69	69	71
		ΔRH value (2071-2100;1971-2000)	-6	-5	-8	-5	0	3	3	5	1	-1	-7	-5	-4	4	-3	-5	-2
		ΔRH percent (2071-2100;1971-2000)	-8	-7	-10	-8	1	4	4	7	1	-2	-10	-6	-6	5	-4	-7	-3
Shida Qartli	Khashuri	RH in 2071-2100; %	80	79	73	72	74	77	75	74	75	78	79	81	73	75	77	80	76
		ΔRH value (2071-2100;1971-2000)	-3	-3	-3	0	-1	1	0	1	-1	-2	-4	-3	-1	1	-2	-3	-1
		ΔRH percent (2071-2100;1971-2000)	-4	-3	-4	1	-1	1	0	1	-1	-2	-4	-3	-1	1	-3	-4	-2
	Gori	RH in 2071-2100; %	78	75	68	70	71	72	70	70	71	76	78	81	70	71	75	78	73
		ΔRH value (2071-2100;1971-2000)	-3	-2	-3	2	0	1	1	2	0	0	-2	-1	0	1	-1	-2	0
		ΔRH percent (2071-2100;1971-2000)	-3	-3	-4	3	1	2	1	3	0	1	-3	-1	0	2	-1	-2	0
Kvemo Qartli	Tbilisi	RH in 2071-2100; %	71	69	66	62	68	66	63	65	68	74	73	72	65	65	72	71	68
		ΔRH value (2071-2100;1971-2000)	-2	-1	-0.5	0	2	4	3	5	4	3	-2	-2	1	4	2	-2	1
		ΔRH percent (2071-2100;1971-2000)	-3	-2	-0.3	-1	4	6	5	8	6	4	-2	-3	1	6	2	-3	2
	Bolnisi	RH in 2071-2100; %	71	73	73	70	75	72	67	70	71	76	74	73	73	70	74	73	72
		ΔRH value (2071-2100;1971-2000)	-2	0	3	3	5	7	9	12	8	4	-1	-1	4	9	4	-1	4
		ΔRH percent (2071-2100;1971-2000)	-2	0	4	4	8	11	15	21	12	6	-2	-2	5	16	5	-1	6
Mtskheta-Mtoaneti	Pasanauri	RH in 2071-2100; %	73	71	69	68	79	80	79	81	80	79	72	76	72	80	77	73	76
		ΔRH value (2071-2100;1971-2000)	-5	-4	-3	-2	3	4	3	5	3	1	-6	-3	-1	4	-1	-4	0
		ΔRH percent (2071-2100;1971-2000)	-6	-5	-4	-3	5	5	4	7	3	2	-8	-4	-1	5	-1	-5	0
	Tianeti	RH in 2071-2100; %	78	79	77	76	80	82	80	81	83	84	79	81	78	81	82	79	80
		ΔRH value (2071-2100;1971-2000)	-4	-3	-3	1	3	5	5	6	4	3	-3	-3	0	5	1	-3	1
		ΔRH percent (2071-2100;1971-2000)	-5	-4	-4	2	4	6	7	8	6	4	-4	-3	1	7	2	-4	1
Kakheti	Kvareli	RH in 2071-2100; %	76	77	71	76	77	73	71	73	75	81	80	80	75	72	79	78	76
		ΔRH value (2071-2100;1971-2000)	-5	-2	-4	3	3	2	2	4	2	2	-2	-1	1	3	0	-3	0
		ΔRH percent (2071-2100;1971-2000)	-6	-3	-6	4	4	3	3	5	2	2	-3	-2	1	4	0	-4	0
	Telavi	RH in 2071-2100; %	74	74	70	72	76	74	71	74	78	84	79	77	73	73	80	75	75
		ΔRH value (2071-2100;1971-2000)	1	2	1	5	6	7	6	8	8	8	3	3	4	7	6	2	5
		ΔRH percent (2071-2100;1971-2000)	1	3	1	7	9	10	9	12	11	10	4	4	6	10	8	2	7
	Gurjaani	RH in 2071-2100; %	76	74	72	70	75	72	69	72	74	82	77	78	72	71	78	76	74
		ΔRH value (2071-2100;1971-2000)	-3	-2	-1	-1	2	3	2	4	2	2	-4	-2	0	3	0	-2	0
		ΔRH percent (2071-2100;1971-2000)	-4	-3	-2	-1	3	4	3	6	2	3	-5	-2	0	5	0	-3	0
	Sagarejo	RH in 2071-2100; %	68	68	68	63	69	68	66	68	70	76	70	68	67	67	72	68	68
		ΔRH value (2071-2100;1971-2000)	-1	-1	-0.1	-1	3	4	4	6	3	4	-2	-1	0	5	2	-1	1
		ΔRH percent (2071-2100;1971-2000)	-2	-1	-0.1	-2	4	6	7	10	5	5	-3	-2	1	7	2	-2	2
	Dedoplistskaro	RH in 2071-2100; %	79	81	80	78	81	78	76	77	78	86	82	81	80	77	82	80	80
		ΔRH value (2071-2100;1971-2000)	-2	-1	0.1	1	2	4	6	8	4	3	-1	0	1	6	2	-1	2
		ΔRH percent (2071-2100;1971-2000)	-2	-1	0.1	2	3	5	8	12	6	4	-1	-1	2	8	3	-1	3

Table B 4: Projected wind speeds during 2071–2100 years and their change between two 30-year periods (1971–2000 and 2071–2100)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Adjara	Kobuleti	Wind in 2071-2100; m/sec	3.8	4.1	3.8	3.6	3.5	3.5	3.5	3.3	3.1	3.3	3.5	3.6	3.6	3.4	3.3	3.8	3.5
		ΔWind, m/sec	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.3	0.4	0.4	0.4
		ΔWind, %	12	11	11	12	11	11	10	8	13	14	15	13	12	10	14	12	12
	Batumi	Wind in 2071-2100; m/sec	6.2	5.4	4.4	4.1	3.5	3.8	3.6	3.7	4.2	4.8	5.6	6.4	4.0	3.7	4.9	6.0	4.6
		ΔWind, m/sec	0.3	0.3	0.4	0.3	0.5	0.4	0.4	0.3	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.4
		ΔWind, %	6	6	10	9	15	11	12	9	12	10	8	5	11	11	10	6	9
	Khulo	Wind in 2071-2100; m/sec	2.4	2.4	2.3	2.0	2.1	1.9	1.8	1.8	1.9	2.0	2.2	2.3	2.1	1.8	2.1	2.4	2.1
		ΔWind, m/sec	0.2	0.1	0.1	0.0	0.2	0.3	0.4	0.3	0.4	0.4	0.3	0.2	0.1	0.3	0.4	0.1	0.2
		ΔWind, %	7	4	4	-1	14	16	26	24	26	22	16	8	5	22	21	6	12
	Goderdzi Pass	Wind in 2071-2100; m/sec	6.0	5.8	5.0	4.0	3.8	3.9	3.9	4.1	4.0	4.3	4.5	5.2	4.3	4.0	4.3	5.7	4.5
		ΔWind, m/sec	-0.5	-0.5	-0.1	-0.3	-0.5	-0.3	0.0	0.0	-0.3	-0.2	-0.3	-0.5	-0.3	-0.1	-0.3	-0.5	-0.3
		ΔWind, %	-7	-8	-3	-8	-13	-7	0	0	-6	-4	-6	-9	-7	-2	-6	-8	-6
Guria	Chokhatauri	Wind in 2071-2100; m/sec	2.2	2.5	2.5	2.3	1.9	1.5	1.3	1.2	1.5	1.9	2.1	2.1	2.3	1.3	1.8	2.2	1.9
		ΔWind, m/sec	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.4
		ΔWind, %	24	19	20	23	36	37	48	44	48	32	30	25	25	42	35	22	29
	bakhmaro	Wind in 2071-2100; m/sec	2.9	2.8	2.6	2.3	2.1	1.5	1.3	1.0	1.4	1.8	2.2	2.7	2.3	1.3	1.8	2.8	2.0
		ΔWind, m/sec	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.3	0.3
		ΔWind, %	12	12	13	18	25	30	38	34	42	28	25	14	18	34	30	13	21
Samegrelo - Zemo Svaneti	Zugdidi	Wind in 2071-2100; m/sec	1.5	1.9	2.0	1.7	1.8	1.5	1.4	1.3	1.2	1.3	1.3	1.4	1.8	1.4	1.3	1.6	1.5
		ΔWind, m/sec	0.4	0.4	0.4	0.2	0.5	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	0.4
		ΔWind, %	35	28	25	18	35	31	43	38	37	40	32	34	25	37	36	32	32
	Poti	Wind in 2071-2100; m/sec	3.3	3.7	3.5	3.1	2.7	2.4	2.4	2.2	2.1	2.8	3.1	3.1	3.1	2.3	2.7	3.4	2.9
		ΔWind, m/sec	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		ΔWind, %	13	11	13	11	19	18	20	19	19	16	13	13	14	19	16	13	15
Imereti	Sachkhere	Wind in 2071-2100; m/sec	1.1	1.3	2.0	2.1	2.3	2.0	1.9	2.0	1.8	1.4	1.0	1.0	2.1	2.0	1.4	1.1	1.7
		ΔWind, m/sec	0.4	0.3	0.4	0.3	0.5	0.4	0.4	0.5	0.5	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4
		ΔWind, %	68	36	24	16	31	27	30	30	40	50	53	73	23	29	46	55	34
	Kutaisi	Wind in 2071-2100; m/sec	6.5	7.0	7.2	6.2	5.8	4.6	4.2	4.2	5.1	6.1	6.1	6.1	6.4	4.4	5.8	6.5	5.8
		ΔWind, m/sec	0.4	0.4	0.4	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
		ΔWind, %	7	6	6	5	9	8	11	9	8	7	6	6	7	10	7	6	7
	Mta Sabueti	Wind in 2071-2100; m/sec	5.3	5.7	5.9	5.9	5.8	4.7	4.8	5.5	5.8	5.9	5.2	4.8	5.9	5.0	5.6	5.3	5.4
		ΔWind, m/sec	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.4	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.3
		ΔWind, %	4	3	5	5	5	4	5	4	7	5	7	7	5	4	6	5	5
	Zestaponi	Wind in 2071-2100; m/sec	1.6	1.9	2.2	1.9	2.0	1.4	1.4	1.6	1.7	1.7	1.5	1.4	2.0	1.5	1.6	1.6	1.7
		ΔWind, m/sec	-0.6	-0.6	-0.6	-0.5	-0.4	-0.4	-0.2	0.1	-0.1	-0.4	-0.4	-0.4	-0.5	-0.2	-0.3	-0.6	-0.4
		ΔWind, %	-27	-24	-21	-21	-17	-23	-9	7	-4	-20	-23	-23	-20	-10	-16	-25	-18

Table B4: Projected wind speeds during 2071–2100 years and their change between two 30-year periods (1971–2000 and 2071–2100)

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Imereti	Samtredia	Wind in 2071-2100; m/sec	2.7	3.0	3.3	2.8	2.9	2.3	2.1	1.9	2.2	2.6	2.4	2.3	3.0	2.1	2.4	2.7	2.5
		ΔWind, m/sec	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5
		ΔWind, %	23	19	17	17	22	23	30	28	25	23	23	25	19	27	24	22	22
Racha - Lechkhumi and Kvemo Svaneti	Shovi	Wind in 2071-2100; m/sec	1.4	1.6	1.7	1.7	1.7	1.6	1.8	1.6	1.9	1.8	1.5	1.4	1.7	1.7	1.7	1.5	1.6
		ΔWind, m/sec	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.3	0.0	0.1
		ΔWind, %	-1	3	1	9	11	5	12	13	22	18	16	5	7	10	19	2	10
	Ambrolauri	Wind in 2071-2100; m/sec	1.4	1.8	2.3	2.2	2.3	2.0	2.1	2.0	2.0	1.8	1.5	1.4	2.3	2.0	1.8	1.6	1.9
		ΔWind, m/sec	0.4	0.3	0.3	0.2	0.5	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4	0.4
		ΔWind, %	42	24	16	13	30	28	30	30	36	38	36	44	19	29	36	35	29
	Lentekhi	Wind in 2071-2100; m/sec	0.5	0.5	0.5	0.5	0.8	0.9	1.0	1.0	1.0	0.8	0.6	0.6	0.6	0.9	0.8	0.5	0.7
		ΔWind, m/sec	0.4	0.4	0.3	0.3	0.5	0.6	0.6	0.7	0.7	0.6	0.4	0.4	0.4	0.6	0.6	0.4	0.5
		ΔWind, %	364	316	216	135	178	167	198	214	237	227	287	374	172	192	245	352	221
Samtskhe - Javakheti	Borjomi	Wind in 2071-2100; m/sec	1.2	1.4	1.4	1.4	1.5	1.5	1.5	1.4	1.4	1.2	1.0	1.0	1.4	1.5	1.2	1.2	1.3
		ΔWind, m/sec	0.4	0.4	0.3	0.4	0.5	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4
		ΔWind, %	43	38	32	44	43	42	43	42	58	76	94	67	40	42	73	47	49
	Akhaltsikhe	Wind in 2071-2100; m/sec	0.9	1.1	1.3	1.5	1.5	1.2	1.4	1.3	1.3	1.1	0.9	0.9	1.4	1.3	1.1	0.9	1.2
		ΔWind, m/sec	0.1	0.1	0.2	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.3	0.2	0.3	0.3	0.4	0.2	0.3
		ΔWind, %	19	15	17	27	40	37	38	32	50	44	47	33	28	36	47	21	33
	Bakuriani	Wind in 2071-2100; m/sec	1.2	1.3	1.5	1.8	1.7	1.4	1.7	1.8	1.4	1.0	1.1	1.3	1.7	1.7	1.2	1.3	1.5
		ΔWind, m/sec	0.2	0.2	0.1	0.2	0.4	0.3	0.3	0.2	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.3
		ΔWind, %	16	13	10	16	25	23	20	13	33	43	39	21	17	18	38	16	21
	Akhalkalaki	Wind in 2071-2100; m/sec	2.4	2.7	2.8	3.0	2.7	2.2	2.1	2.1	2.1	2.1	2.3	2.4	2.8	2.1	2.2	2.5	2.4
		ΔWind, m/sec	0.1	0.1	0.1	0.2	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.1	0.2
		ΔWind, %	4	4	4	9	16	14	16	15	23	18	12	7	10	15	17	5	11
	Paravani	Wind in 2071-2100; m/sec	5.2	4.9	4.3	4.2	4.1	3.9	4.2	4.3	3.9	4.2	4.7	5.2	4.2	4.1	4.3	5.1	4.4
		ΔWind, m/sec	0.4	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.5	0.6	0.5	0.4	0.3	0.3	0.5	0.4	0.4
		ΔWind, %	9	8	8	6	8	7	8	9	13	15	12	8	7	8	13	8	9
Shida Kartli	Khashuri	Wind in 2071-2100; m/sec	1.5	1.4	1.9	2.2	1.9	1.8	1.9	1.9	1.7	1.4	1.3	1.4	2.0	1.8	1.5	1.4	1.7
		ΔWind, m/sec	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1
		ΔWind, %	12	5	5	12	9	6	6	5	10	15	21	17	9	6	15	11	10
	Gori	Wind in 2071-2100; m/sec	1.7	2.0	2.3	2.3	2.1	1.9	2.0	2.0	2.0	1.7	1.5	1.5	2.2	2.0	1.7	1.7	1.9
		ΔWind, m/sec	0.1	0.0	0.1	0.2	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2
		ΔWind, %	7	2	3	11	12	9	9	7	14	14	18	18	8	8	15	8	10
Kvemo Kartli	Tbilisi	Wind in 2071-2100; m/sec	1.5	1.7	1.8	1.9	1.8	1.8	1.9	1.7	1.8	1.6	1.5	1.4	1.9	1.8	1.6	1.5	1.7
		ΔWind, m/sec	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.2	0.4	0.5	0.5	0.5	0.4	0.3	0.5	0.5	0.4
		ΔWind, %	41	36	30	35	26	22	19	16	29	42	49	62	30	19	39	45	32

Table B4: Continuation

Region	Station		Month												Spring	Summer	Autumn	Winter	Year
			1	2	3	4	5	6	7	8	9	10	11	12					
Kvemo Kartli	Bolnisi	Wind in 2071-2100; m/sec	1.2	1.3	1.3	1.4	1.3	1.3	1.1	1.0	1.1	1.1	1.1	1.2	1.3	1.1	1.1	1.2	1.2
		ΔWind, m/sec	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.5	0.5	0.3	0.2	0.4	0.4	0.3
		ΔWind, %	55	43	39	28	27	29	28	18	33	58	73	77	31	25	53	57	40
	Tsalka	Wind in 2071-2100; m/sec	1.8	1.5	1.4	1.7	1.5	1.4	1.3	1.3	1.5	1.4	1.7	1.8	1.5	1.3	1.5	1.7	1.5
		ΔWind, m/sec	0.1	0.1	0.1	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.2	0.2
		ΔWind, %	8	5	8	21	22	19	22	18	27	29	31	17	17	19	29	10	18
	Gardabani	Wind in 2071-2100; m/sec	1.2	1.3	1.7	1.7	1.6	1.8	2.0	1.7	1.6	1.3	1.2	1.1	1.7	1.8	1.4	1.2	1.5
		ΔWind, m/sec	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.4
		ΔWind, %	61	50	33	30	36	30	25	31	41	72	71	85	33	29	58	63	42
Mtskheta-Mtianeti	Pasanauri	Wind in 2071-2100; m/sec	1.5	1.7	1.7	1.7	1.7	1.6	1.6	1.4	1.5	1.5	1.3	1.3	1.7	1.5	1.4	1.5	1.5
		ΔWind, m/sec	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.3	0.4	0.2	0.3
		ΔWind, %	16	15	11	15	17	17	21	23	34	31	36	29	14	20	34	19	21
	Tianeti	Wind in 2071-2100; m/sec	1.4	1.6	1.7	1.7	1.7	1.6	1.4	1.5	1.5	1.6	1.3	1.4	1.7	1.5	1.5	1.5	1.5
		ΔWind, m/sec	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		ΔWind, %	50	37	37	30	44	42	51	57	55	52	55	57	36	49	54	47	46
	Stepantsminda	Wind in 2071-2100; m/sec	2.2	2.4	2.3	2.5	2.5	2.1	1.9	1.9	2.3	2.2	2.3	2.4	2.4	2.0	2.3	2.3	2.3
		ΔWind, m/sec	-0.3	-0.2	-0.2	-0.1	0.1	0.0	-0.1	-0.2	-0.1	-0.2	-0.3	-0.3	-0.1	-0.1	-0.2	-0.3	-0.2
		ΔWind, %	-13	-7	-6	-4	3	-1	-4	-11	-4	-9	-10	-11	-2	-6	-8	-10	-7
Kakheti	Telavi	Wind in 2071-2100; m/sec	1.8	1.9	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.7	1.8	2.0	1.9	1.8	1.8	1.9
		ΔWind, m/sec	0.6	0.6	0.5	0.4	0.5	0.6	0.6	0.6	0.7	0.7	0.6	0.7	0.5	0.6	0.6	0.6	0.6
		ΔWind, %	50	43	34	28	38	41	45	51	52	56	50	58	33	46	53	50	45
	Gurgaani	Wind in 2071-2100; m/sec	1.2	1.4	1.5	1.6	1.5	1.4	1.2	1.2	1.3	1.2	1.2	1.3	1.6	1.3	1.3	1.3	1.4
		ΔWind, m/sec	0.4	0.4	0.5	0.5	0.5	0.4	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
		ΔWind, %	47	49	45	43	44	38	36	37	50	48	60	66	44	37	52	54	46
	Lagodekhi	Wind in 2071-2100; m/sec	0.7	0.8	0.9	0.9	1.0	1.0	0.8	0.9	0.9	0.8	0.6	0.7	0.9	0.9	0.8	0.8	0.8
		ΔWind, m/sec	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4
		ΔWind, %	146	96	91	76	106	96	132	132	112	127	171	154	91	117	130	127	114
	Sagarejo	Wind in 2071-2100; m/sec	2.2	2.1	2.0	2.1	2.0	1.9	1.8	1.7	2.0	2.0	2.0	2.2	2.0	1.8	2.0	2.2	2.0
		ΔWind, m/sec	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.5	0.5	0.5	0.4	0.3	0.5	0.4	0.4
		ΔWind, %	23	25	25	26	27	23	23	20	28	31	29	28	26	22	29	26	26
	Kvareli	Wind in 2071-2100; m/sec	1.1	1.2	1.3	1.3	1.4	1.3	1.1	1.1	1.3	1.2	1.1	1.1	1.3	1.2	1.2	1.1	1.2
		ΔWind, m/sec	0.3	0.3	0.2	0.2	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.3
		ΔWind, %	46	33	24	22	36	35	39	41	53	56	57	68	27	38	55	48	41
	Dedoplistskaro	Wind in 2071-2100; m/sec	1.4	1.1	1.7	1.4	1.2	1.0	1.4	1.1	1.2	1.3	1.4	1.3	1.4	1.2	1.3	1.3	1.3
		ΔWind, m/sec	-0.2	-0.7	0.2	-0.4	-0.3	-0.3	0.2	-0.2	0.0	0.1	0.0	-0.2	-0.2	-0.1	0.0	-0.4	-0.2
		ΔWind, %	-14	-39	10	-21	-22	-23	20	-14	-3	4	2	-14	-11	-7	1	-23	-11

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