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THE GEORGIAN ROAD MAP ON CLIMATE CHANGE ADAPTATION

FOREWORD

The National Association of Local Authorities of Georgia (NALAG) has been implementing a USAID-funded Initiative "Institutionalization of Climate Change Adaptation and Mitigation in Georgian Regions (ICCAMGR)" since 2012. The program is designed to foster climate change adaptation measures in regions of Georgia through the institutionalization of climate change adaptation and mitigation at the local and national levels by building the capacities of local authorities.
The Project is a flagship initiative that integrates environmental and climate change considerations into the agendas of the local authorities of Georgia. The Project envisages establishment of special units on climate change, environment and sustainable agriculture at the level of self-government to ensure the implementation of a broad range of statutory functions of local authorities in terms of natural resources management, spatial planning and sustainable development stipulated in the "Organic Law of Georgia on Local Self-Government" and sectoral legislation.

The Georgian Road Map on Climate Change Adaptation is an important contribution of the efforts of NALAG and the ICCAMGR project.

THE GEORGIAN ROAD MAP ON CLIMATE CHANGE ADAPTATION

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Acronyms

AutRC	Austrian Red Cross
CBD	Convention on Biological Diversity
CENN	Caucasus Environmental NGO Network
CID	Daytime Comfort Index
CoM	Covenant of Mayors
DCFTA	Deep and Comprehensive Free Trade Area
EEA	European Environment Agency
EIA	Environmental Impact Assessment
ESPON	European Spatial Planning Observation Network
EU	European Union
FIRMS	Fire Information for Resource Management System
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIS	Geographic Information System
GIZ	German Society for International Cooperation
GoG	Government of Georgia
ICCAMGR	Institutionalization of Climate Change Adaptation and Mitigation in Georgian Regions
ILO	International Labor Organization
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LAU	Local Administrative Unit
LEDS	Low-Emission Development Strategies
MoA	Ministry of Agriculture of Georgia
MoENRP	Ministry of Environment and Natural Resources Protection of Georgia
MoU	Memorandum of Understanding
NALAG	National Association of Local Authorities of Georgia
NAPA	National Adaptation Program of Action
NGO	Non-Governmental Organization
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organization for Economic Cooperation and Development
SRES	Special Report on Emission Scenarios
TSA	Targeted Social Assistance
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
USAID	United States Agency for International Development
WHO	World Health Organization
WMO	World Meteorological Organization

Climate change is one of the most significant contemporary problems for the environment and socio-economic development worldwide. The geographical location and natural conditions of Georgia – a small country with a complex mountainous landscape, a significant Black Sea coastal zone and semi-arid areas in the Southeast – predetermine the country's substantial vulnerability to climate change. A higher frequency of natural hazards and other changes occurring during recent decades, such as increasing temperatures, increased frequency of droughts and hail storms, etc., are the observable signs of climate change. All this is a significant challenge for the developing economy of the country with a GDP of USD 16.5 billion.

Georgia is a party to different international environmental treaties, including the United Nations Framework Convention on Climate Change (UNFCCC)[1], the Kyoto Protocol to the United Nations Framework Convention on Climate Change (the Kyoto Protocol)[2], the Convention on Biological Diversity (CBD)[3] and the United Nations Convention to Combat Desertification (UNCCD)[4].

These conventions compel the country to work on a wide spectrum of issues related to climate change. For instance, taking into account provisions of the UNFCCC, Georgia, as a signatory, is required to contribute to decreasing greenhouse gas emissions, as well as adaptation to climate change in ecosystems and economic sectors.

To assess the impact of climate change on socio-economic sectors, a country needs to develop climate change scenarios, which are future climate projections that can be forecasted with mathematical modeling of the climate system in different socio-economic development scenarios. Such modeling research allows the determination of a probabilistic set of developments, based on which the ability to resist the impact of climate change can be assessed, the connected risks can be defined, and strategies on adaptation and mitigation of negative consequences can be elaborated to ensure the sustainable development of a country.

All of the above-mentioned climate change elements are especially significant for small, high-mountain countries such as Georgia, where the climate often has a decisive role in everyday life. Knowledge of scenarios of climate change consequences and of the development of extreme phenomena is vital for these countries and for planning of almost all economic or social sectors, including for water resources management, sustainable development of agriculture, tourism, and construction of roads, railways and buildings.

While policies for adaptation to climate change are being developed at the sub-regional, regional and national levels, the actual implementation of adaptation measures will be conducted at local levels. Consequently, self-governed municipalities[5] should have their own vision corresponding to local development plans and goals. In addition, municipalities should have their own means to reach their goals and to implement action plans.

[1] Georgia acceded to the Convention on May 16, 1994 by the Decision #302 of the Cabinet of Ministers (in force since September 27, 1994).
[2] In force in Georgia by the decision of the Parliament of Georgia of May 28, 1999.
[3] Ratified by the decision of the Parliament of Georgia of April 21, 1994 (in force since August 31, 1994).
[4] Ratified by the decision of the Parliament of Georgia of June 23, 1999 (in force since October 21, 1999).
[5] There is one tier of self-governance in Georgia called a municipality that can be either a self-governing community or a self-governing city.

This document entitled "The Georgian Road Map on Climate Change Adaptation" (hereinafter the Road Map) is a comparative assessment of the impact of climate change on different priority economic, social or environmental sectors by municipality and includes adaptation recommendations developed on the basis of the assessment. The Road Map has been developed in the framework of the "Institutionalization of Climate Change Adaptation and Mitigation in Georgia Regions" project with support from the United States Agency for International Development (USAID)[6]. The Road Map was developed utilizing a rapid assessment methodology, not in-depth analysis in particular sectors.

The report includes the following sections:

1. Methodology: the description of approaches utilized for analysis of sensitivity and climate change impacts;
2. Climate change scenario overview: for the periods of 2021-2050 and 2071-2100 in Georgia;
3. Sensitivity: description of the sensitivity of the environment, economic and social sectors to climate change for the base year (for the majority of sectors, data is for 2015);
4. Impact analysis: potential climate change impact analysis on the given sectors for the periods 2021-2050 and 2071-2100;
5. Recommendations: developed based on the analysis.

The document covers the following economic, social and environmental sectors:

1. Tourism
2. Cultural heritage
3. Protected areas
4. Agriculture
5. Forest ecosystems
6. Industry
7. Energy
8. Infrastructure and natural hazards
9. Social sector

The three components of the analysis (climate change exposure, sensitivity and impact) are illustrated by relevant maps:

1. Climate change exposure for the two projection periods by municipality;
2. Climate change sensitivity for the different socio-economic sectors by municipality; and
3. Climate change impact on the socio-economic sectors for the two projection periods.

The above-mentioned maps are created in accordance with quantitative indicators and give the possibility to provide comparative analyses of climate change impact and sensitivity among Georgian municipalities.

The analytical part of the Road Map is based on quantitative indicators of climate exposure and sensitivity selected for each socio-economic or environmental sector. The quantitative indicators were selected: (a) to be comparable with international indicators, European in particular[7] ; (b) as a function of the availability of statistical data in Georgia; and, most importantly (c) based on the needs and peculiarities of the country.

[6] NALA project web page: http://nala.ge/climatechange/eng/home (accessed March 20, 2016).
[7] Selected indicators mostly comply with the indicators defined by the European Environment Agency (EEA). See EEA, Climate change, impacts and vulnerability in Europe 2012. An indicator-based report, 2012. http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012 (accessed March 20, 2016).

The information collected based on quantitative indicators clearly demonstrates what statistical information related to climate change assessment is available in Georgia. Taking into account the main project goal of supporting the institutional development of self-government units to combat climate change as well as the administrative-territorial arrangement of Georgia, information was collected through municipalities. Municipalities are the key self-governing units for which statistical data should be collected, though statistical data at the regional level is more diverse and readily available. Decisions on socio-economic development should be made at the municipal level by elected local authorities for each municipality. According to European standards, Georgian self-governing units (municipalities) correspond to a LAU1 European statistical region[8]. Taking into account that climate change adaptation measures must be implemented at the local level, statistical information should be available not only at the municipal level, but also at the level of territorial units of a municipality (European statistical region – LAU 2). However, for the moment, obtaining information for these smallest territorial units from official sources is almost impossible.

[8] NUTS and LAU: Statistical regions of the European Union. Nomenclature of Territorial Units for Statistics (NUTS, levels 1, 2 and 3) and Local Administrative Unit (LAU, levels 1 and 2). Concordance for Georgia with the European Union nomenclature is not yet defined.

In the "EU-Georgia Association Agreement" signed in 2014, it is noted: "the Parties shall develop and strengthen their cooperation on statistical issues, thereby contributing to the long-term objective of providing timely, internationally comparable and reliable statistical data. It is expected that a sustainable, efficient and professionally independent national statistical system shall produce information relevant for citizens, businesses and decision-makers in Georgia and in the EU, enabling them to take informed decisions on this basis[9]."

Cooperation between European Union and Georgia in this field aims at:

(a) Further strengthening the capacity of the national statistical system, focusing on the sound legal basis, production of adequate data and metadata, dissemination policy and user friendliness, taking into account various groups of users, in particular public and private sectors, academic community and other users;
(b) Progressive alignment of the statistical system of Georgia with the European Statistical System;
(c) Fine-tuning of data provision to the EU, taking into account the application of relevant international and European methodologies, including classifications;
(d) Enhancing the professional and management capacity of the national statistical staff to facilitate the application of European statistical standards and to contribute to the development of the Georgian statistical system.

Parties shall cooperate within the European statistics system, in which Eurostat is the leading body responsible for European statistics. Cooperation shall cover the following fields:

(a) Macroeconomic statistics, including national accounts, foreign trade statistics, balance of payments statistics, foreign direct investment statistics;
(b) Demographic statistics, including censuses and social statistics;
(c) Agricultural statistics, including agricultural censuses and environment statistics;
(d) Business statistics, including business registers and use of administrative sources for statistical purposes;
(e) Energy statistics, including balances;
(f) Regional statistics;
(g) Horizontal activities, including statistical classifications, quality management, training, dissemination, use of modern information technologies, and
(h) Other relevant areas.

Collection of European statistical data is carried out through subdivisions of countries as defined by the Nomenclature of Territorial Units for Statistics standards describing several administrative levels (NUTS1, NUTS2, NUTS3) and Local Administrative Units (LAU1 and LAU2) in a descending order of size[10]. Many reports (i.e. reports on climate change and environmental reports) use statistics collected by the above-mentioned administrative-territorial units. Hence, to make decisions efficiently, it is necessary to develop a system of regional statistics similar to the European system, as well as to integrate environmental, agricultural, and climate change components. The country can then develop more precise projections using climate change models and, in addition, can observe climate change in so-called 'non-climactic' socio-economic quantitative data. Such information will reveal trends of climate change more clearly across different sectors. For the time being, the type of information (quantitative and spatial data) necessary for conducting indicator-based research in Georgia (e.g. as conducted under the Road Map), is not sufficient, and does not allow observation of changes in a historical perspective. It is especially challenging to collect such data by regions and municipalities. To tackle the mentioned challenges, it is advisable to develop and adopt quantitative indicators for climate change observation at the national level, based on which the relevant state institutions, including the National Statistics Office of Georgia, would be able to collect the necessary data.

[9] EU-Georgia Association Agreement, Title V: Chapter IV: Statistics, 2014: http://eeas.europa.eu/georgia/pdf/eu-ge_aa-dcfta_en.pdf
[10] Ibid.

It should be noted that while making climate projections for different exposures through modeling in this document, it was impossible to develop forecasts for socio-economic sectors based on non-climactic data for different reasons, including limited availability of concrete historical non-climactic data necessary for future modeling and consequently for the development of more reliable forecasts. That is why the projections are based only on the climate change data and do not consider future changes in socio-economic parameters.

As mentioned above, the availability of spatial data is also limited, a situation that hinders implementation of the relevant provisions of the Association Agreement, Chapter 21, under "Title VI: Other Cooperation Policies." This document describes cooperation on regional development, cross-border and regional levels, as well as enforcement of relevant national guiding documents, such as the National Strategy and Regional Development of Georgia for 2010-2017 and the Regional Development Program[11], developed based on EU cohesion policy with the experience of the last decades. This policy has been significantly strengthened in Europe since 1990, when Europe first decided to provide assistance to less developed member countries and later when Europe used this policy with regard to satisfying the needs of new member states.

Chapter 4, under "Title VI: Other Cooperation Policies" of the Association Agreement contains provisions on development and strengthening of cooperation to combat climate change. The cooperation shall aim at mitigating and adapting to climate change, as well as promoting measures at the international level, including in research, development, demonstration, deployment and diffusion of safe and sustainable low-carbon and adaptation technologies; distribution of climate-related information and integration of climate-related issues into sectoral policies. The Chapter also underlines the need to develop and implement the National Adaptation Program of Action (NAPA) and the Low-Emission Development Strategy (LEDS) including "nationally acceptable mitigation actions".

[11] Order N1215 of the Government of Georgia of July 9, 2014, on Adoption of The Regional Development Program of Georgia for 2015-2017.

The Government Programs[12] for the period 2012-2016 underline the necessity of the development of the National Adaptation Action Plan and the Adaptation Strategy to Climate Change. Separate chapters of the documents dedicated to environmental protection and rational use of natural resources define actions to be undertaken on adaptation to climate change. As noted in the document, National Adaptation Plan for Economic Sectors and Ecosystems and National Low Emission Development Strategy will be prepared in accordance with the UN Framework Convention on Climate Change. Climate change mitigation and adaptation measures will also be undertaken.

Analysis conducted within the framework of the Road Map on Adaptation to Climate Change can serve as a basis for the development of an adaptation strategy as, for the time being, this is the only document that covers the entire territory of Georgia and all major economic, social and environmental sectors. The analysis allows comparisons at the country scale of the levels of vulnerability of different sectors to climate change within different municipalities.

Other national action plans, strategies and programs also promote the necessity of developing adaptation measures to climate change and the need for continuing relevant studies in this direction.

The Socio-Economic Development Strategy for Georgia: Georgia 2020, a key socio-budgetary and economic planning document, defines directions for socio-economic policy of the state[13]. The document highlights socio-economic priorities until 2020. One of the sections of this document describes the state vision on directions of infrastructure development and, at the same time, concerns possible threats of climate change. In particular, according to the strategy, "the environmental impact and negative impact of global warming on the country's economy must also be taken into consideration during the planning of infrastructure development."

Several chapters of this Road Map are dedicated to the assessment of the increasing impact of natural hazards from climate change on existing infrastructure (roads, settlements, energy infrastructure and cultural heritage sites). The analysis given in the Road Map is limited by a lack of information availability from official sources, though it shows the scale of the problem and points out directions for future research and fields where more in-depth analysis is needed to make proper decision-making. For instance, spatial coordinates for industrial sites have not been defined within the framework of research conducted and consequently, attaching the mentioned sites to any of the natural hazard prone areas was not possible, and consequently, the related risks to industry were not defined.

The State Strategy on Regional Development of Georgia 2010-2017 was adopted by Decree of the Government of Georgia N172 (June 25, 2010)[14], while the Action Plan of 2011 for the State Strategy on Regional Development of Georgia for the period of 2010-2017 was later adopted by Order N1448 of the Government of Georgia on November 16, 2010. One of the main aims of the Strategy is ensuring environmental protection. The document emphasizes different environmental and other relevant complex issues, including management of natural hazard phenomena, soil protection, water resources management, etc. Generally, the Strategy focuses on decreasing inequality between the regions, while a separate component of its Action Plan is dedicated to the management of spatial data and promotion of spatial planning in general.

The Second National Environmental Action Program for 2012-2016 was adopted by Order N127 of the Government of Georgia on January 24, 2012. The Program covers climate change as one of the main environmental issues. Within the climate change field, the main vulnerabilities are identified as follows: impact on natural ecosystems; forest and land degradation; desertification; glacier melting; decreasing soil fertility, water resources and increasing frequency of natural hazards.

[12] Government Programs for 2012-2016, http://gov.ge/index.php?lang_id=ENG&sec_id=41 (accessed March 19, 2016).

[13] Decree N400 of the Government of Georgia of June 17, 2014, on Adoption of the Socio-Economic Development Strategy of Georgia (Georgia 2020) and its Associated Measures, http://www.adb.org/sites/default/files/linked-documents/cps-geo-2014-2018-sd-01.pdf (accessed March 20, 2016).

[14] Decree #172 of the Government of Georgia of June 25, 2010 on Adoption of the State Strategy on Regional Development of Georgia for the period of 2010-2017, and on the Establishment of the Governmental Commission on Regional Development of Georgia.

In the Program, the regions affected the most by climate change and the most vulnerable regions are identified: coastal zones, semi-arid regions and high mountain regions. In addition, the Program emphasizes that no definitive picture of possible climate change impacts on other regions or sectors exists.

The Road Map aimed not only to assess the vulnerability of different regions to climate change, but also to evaluate information availability from official sources, including spatial data. The study showed that the management of spatial data in Georgia is in its initial stages and that it is less available than general statistical data. In some cases, the existing spatial data was not provided.

Among the issues planned for future research, the Second National Environmental Action Program highlights: assessment/more precise definition of vulnerability of ecosystems of Georgian regions to current and expected climate changes; planning and implementation of relevant adaptation measures; and fundraising for implementation of concrete programs and projects.

The Road Map covers the above-mentioned issues (impact of climate change on natural ecosystems and biodiversity, forest and land degradation, increased frequency of natural disasters, etc.) to the extent possible due to limited availability of statistical data from official sources. In addition, the analytical part of the Road Map covers not only regions defined in the program as most vulnerable to climate change, but the whole territory of Georgia.

The National Forest Concept of Georgia was adopted by Decree of the Parliament of Georgia on December 11, 2013[15]. The Concept pays special attention to adaptation of forests to climate change. In particular, it underlines that global warming has already influenced the climate of Georgia; that climate change will have a significant impact on the forests of Georgia; and that inactivity or delayed response to these developments will create a threat of catastrophic degradation to immense forest areas and will lead to an abrupt decrease of quantity and quality of forest resources and their functions, on which a significant part of the population depend in their everyday life.

Due to the absence of unified indicative data for forest cover on the country level, the sensitivity of forest ecosystems to climate change and correspondingly the impact of climate change on these ecosystems is assessed by a possible increase in the risk of forest fires in conditions of climate change. Forest ecosystems and other aspects of climate change are also considered through information from other studies in this sector, though this does not allow for the conduct of a comparative analysis for the whole territory of Georgia.

The National Biodiversity Strategy and Action Plan for 2014-2020[16] defines the strategy on biodiversity protection and rational use and the actions (measures) developed for the years 2014-2020. According to the Strategy (sub-chapter 2.3: Biodiversity and Climate Change), climate change is recognized as one of the major factors of biodiversity loss, alongside with habitat degradation, overexploitation of resources, environmental pollution and the spread of invasive species. One of the goals of the Strategy (national goal D.2) is to assess the potential impact of climate change on the biodiversity of Georgia for 2020 and to increase the resilience of the ecosystems to climate change.

As mentioned above, the Road Map covers the vulnerability of forest ecosystems to climate change. The document also gives an assessment of potential impact of climate change on protected areas within municipalities. The projections are also based on indicator data and assume that any expression of climate change would impact the ecological balance preserved within protected areas.

[15] Decree N 1742-I of the Parliament of Georgia of December 11, 2013, on the Adoption of National Forest Concept of Georgia.

[16] Decree N 343 of the Government of Georgia of May 8, 2014, on the Adoption of the National Biodiversity Strategy and Action Plan for the period of 2014-2020.

The Strategy for Agriculture Development in Georgia for 2015-2020 adopted in 2015[17] elaborates a strategic view of the country's development of agriculture based on the principles of sustainable development. The Strategy also states that during the implementation process special attention will be paid to economic development measures of regions and municipalities, as well as to improvement of institutional arrangements, operation of information-consultancy services, etc. One of the directions of the Strategy concerns climate change and underlines the need to support the introduction of so-called "climate-smart" agricultural practices.

The vulnerability of the agricultural sector to climate change and its impacts on the sector are broadly examined in the Road Map, covering the important issues related to climate change such as vulnerability of plants, increasing risk of reduction of soil moisture, potential increases of water and wind erosion processes, etc.

On September 25, 2015, the Government of Georgia presented the Intended Nationally Determined Contribution (INDC)[18] to the Secretariat of the UNFCCC. The adaptation component of the mentioned document contains a wide spectrum of geographical areas under risk of climate change exposure, such as coastal zone, mountain regions and forest ecosystems as well as agriculture, tourism, and the social sector. Increased natural hazards are also mentioned.

The Georgian Road Map on Climate Change Adaptation corresponds to INDC priorities to a certain extent, for example, it covers socio-demographic issues and different types of climate change impacts, such as changes in extreme temperatures, increasing risks of natural hazards, etc., on socially vulnerable groups. The document also considers the potential impact of increased expression of these phenomena on an even more vulnerable social group – women. The analysis revealed that the proportion of women in socially and demographically vulnerable groups is greater than that of men, and that, to solve related problems, it is necessary to plan special, targeted socio-economic activities.

A considerable part of the Road Map is dedicated to the impact of climate change on the tourism sector. As revealed in the study, climate change will have the greatest affect on winter tourist centers in the medium and long term. This challenge needs special attention during the relevant projection periods. Tourist services should be diversified and special adaptation measures should be planned taking into consideration existing international experience.

The document also contains a noteworthy section concerning impact of climate change on cultural heritage. The first attempt to assess the impact of climate change on cultural heritage was made within the framework of the Third National Communication of Georgia to the UNFCCC and the need for more in-depth research on these issues was very clear in the present study.

The present document also contains a separate chapter on the impact of climate change on the energy sector. In particular, it covers the analysis of changes in energy consumption due to climate change. The Road Map also covers other related issues such as, for instance, the impact of natural hazards on energy infrastructure and how the impact of changes in rivers' hydrology regimes will influence energy-generation processes.

Taking into account the above, the Road Map on Adaptation to Climate Change meets the requirements of the national strategies and programs, as well as international treaties and agreements.

[17] Decree #167 of the Government of Georgia of February 11, 2015, on the Adoption of the Strategy of Georgia on Development of Agriculture for the period of 2015-2020.

[18] Georgia's Intended Nationally Determined Contribution (INDC) Submission to the UNFCCC, 2015, http://www4.unfccc.int/submissions/INDC/Published%20Documents/Georgia/1/INDC_of_Georgia.pdf (accessed March 20, 2016).

1. Methodology

The methodology employed in the USAID-supported Institutionalization of Climate Change Adaptation and Mitigation in Georgian Regions (ICCAMGR) project and therefore in the Road Map closely follows the methodology described in the "ESPON Climate: Climate Change and Territorial Effects on Regions and Local Economies Report" (2011)[19]. This methodological choice was made for several reasons: Georgia's national aspirations with regard to association with the European Union, Georgia's Eastern European geographical location, methodological soundness, a comparable set of indicators and approaches followed, the wide use of the methodology applied in this report by the climate change and impact research community and its applicability to Georgian realities in terms of data availability and other related issues.

The indicators employed in this study are also comparable with ones used in the "European Environmental Agency Report: Climate change, impacts and vulnerability in Europe 2012 (an indicator-based report)[20]", a background document for elaboration of EU Strategy on adaptation to climate change.

The ESPON (2011) report was developed in response to provisions in various European policy documents related to territorial development and spatial planning. The methodological approach utilized under the report follows the NUTS 3 system for the purpose of collecting statistical data on non-climatic factors[21].

This approach seemed the most appropriate for the purpose of comparative climate change assessment for the entire territory of Georgia, where official (legally-defined) territorial self-government units are called municipalities (approximately equivalent to LAU 1) with smaller settlements approximately equivalent to LAU 2. The municipalities are the administrative units for which ICCAMGR developed this report and recommendations for adaptation to climate change included herein. Moreover, the methodology chosen provides the opportunity to compare climate impact across municipalities and to select the most vulnerable ones for further policy planning at the national level.

[19] ESPON Climate, "Climate Change and Territorial Effects on Regions and Local Economies", Scientific Final Report (Version 25/2/2011) http://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/CLIMATE/ESPON_Climate_Final_Report-Part_C-ScientificReport.pdf (accessed February 29, 2016).

[20] EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit.

[21] NUTS and LAU: Nomenclature of Territorial Units for Statistics (NUTS; levels 1, 2 and 3) and Local Administrative Unit (LAU; levels 1 and 2). Concordance not defined yet for Georgia.

The conceptual framework used is a slightly simplified version of the one widely used for climate change impact and vulnerability assessment (see Figure 1), explained further below.

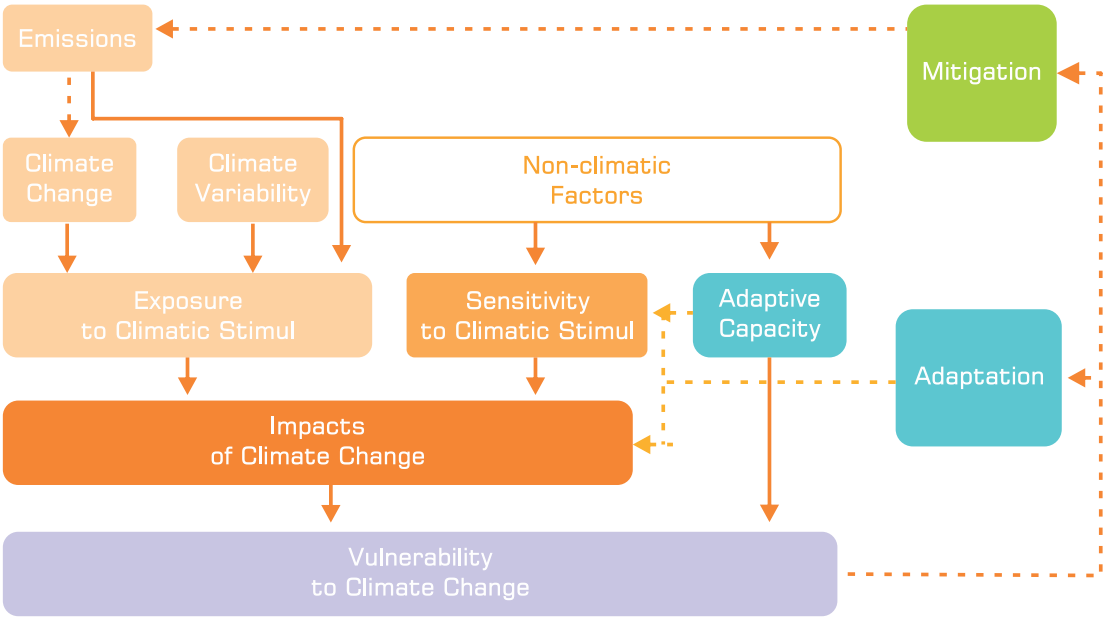


Fig. 1. Methodological flow diagram for climate change assessment (source: ESPON, 2011)

Anthropogenic greenhouse gas emissions contribute to climate change globally and consequently affect Georgia too. The effects of climate changes will vary depending on the geographical area of the country and its economic and social sectors. These influences of changing climate are expressed through sets of exposure indicators.

Various geographical areas of Georgia can be characterized by key dimensions of physical, environmental, social, cultural and economic parameters that result in differing sensitivities to climate change exposure. Selected sensitivity indicators have to be introduced, to characterize the sectors/subsystems such as health and social sector; natural hazards; infrastructure; industry and business; tourism (including cultural and natural heritage); and agriculture and forests among others. In addition to thematic dimensions, the geographic expression of these subsystems is depicted in Figure 2.

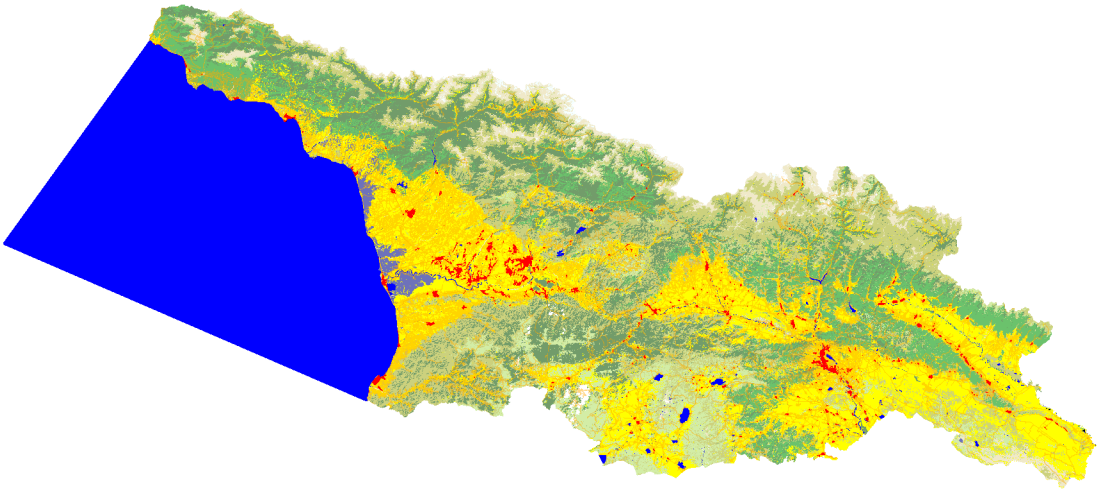


Fig. 2. Subsystems: urban (red), roads (amber), agricultural (yellow), natural (green; several shades), water (blue)

After a series of spatially explicit normalization, aggregation (at the various levels of administrative subdivisions of the country) and weighting steps (attributing expert-defined weights to each dimension), exposure and sensitivity indicators were combined to determine firstly, the integral sensitivity indices and secondly, the possible impact that climatic changes may have on various sectors and geographical areas of the country.

Vulnerability assessment normally includes the treatment of adaptive capacity[22], and mitigation and adaptation measures, but at this stage of development the ICCAMGR study is limiting its scope to impact analysis, while the next iteration of the impact assessment will include a complete vulnerability assessment towards climate change, taking account of adaptability indicators as well as mitigation and adaptation measures.

[22] It was assumed that the adaptive capacity of Georgian municipalities, other than Tbilisi and a few self-governing cities of the country, is relatively comparable.

For the sake of terminological compatibility (between English and Georgian languages) and clarity, the terms are first noted in both languages below, followed by the IPCC[23] definitions of key climate change impact assessment terms employed in this report (in italics). These definitions are completed by more extended explanations extracted from GIZ (2015)[24] explaining their meaning in greater depth and in easily accessible language for four of the concepts below:

EXPOSURE (ზემოქმედება, ექსპოზიცია): The nature and degree to which a system is exposed to significant climatic variations. Exposure refers to changes in climate parameters that might affect socio-ecological systems. Such parameters are for example temperature, precipitation and wind speed, which climate change alters with regard to their quantity and quality as well as their spatial and temporal distribution.

SENSITIVITY (მგრძნობელობა, სენსიტიურობა): The degree to which a system is affected, either adversely or beneficially, by climate related stimuli. The effect may be direct or indirect. Sensitivity tells us about the status quo of the physical and natural environment of the affected systems that makes them particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use land cover, distribution and density of population, built environment, proximity to the coast, etc.

IMPACT (ზემოქმედება, იმპაქტი): Consequences of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential and residual impacts. Potential Impact is determined by combining exposure and sensitivity to climate change on a system.

ADAPTABILITY OR ADAPTIVE CAPACITY (შეგუების უნარი, ადაპტაციის უნარი): The ability of a natural or human system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

VULNERABILITY (მოწყვლადობა, ვულნერაბლობა): The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

MITIGATION (შერბილება, მიტიგაცია): Climate change mitigation refers to all human attempts to mitigate the effects of climate change.

[23] IPCC Annex B Glossary of Terms, http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf, (accessed February 29, 2016).

[24] GIZ, "Training Manual on the Integrated Vulnerability Assessment Methodology", GIZ, in cooperation with Adelphi/EURAC. United Nations Economic and Social Commission for Western Asia (ESCWA), 2015, http://www.escwa.org.lb/divisions/div_editor/Download.asp?table_name=divisions_other&field_name=ID&FileID=1705, (accessed February 29, 2016). See also GIZ in cooperation with Adelphi/EURAC, Vulnerability Sourcebook: Concept and Guidelines for Standardised Vulnerability Assessments, August 2014. https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/va/vulnerability-guides-manuals-reports/Vulnerability_Sourcebook_-_Guidelines_for_Assessments_-_GIZ_2014.pdf, (accessed February 29, 2016).

There is a great deal of literature devoted to describing the various methodologies of decision-making instruments such as indicators and indices in multiple fields of application, and more specifically in climate change impact and vulnerability assessment.

Various sets of indicators are usually defined to measure specific symptomatic aspects of certain phenomena of societal importance. The rationale here is that due to various restrictive factors (primarily constraints of time, resources or expertise) not all variables can be measured or numerically represented and therefore a smaller subset of informative key variables[25] are employed as indicators of the wider range of variables affecting or being affected by these phenomena.

Indicator variables require further weighting and cumulative aggregation to be useful for real life decision-making. Limiting factors are again the short timeframes available, as well as the difficulty for the policymaker to consciously discriminate between too many values, even if they are derived from selected key indicator variables. In other words, even with a reduced set of data, for decision-making purposes, there are only three possible responses to this information: to act, to not act or to postpone acting. Therefore indices (or even a single index) need to be presented as simply as possible as weighted scores or as an otherwise derived combination of calculations performed over selected indicators.

Following on this general definition of indicators and indices, and in accordance with the framework for climate change impact and vulnerability assessment outlined above, the methodology proposed here is concerned with the application of the following main types of indicators and aggregated indices:

1.3.1. Exposure

The exposure indicators are constructed utilizing the observed climate baseline data and modeled data describing future climate change variables. Projections of climate change and climate variability in this report are based on the Regional Climate Model RegCM4, and a Global Climate Model EH5OM (MPI, Hamburg), properly downscaled and compiled for Georgia (and the Caucasus region), within the spatial extent of N $40^{0}30'$-47^{0} ; W $39^{0}25'$-44^{0} and time period of 1959-2100, as performed for the Georgia's Third National Communication to the UNFCCC[26]. Global scenario A1B[27] of the IPCC Working Group II was selected to generate climate model data aggregated for two projection periods of time 2021-2050 and 2071-2100 (referred to as Future 1 and Future 2, respectively, horizontal grid size of 20 km) compared against the data covering the period from the past measurements 1961-1990 (referred to as Baseline, horizontal grid size of 0.5 km).

[25] Based on information available from the statistical agency of Georgia and other official sources.
[26] The Third National Communication of Georgia to the UNFCCC, MoENRP, 2015, http://moe.gov.ge/files/Klimatis%20Cvlileba/ErovnuliShetkobinebebi/2015_bolo/3rd_National_Communication_ENG.pdf, (accessed February 29, 2016).
[27] Scenario A1B definition: "very rapid economic growth, global population that peaks mid-century and declines thereafter, and rapid introduction of new and more efficient technologies" as well as a balanced use of all sources of energy, Working Group II: Impacts, Adaptation and Vulnerability, http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=154, (accessed February 29, 2016).

The following set of Baseline and Future 1 and 2 climate data were generated for the application of selected exposure indicators (see Table 1) for climate change impact analysis in this assessment.

In a subsequent section: "Climate Change Patterns in Georgia: Main Conclusions", there is a detailed presentation of the climate modeling and analysis for deriving exposure parameters for Baseline and Futures 1 and 2 timescale scenarios, characterization of exposure trends and patterns for Georgian geoclimatic conditions, selecting the exposure indicators in general and for specific sensitivity-analysis cases, including combining of certain exposure indicators into exposure indices, applicable in particular cases of sensitivity analysis.

Many greenhouse gases stay in the atmosphere for long periods of time. As a result, even if emissions were to stop increasing, concentrations of atmospheric greenhouse gases would continue to increase and would still remain in the atmosphere for hundreds of years. Moreover, even if the composition of today's atmosphere were to be stabilized (which would require a dramatic reduction in current greenhouse gas emissions), surface air temperatures would continue to increase. This is because the oceans, which store heat, take many decades to fully respond to higher greenhouse gas concentrations. Higher temperatures will therefore continue to impact the climate over the next several decades at least and possibly for hundreds of years (IPCC, 2013)[28]. Medium- to long-term modeling of climate exposure and impacts are therefore necessary to better understand the situation at hand.

1.3.2. Sensitivity

Administratively designated municipalities (self-governing units) of Georgia were selected as the largest scale of the assessment and as the source of statistical data for climate change sensitivity indicators[29]. Recently designated self-governing cities[30] were included whenever data was available, otherwise they were dissolved into municipalities (to which they had belonged before the Self-government reform of 2014). Each municipality or self-governing city (a total of 70, not including Tbilisi) was then assessed in regard to its climate change sensitivity. Sensitivity dimensions can be generically classified as physical, environmental, social, economic and cultural. Specific 'sectoral' sensitivity indicators were developed to cover the following themes and involved their respective experts: health and social issues, natural hazards, industry and businesses (where statistical data was rare), tourism (including cultural and natural heritage), agriculture (including forests). The list of sensitivity indicators identified and covered in this study are provided in Table 1.

[28] T.F. Stocker, D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom.

[29] Selection of the spatial aggregation level was largely determined by the availability of statistical data, albeit the finding of this study is that for genuine analysis of climate change impacts, statistical data for key sensitivity dimensions needs to be collected at the lowest administrative level possible, preferably for each settlement, with clearly designated urban/rural spread and the subordinated administrative area beyond settlement limits (equivalent to LAU2 in the European classification system for statistical proposes). Some examples of the benefit of such an approach are provided in this report, such as for historic census data, which is available at the lowest administrative level of spatial aggregation.

[30] Established within the Self-governing reform of 2014. As a result of this reform, in addition to the five existing self-governing cities, an additional seven new ones were established by splitting some municipalities into "urban" and "rural" areas.

Table 1. Baseline and Future 1 and Future 2 climate and sectoral datasets matrix for exposure and impact analysis

	Change in annual mean temperature	Change in seasonal mean temperature	Change in extreme temperatures (max. & min.)	Change in annual mean of temperatures below 8°C (heating period length)	Change in annual mean of temperatures above 25°C (cooling period length)	Change in annual mean number of summer days	Change in annual mean number of frost days	Relative change in annual mean precipitation	Relative change in seasonal mean precipitation	Change in annual mean number of days with heavy rainfall	Relative change in annual mean evaporation	Change in annual mean snow cover (CDSC) depth	Change in annual mean wind speed[31]	Avalanches[32]	Trigger Climate effects: River floods
PHYSICAL SENSITIVITY															
Municipalities' sensitivity to landslides								X	X	X				X	X
Municipalities' sensitivity to debris-flows, flash floods, and mudflows								X	X	X				X	X
Municipalities' sensitivity to river floods															
Municipalities' sensitivity to avalanches															
Motorways' sensitivity to river floods															X
SOCIAL SENSITIVITY															
Population sensitivity to summer heat			X			X									
Population sensitive to natural disasters								X	X	X					
AGRICULTURAL SENSITIVITY															
Agriculture sensitivity to soil moisture		X							X						
Agriculture sensitive to water & wind erosion		X							X				X		
Forestry sensitive to forest fires		X							X						
TOURISM SENSITIVITY															
Summer tourism sensitive to summer temperatures									X						
Winter tourism sensitive to snow cover changes												X			
Protected areas sensitive to different climate exposures	X	X	X	X	X	X	X	X	X	X	X	X	X		
Cultural heritage sites sensitive to river flooding and avalanches														X	X
Museums sensitive to river floods and avalanches														X	X
ENERGY SECTOR SENSITIVITY															
Energy demand correlated to summer heat (HDD)				X		X									
Energy demand (CDD)					X										
Cooling load			X		X										
Heating load			X												
Energy supply sensitive due to changing river water levels and hydrology									X						
Physical infrastructure sensitivity to river floods and avalanches															

[31] This indication was not calculated through climate change modeling. Data was taken from the Georgian Climate and Agroclimate Atlas, Tbilisi, 2011.

[32] Avalanches are not a trigger indicator but the methodology used for calculation of their impact on infrastructure is similar to one of floods.

Each 'sectoral' sensitivity indicator was calculated in absolute and/or relative terms, thus integrating two equally valid perspectives on sensitivity. While relative sensitivity (e.g. density of the sensitive population) is advantageous from a comparative point of view, the absolute sensitivity (e.g. absolute number of sensitive inhabitants) is more relevant from a policy/action point of view. 'Sectoral' sensitivity indicators were then combined and aggregated to calculate the cumulative effect of each sector with weights assigned to each sensitivity indicator by thematic experts (with proper justifications given) and scrutinized by all other expert team members in terms of both weight values and justifications. The final results of the spatial distributions were validated by the thematic expert concerned and again scrutinized by all expert team members. The GIS team provided interactive rapid mapping capability so that considerations of analysts and experts were promptly reflected in the new calculations and iterated into updated mapping and spatial aggregation patterns for review and endorsement by respective experts. Results for each sensitivity indicator (and aggregated indexes) were presented in normalized form (see the methods used below).

1.3.3. Impacts

To determine the potential impacts of climate change, exposure and sensitivity indicators were normalized, aggregated (combined) and again normalized to produce impacts calibrated for comparative analysis and/or further aggregation. Each sensitivity indicator was related to one or more specific exposure indicator(s) to determine impacts. For example, in the case of health and social indicators, the heat-sensitive population (the sensitivity indicator of a municipal population older than 65 years) was normalized and combined with socially vulnerable population statistics, Targeted Social Assistance (TSA) was proposed as a social indicator and this combined health and social normalized index was related to the aggregated impact index of two exposure indicators – changes in the number of summer days (above 25°C) and changes in average maximal summer temperatures. Similarly, forests sensitive to fire were related to exposure to average summer temperatures and average precipitation in summer months. In other cases, according to expert judgment and decision, all impacts of one dimension were aggregated after determining the individual impacts, rather than combining aggregated exposure with aggregated sensitivity. The impact values of the five sensitivity dimensions (sectors) were finally combined into one overall sensitivity index value for three economic sectors (tourism, industry, agriculture) and another aggregated sensitivity index for social sectors (health and social, natural hazards). In both cases, the cumulative/aggregated combination was calculated based on the weights, which were determined per methodology similar to the ESPON study, i.e. through a Delphi survey among the members of the inter-sectoral expert team, setting averaging weight scores. Results were validated through comparison with similar sectoral distribution of weights used in the ESPON study.

As mentioned above, the impact analysis concluded a climate change assessment for Georgia that did not take account of adaptability in the vulnerability assessment. Lack of data to define adaptability indicators and low adaptive capacity in the country did not allow for such an analysis this time. However, two short subsections below describe a suggested methodology for the steps to perform for a complete vulnerability analysis for the next iteration of this study.

1.3.4. Adaptability

The next iteration of the climate change impact and vulnerability assessment should take account of adaptive capacity in regard to climate change, i.e. the economic, socio-cultural, institutional and technological ability of Georgian municipalities and self-governing cities to adapt to the impacts of a changing climate in various parts of the country. Indicators need to be developed for each of these five determinants of adaptive capacity. The individual normalized indicators can then be combined through the proper weighting of each determined adaptability indicator (again based on inter-sectoral expert judgment through the Delphi survey method) and aggregated into an overall adaptability index.

1.3.5. Vulnerability

To determine the overall vulnerability of Georgian municipalities to climate change the impacts and the adaptive capacity to climate change have to be combined for each administrative subdivision level considered. Municipalities with a high climate change impact may still be less vulnerable if they are better adapted to the anticipated climate changes. On the other hand, high impacts would result in high vulnerability to climate change if a municipality has a low adaptive capacity. Such an analysis would also provide an invaluable tool in setting priorities for adaptive actions based on the results of a qualitative analysis for more targeted application of the scarce resources available for adaptation action.

It should be highlighted that the subsequent thematic sections of the report that analyze and provide the results of each sectoral assessment have methodologies characterizing particular sensitivity indicators, including the selection of the respective exposure indicators relevant for specific sectoral analysis and combining certain exposure indicators into aggregated exposure indices as applicable in particular cases of sensitivity analysis. The sectoral assessments provide cumulative aggregation of exposure, sensitivity and impact as final outcomes of this report, showing changing climate patterns for Georgia (see Fig. 4).

Climate change assessment in a data-scarce country such as Georgia required the use of a pragmatic approach with the careful selection of various indicators and calculation methods, which were, in turn, largely determined by data availability. At the same time, a great deal of attention was paid to the transparency of data and calculations made; ensured through the scrupulous documentation, maintenance and storage for future use of all sources of data used and all calculations and mapping performed throughout the process.

Instead of complicated modeling (for which capacity is lacking and even if it had been available, it could have been counterproductive in terms of transparency of results), the approach was taken to apply as simple and as minimal a sequence of calculations as possible to derive the needed results. The normalization and aggregation methods applied and weights used were clearly stated in each considered case and thoroughly documented within the GIS geodatabase produced and in the metadata describing each product and layer generated. Individual indicators can thus be easily updated or replaced or new indicators added to produce updated impact assessments with more refined datasets for exposure and sensitivity indicators/indices, while similar methodologies and calculation routines can easily be extended to and applied for taking account of adaptive capacity assessments and for completing a more comprehensive vulnerability assessment in any future iteration of this study.

With this perspective in mind, described below in a concise manner are those methods of calculation that were applied in various combinations for each sector and indicator/index considered in this study. This presentation includes a description of both the calculation methods used, as well as the data preparation and other tasks performed using the spatial analysis tools from the GIS environment. All these datasets (with metadata) and toolsets (with software versioning) are free and open source (with the exclusion of the proprietary ArcGIS) and can be used for future application in the next iteration of the climate change impact analysis for Georgia.

1.4.1. Normalization

In order to aggregate various types of indicator datasets, the data first needs to be transformed into a unit-less score on a common scale. This process is called normalization. For the integrated assessment of vulnerability, a scale with a value range of 1-to-10 was preferred, with the value 1 representing low vulnerability and the value 10 representing high vulnerability (see Figure 3 for typical legends applied). Methodologically it is feasible that all dataset values are normalized to this scale at each step needing normalization, though depending on particular data characteristics, different methods can be applied. These are briefly explained below.

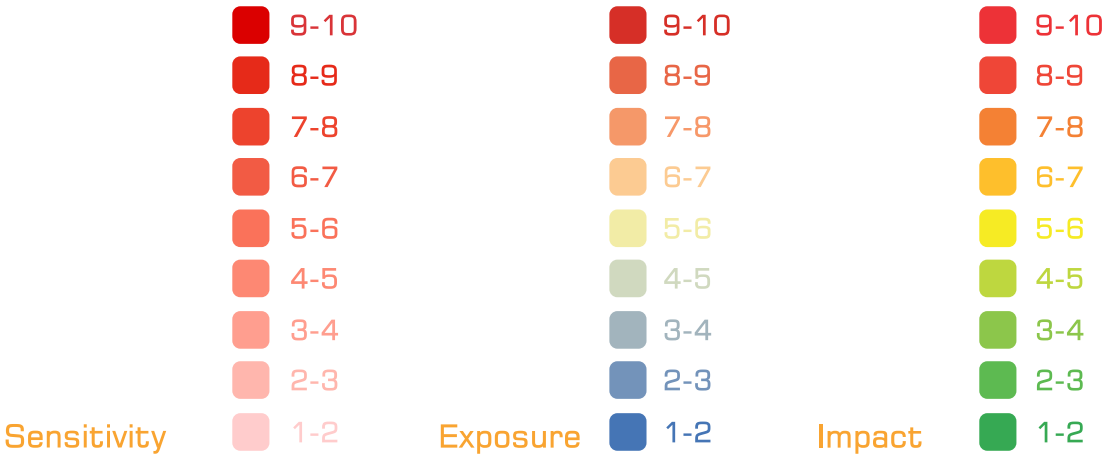


Fig. 3. Equal interval scales typically used for normalized indicators and indices (from left to right: sensitivity, exposure and impact indicators/indices)

Typically, the following linear transformation can be applied to statistical or other types of data for normalization (so called Min-Max normalization):

$$X_{i,\ 0\ to\ 1} = (X_i - X_{Min}) / (X_{Max} - X_{Min})$$

This provides a result in a 0-to-1 range for normalized datasets. The presence of 0 in the dataset can pose a problem for certain datasets when deriving impact by multiplying sensitivity to exposure change, resulting in 0 after multiplication. It is therefore preferable to apply another simple linear transformation to the Min-Max normalized value, namely to multiply by a range of 9 and add 1 so that the above-mentioned value range of 1-to-10 is achieved:

$$X_{i,\ 1\ to\ 10} = (X_{i,\ 0\ to\ 1}) \times 9 + 1 = (X_i - X_{Min}) / (X_{Max} - X_{Min}) \times 9 + 1$$

In case of orders of magnitude of the data skewness/variability in the data statistics (one order of magnitude is considered approximately one multiple of ten), it is necessary to apply a logarithm to the indicator dataset and then to normalize the result into a 1-to-10 range. Typical GIS visualization through categorization of data implies the application of such logarithmic scales as a default choice, therefore it is more appropriate to convert data into a logarithmic scale rather than leaving it in original shape and get the same result through GIS visualization only.

Some practical tips with regard to application of normalization are provided below:

- Both 'absolute' (such as population numbers) and 'relative' (such as density) values are relevant representations for various sensitivity indicators and other types of indicators, depending on particular circumstances. Both ESPON (2011) and GIZ (2015) reports consider relative values more appropriate for impact and vulnerability assessment, and absolute values more suited to assessing the overall 'cost' of impact and therefore of more relevance for policy decisions. It is also possible to combine normalized values of absolute and relative variables in order to benefit from both types of representations.
- An analysis of the raw data is essential to determining its skewness level and, if required, transforming data towards better symmetry mathematically, such as by applying a logarithmic scale.
- Several methods exist for classification of normalized data: equal intervals; quantile; natural breaks; user defined; geometrical; standard deviation and others. These methods are listed in the sequence of preferred application, in our case of climate change assessment.
- Depending on data type, it may be necessary to invert indicator values before application of geometric aggregation (see note at the end of the next sub-section 1.4.2). In such cases, normalized data [x], presented in 1-to-10 range, should be inverted by applying the formula [11-x] through transformation [x] [11-x], and after application of geometric aggregation reverted back so that the resultant index data range remains in the 1-to-10 interval with the correct direction of impact level.

1.4.2. Aggregation and weighting

There is a wide range of different aggregation methods that can be used to build integral indices from the values of composite indicators. As these methods can have a major influence on the result of the impact and vulnerability assessment, our approach was to use the simplest and most straightforward methods so that less influence is introduced by the aggregation method chosen. This section describes aggregation methods that can be applied in various cases. Next we discuss the methods used for weight allocation. Choices primarily depend on statistical properties of the indicator data, and the meaningfulness of the end result of the aggregation, which is ultimately judged by sectoral experts.

An arithmetic aggregation index is derived through weighted summation of normalized indicators in accordance with the following linear averaging formula:

$$\text{Index value} = \Sigma W_i * XI = (W_1 * X_1 + W_2 * X_2 + W_3 * X_3 + \ldots + W_n * X_n)$$

Where n is the number of composite indicators, Xi and Wi are normalized indicators and respective weights. The weight Wi should comply with the following criteria: 0 Wi 1 and Σ Wi = 1.

In case of equal weights (when knowledge is insufficient to allocate differing weights) the common weight should respectively satisfy the condition W * n = 1, which transforms the formula into simple arithmetical averaging with weight W = 1 / n:

$$\text{Index value} = \Sigma XI * (1 / N) = (X_1 + X_2 + X_3 + \ldots + X_n) / n.$$

Arithmetic aggregation is a very simple method but two main weaknesses are interaction and compensability. First, while composite indicators should be independent from each other, frequently in social and environmental studies interaction occurs. Secondly, large values of one indicator may compensate for the small value of another indicator, thus masking the influence of these small values.

A geometric aggregation index avoids issues with interaction and compensability. It is defined as the weighted product of normalized indicators, calculated using the following non-linear averaging formula:

$$\text{Index value} = \Pi XI * WI = (X_1)^{W1} * (X_2)^{W2} * (X_3)^{W3} * \ldots * (X_n)^{Wn}$$

The same meaning of variables as above is retained, including the summation condition for weights Σ Wi = 1.

In case of equal weights, which should satisfy condition W * n = 1, the formula transforms into geometric averaging with weights W=1 / n:

$$\text{Index value} = \Pi (X_i)^{1/n} = (X_1 * X_2 * \ldots * X_n)^{1/n}$$

This is the nth root from multiplication of normalized indicators.

NB: The precondition for the use of geometric aggregation is that low values should correspond to high impact/vulnerability, while higher values should correspond to lower impact/vulnerability. In many cases however, higher attribute values indicate higher impact/vulnerability. In such cases, the classes in the range 1 (positive) to 10 (negative) should be inverted with formula [11-x] prior to aggregation and the result should be inverted back with the same [11-x] formula upon completion of the aggregation (cf. last bullet point of the previous sub-section).

1.4.3. Weights

There can be various methods of weight allocation when indicators are from different sectors and require the setting of priorities. In the case of not allocating specific weights, equal weights are assumed during aggregation (when weights are 1/n). Due to the need to set priorities for decision-making, it is important to apply the most straightforward and practical methodology for weight allocation.

In case of intra-sectoral weight allocations (for instance, two or more agricultural sensitivity indicators) the respective expert team member was requested to individually provide weights and justification arguments, validated on self-consistency interactively by the experts from other sectors. Results of the expert intra-sectoral weight allocation are documented in each sectoral methodology description provided by each sectoral expert for each thematic dimension of this assessment.

As for inter-sectoral weight allocations, the Delphi expert survey method was applied in this assessment, described briefly here. The survey for weight allocation among sectors/dimensions was conducted in two interactive rounds. First, all members of the expert group were asked to allocate percentages to each sensitivity dimension as well as to each component of the two 'impact pairs' of exposure-sensitivity. Each of these two estimations added up to a sum of 100% (which is equivalent to summation of weights to 1). In the second round, all experts were informed about the results of the first round and those who wished to do so and whose opinions differed significantly from the average scores of the first round were given the opportunity to adjust to more moderate scores. Two sets of weights were then recalculated from percentages to fractions of 1 for use in sensitivity and impact aggregate index calculations. The results of the inter-sectoral Delphi survey exercise is provided in Table 2 below. Results obtained were compared to similar figures given in ESPON (2011) in order to be compatible with similar international studies.

Table 2. Weights resulting from the Delphi-based inter-sectoral expert survey

Delphi Survey	Agriculture	Tourism	Energy	SUM
Project Coordination Team	50%	25%	25%	100%
Report Reviewer/Editor	50%	20%	30%	100%
Tourism Expert	50%	20%	30%	100%
Industry Expert	40%	20%	40%	100%
Energy Team	40%	20%	40%	100%
Agriculture Team	45%	15%	40%	100%
GIS Analysis Team	40%	20%	40%	100%
AVERAGE	45%	20%	35%	100%

Average weights derived through the Delphi survey were used to aggregate sensitivity as well as the Future 1 and Future 2 period climate change impact indicators for three economic sectors (agriculture, tourism and energy). The results are illustrated on the maps in Figure 4.

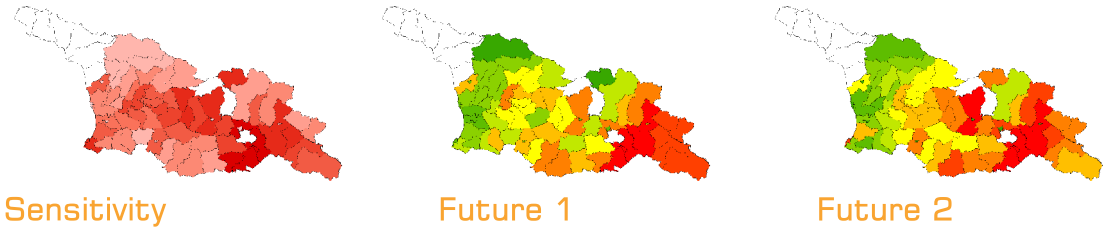


Fig. 4. Aggregated sensitivity and impact maps for economic sectors (legends similar to figure 1.3)

1.4.4. Integration

Various combinations of normalization (0 to 1, 1 to 10, equal interval, quantile, etc.), aggregations (geometric, arithmetic), weightings (equal, non-equal, intra-sectoral expert opinion, inter-sectoral Delphi survey of expert team) were applied to various indicators (groups of sensitivity, respective groups of exposure indicators, and derived groups of impact indicators). Sectoral experts for each sensitivity dimension then further described these efforts. Their results are combined into sectoral indices, taking account of respective sensitivity, exposure and impact levels (see Figure 5). A similar approach can be applied to take account of adaptation and mitigation capacity indicators (once proper data is available), to derive not only climate change impact, but also overall vulnerability assessment in the next iteration of the assessment presented in this report.

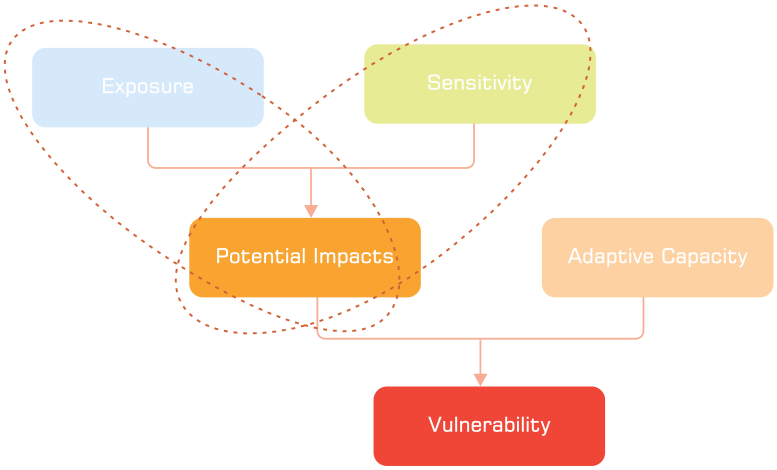


Fig. 5. Indicator integration into impact (doted lines) and vulnerability indices (source: GIZ, 2015)

The last integrative step applied in this assessment is thus the aggregation of sensitivity and exposure indicators to derive the potential impacts of climate change.

It is important to note that in the methodological formula for this impact aggregation, sensitivity would be represented by the value of the indicator (or combined sensitivity index thereof), while exposure would be represented by indicator or index values composed of change(s) in climatic variable(s), i.e. the difference between modeled future and baseline values. This can be expressed with the following generic proportionality relationship:

[Impact] $\propto$ [Sensitivity] * [Change in Exposure]

The final result shall again be normalized and, if necessary, any skewness would be removed prior to visualizing results of the impact index with a map having a three-color, traffic light-type legend (as in Figure 1.3) presented in equal interval scale.

An important assumption with such calculations is that the sensitivity parameter is driven from baseline condition into Future 1 or Future 2 climate change to assess the impact. Future scenarios for the dynamics of the sensitivity parameter itself (such as demographic changes, for instance), although extremely important, certainly go beyond the scope of this assessment, which is only concerned with the quantification and the visualization of the effects of climate change for Georgia.

1.5. Data processing

Data processing transparency is an essential component of the impact and vulnerability assessment methodologies such as the one used in this climate change assessment for Georgia. This sub-section therefore describes the data preparation steps performed by the GIS team in advance of processing sensitivity and exposure indicators into the assessment of integral impact indices. These methods are briefly presented here and further explained, as necessary, in the expert presentation of applied methodologies for each sector or for combined integral assessment steps.

1.5.1. Data collection

The GIS team took responsibility for proper technical organization of the data collection process. FTP storage was allocated and access credentials were organized for all experts participating in the study. Two main storage folders were designated (Input and Output). After obtaining and processing the respective data for indicators, experts could name and store their data in newly created folders in the Input folder, indicating upload dates in the folder name (in the format YYYYMMDD) for the sake of chronological ordering. Sectoral experts could then create folders and upload data files, but for accountability and organizational reasons were not able to rename or delete files without authorization of GIS experts in charge of organizing the data collection.

Most experts provided sectoral data in Excel spreadsheets, while some experts provided some datasets in GIS format. GIS experts provided the basic naming convention for folders, files and data fields, as well as guidance regarding metadata. The sample geodatabase with naming conventions (municipality names in particular, as well as data fields) in both Georgian and English languages were stored in FTP so that all experts could provide datasets in the same format for ease of processing and integration in the GIS. No special symbols, punctuations or blank spaces were allowed in the feature names. Feature and field names were agreed upon in English, while all the processing was inherently conducted to produce maps in two languages and fonts, in both Georgian and English. The initial product was first produced in Georgian, with subsequent translation into English.

GIS experts generated properly processed and visualized maps and GIS datasets and stored them in folders placed in the main Output folder that appeared in chronological order. ArcGIS version 10.3 was utilized for GIS processing, with all standard extensions installed; Spatial Analyst in particular. While most data was collected in Excel format, datasets produced were stored in the ArcGIS geodatabase, with GIS map projects as well as TIFF images for effortless sharing. In addition to accessing TIFF image files, the sectoral experts were advised to install ArcGIS trail software so that they could interactively explore GIS map projects and geodatabases as the data collection, processing and visualization efforts progressed.

Final database outputs were compiled in a highly interactive manner and were deployed in the folder clearly showing final products. Each dataset was supplied with appropriate metadata. Care was taken that geodatabases and GIS map projects were compiled in a transparent manner across sectors, ultimately allowing easier deployment for interactive web services (a separate project), should the decision be taken to make databases available to the wider public, in addition to internal use by relevant experts, stakeholders and decision-makers. Final files are stored in a compact manner for ease of reporting and sharing, as well as for scrutiny of data and processing transparency in case of the next iteration of this climate change impact and vulnerability assessment. In addition to final datasets, for the sake of accountability and transparency, all chronologically ordered input and output folders are maintained by the GIS team (and the study client) for future reference (Figure 6).

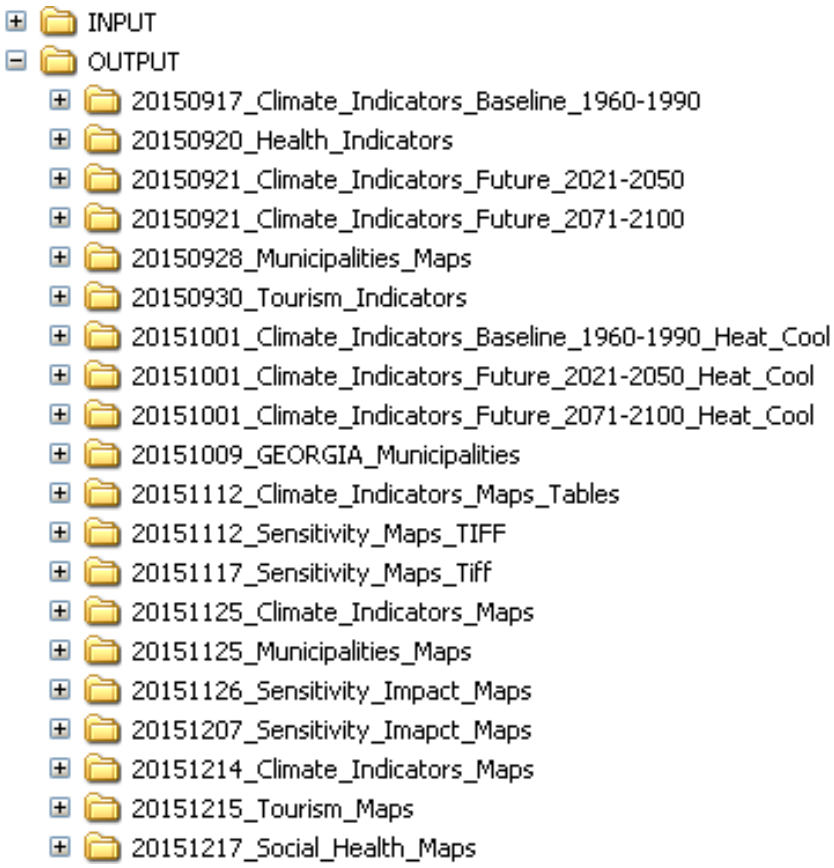


Fig. 6. Sample view of dataset tree for the Output folder

1.5.2. Data preprocessing, documenting and visualization

The following data processing steps were, in general, performed upon collection of the datasets:

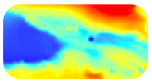
- Datasets are in, or are converted into, the same spatial reference systems (such as WGS 84).
- Datasets are in, or are converted into, the same projection (such as UTM 38).
- Converting data into the appropriate format (raster, vector).
- Defining spatial resolution for raster data and map scale for vector data.
- Organizing in compatible formats various types of indicators (sensitivity, exposure).
- Organizing proper administrative layers (municipalities and settlements, as appropriate).
- Producing maps in native units for needed indicators.
- Normalizing native units to required normalization (Max-Min, 1-10, inverting as needed).
- Applying a logarithmic scale or other processing whenever necessary.
- Aggregating relevant indicator datasets via geometric or arithmetic methods, as appropriate.
- Producing combined sensitivity, exposure and impact indices with proper weight factors.
- Visualizing all relevant normalized indicators and indices in an equal intervals legend.
- Setting legend schemes as graduated color ramps (single; double, cold/warm; or triple, traffic light).
- Producing final maps with all formatting, attributes and metadata completed and stored.
- Overlaying and underlaying baseline layers for map readability (basic topographic elements).
- Sharing datasets, map projects and TIFF image-maps with experts for corrections/validations.
- Documenting metadata to include: input data sources, classification/aggregation methods, etc.
- Finalizing map titles, legend, scale bar, coordinates, authors, dates, other attributes, etc.

Provided below is the description of specific data processing steps performed on various supplied datasets to convert them into useable and convenient formats for subsequent derivation of sensitivity and exposure indicators and calculation of impacts and other relevant integral indices. These steps are described for the sake of transparency of dataset processing and overall assessment flow. All tools and routines are available as a single data and toolset package for sharing and utilization for the preparation of future iterations of a climate change impact and vulnerability analysis.

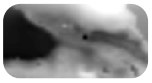
Here is the summary of the specific GIS and other preprocessing steps and tools applied:

Exposure

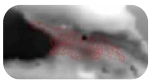
Transforming climate model output datasets provided in NetCDF format into ArcGIS layers; applying Make NetCDF Raster Layer (Multidimension).



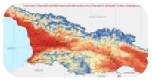
Converting layer files into raster files and defining projection WGS 1984 and UTM Zone 38N using Project Raster (Data Management).



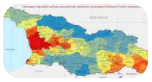
Averaging over administrative districts (in this case over Municipalities) using Personal GeoDatabase Feature Class and Zonal Statistics as Table (Spatial Analyst).



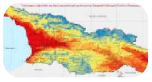
Importing baseline climate datasets into ArcGIS.



Averaging over administrative units, in this case over Georgia Municipalities.



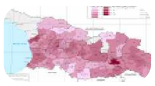
Averaging over the smallest administrative units, i.e. subdivisions of Georgian Municipalities.



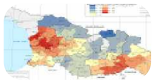
Due to the large number of exposure maps, automating processing of above steps using two ArcGIS Model Builder scripts [(i) importing climate files; (ii) averaging].

Sensitivity

Visualizing sensitivity data provided by various experts in ArcGIS environment, distributing results via FTP as geodatabases, GIS map projects and image-maps.



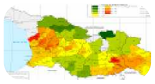
Combining respective exposure indices for specific sensitivity indicators in the ArcGIS environment, distributing via FTP as geodatabases, GIS map projects, image-maps.



Assisting thematic experts in calculating various sensitivity indicators in ArcGIS environment, distributing via FTP as geodatabases, GIS map projects, image-maps.

Impacts

Assisting thematic experts in calculating various impact indices in ArcGIS environment, distributing via FTP as geodatabases, GIS map projects. Image-maps.



Assisting thematic experts in visualizing various impact indices directly calculated by experts, distributing via FTP as geodatabases, GIS map projects, image-maps.

2. Patterns of climate change across Georgia

In order to assess the socio-economic effects caused by climate change, individual countries need climate change scenarios and future climate scenarios, which are provided by mathematical modeling of the climate system according to different socio-economic scenarios defining the conditions of development of the society in the future. Such modeled studies provide a set of probable climate parameters, based on which the sustainability of the country and its ability to manage climate change impacts are assessed, consequent risks are identified, and adaptation and mitigation strategies are elaborated.

These studies are especially important for small, highland countries, where weather and climate have a decisive role in everyday life. Climate change scenarios, especially of extreme events, are also essential for such countries for planning development projects including for water resources, agriculture, irrigation, ground drain capacity (during heavy rains), roads, railways, buildings and tourism development.

Almost all climatic zones are represented on Georgia's territory. Such diversity is predetermined by the country's geographic location between the Black and Caspian seas with complex mountainous terrain. The Black Sea and the Caucasus Mountains are the main climate-determining factors in Georgia. The Caucasus prevents the penetration of cold air masses from the north, while the Black Sea causes a distribution of moderate temperatures and large amounts of precipitation. In West Georgia, the climate is humid subtropical, within which seven climate zones and several subzones are identified, depending on their distance from the sea and orography. East Georgia is a moderately humid subtropical area, with nine climate zones, while in South Georgia, the climate is a transitional zone ranging from moderately humid to a dry climate of the mountainous areas, where five climate zones are to be found.

Due to these natural variations, the consequences of climate change significantly differ in the regions of Georgia. The project "Institutionalization of climate change adaptation and mitigation in Georgian regions", aims at the enhancement and enforcement of the statutory functions of self-governments stipulated under the Organic Law of Georgia "Local Self-government Code" and in addition to other legislation in the field of resource management, spatial planning and sustainable development to address challenges on the local level (municipalities), through the institutional and organizational capacity building of local self-governments.

In the Special Report on Emission Scenarios (SRES) of the IPCC certain emission forecasts based on world socio-economic development scenarios were defined[33].

Regional Climate Model 4 (RegCM4) was used for the South Caucasus region[34]. This model belongs to the group of so-called "limited models", it uses large-scale meteorological parameters as initial and boundary conditions on the area limited by the user, on which high-resolution geographical information (such as: topographic elevations, land use, vegetation and so on) can be used in high-definition calculations. A simulation was done (N 40°30'-47°; W 39°25'-44°) with maximal horizontal resolution of 20km, admissible in the area. The area used for simulation includes the territory of Georgia as well as part of the territories of Armenia, Azerbaijan, Turkey and the Russian Federation. Initial and boundary conditions were taken from EH5OM (MPI, Hamburg), global model output data (existing from 1941-2100) and A1B socio-economic scenarios. All data were downloaded from the website: http://users.ictp.it/~pubregcm/RegCM4/globedat.htm. The simulation was done to cover 1959 to 2100 inclusively. The 1961-1990 period was taken as the baseline, compared to which current and future climate parameters and extreme events were evaluated. Out of 180 different parameters, available as a result of modeling, we analyzed the below-listed climate parameters. Future scenarios were developed for the periods: 2021-2050 and 2071-2100, called Future 1 and Future 2 respectively.

The following climate parameters were studied to assess climate change in Georgian municipalities:

1. Average annual and seasonal air temperatures (°C);
2. Total annual and seasonal atmospheric precipitation (mm);
3. Absolute maximum and minimum air temperatures (°C);
4. Evaporation (mm);
5. Height of snow cover (cm);
6. Average annual number of snow days;
7. Average annual number of heavy rains;
8. Average annual number of frost days;
9. Average annual number of hot days;
10. Duration of heating/cooling periods.

The above-mentioned parameters were developed for the two future scenarios: Future 1 (2021-2050) and Future 2 (2071-2100), which are compared, on the one hand, with parameters based on simulated parameters for the baseline period (1961-1990) and, on the other hand, with data from meteorological observations of the same period. Maps were developed based on expert knowledge of spatial distribution regularities of the mentioned parameters, using GIS spatial analysis.

As we have already mentioned, regional climate models calculate many climate parameters (about 180), which can be used for solving different issues. With the aim of detecting climate impact on the environment and economic sectors in Georgian regions, seven basic temperature indicators were selected, the nature of change of which directly impacts the social and economic condition of a community. The unit of this climate indicator is in degrees Celsius and their change is calculated as the difference between average values of predicted (2021-2050 or 2071-2100) and baseline (1961-1990) periods.

Within these indicators, the change of average annual air temperature (at an altitude of 2 m) is considered a key indicator of climate change intensity. Different sectors will be sensitive towards the change of average temperature indicators by seasons. Changes in extreme temperature values shall also be mentioned here, since it is known that especially large deviations of extreme values are one of the forms of manifestation of climate change.

[33] IPCC Special Report: Emissions Scenarios, WMO/UNEP, 2000, www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf (accessed March 20, 2016).
[34] www.ictp.it/research/esp/models/regcm4.aspx (accessed March 20, 2016).

Other than the mentioned key temperature indicators, four more temperature indexes were used in this study. Two of these – duration of heating and cooling periods – were calculated by the method indicated in climate construction norms whose key user is the energy sector. Duration of cooling period per year equals the number of days when the average daily temperature is higher than 25°C, while duration of heating period means number of days when the average daily temperature is lower than 8°C. Two additional temperature parameters were calculated according to IPCC[35] recommendations: the number of hot days and frost days and one additional hydrological indicator – the number of heavy rains. The number of hot days is the number of days in a year when maximal daily temperature is more than 25°C. Number of frost days means the number of days in a year when daily minimum temperature is less that 0°C, and number of heavy rains in a year is the number of days when total daily precipitation exceeds 20 mm. Daily data on extreme values of temperature and total precipitation are necessary for the mentioned calculations and are provided by the model. Changes in these temperature indicators have an especially severe impact on the sectors of agriculture and health care, while the increase of the number of days with heavy rains will influence the threat of floods and flash floods. All these values are without dimension and their change, as well as that of key temperature indicators, is calculated by the difference between the average predicted values and baseline periods.

The remaining eight indexes are hydrological. Their measurement unit is either in millimeters (mm) or centimeters (cm) in the case of snow cover. The relative (percentage) figures were used for assessment of the change of these parameters. This means that the predicted change of such hydrological indicators shall be calculated as the mean difference of predicted and baseline periods with the value of the baseline period. In this case, the number of snow days is an exception as it is a value without a measured dimension. The change in extreme temperature indexes is calculated by a simple difference.

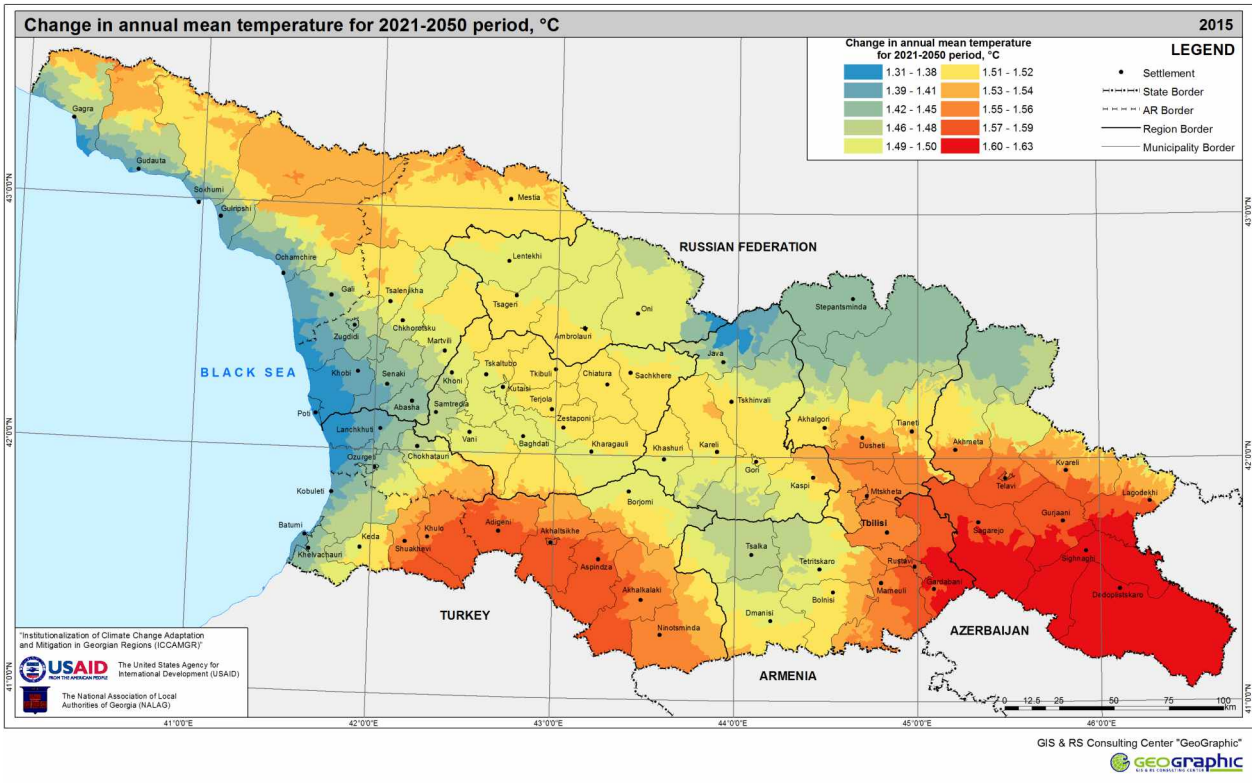
[35] Datasets for Indices of Climate Extremes (CLIMDEX project), 2012-2014, http://www.climdex.org/indices.html (accessed March 20, 2016).

2.3. Predicted climate change maps

Predicted values of the above-mentioned indicators for detection of climate change were averaged for municipal territories and for the smallest administrative units within municipal territories[36] and the maps were developed based on GIS technologies. As mentioned, climate change is usually calculated compared to 1961-1990. In this report, climate exposure indicators are represented for the smallest administrative units[37], since such an approach provides a more precise picture. However, for the drawing of the climate change impact maps for projection periods, the same exposure indicators were used, but this time averaged for each municipal territory since access to "non-climactic" (socio-economic) data or its analysis was not possible for administrative units smaller than municipalities.

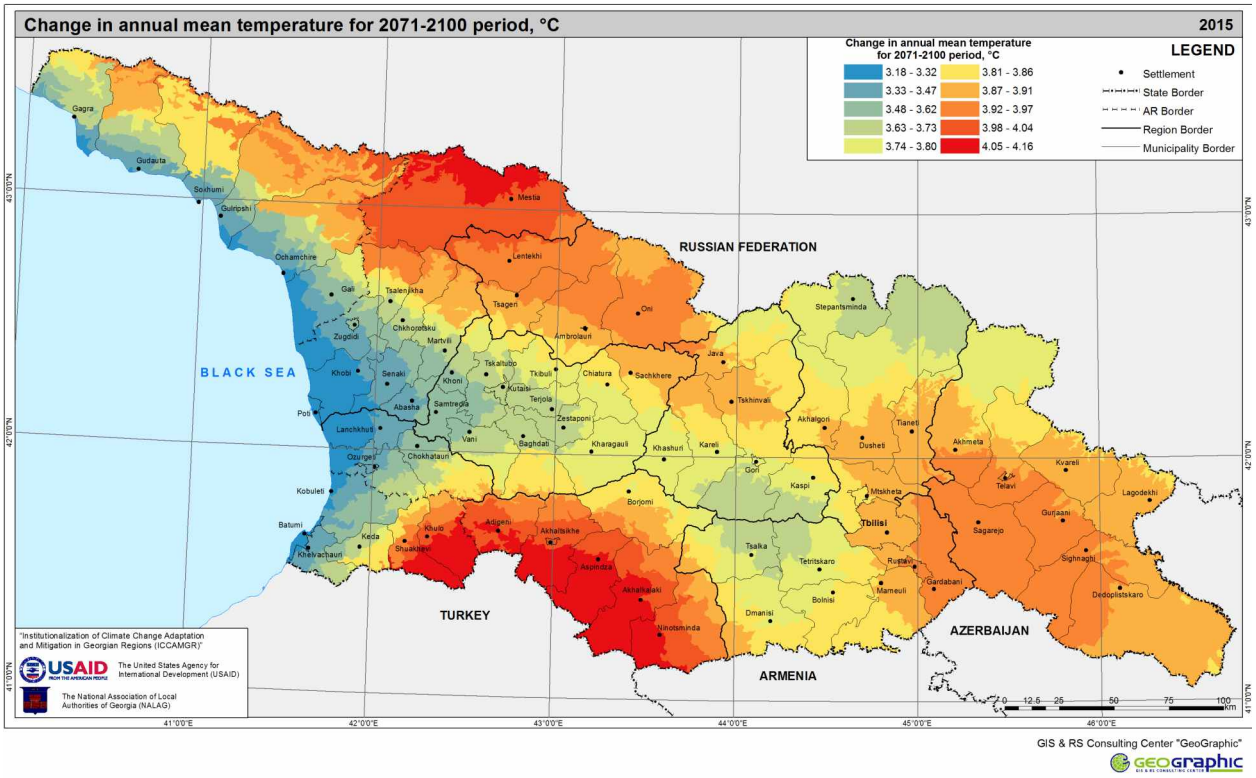
[36] The Organic Law of Georgia, "Local Self-Government Code", Article 4.4, Georgian Parliament, 2014.
[37] Administrative units within the borders of municipalities.

Climate change maps for Future1 (2021-2050) & Future 2 (2071-2100)



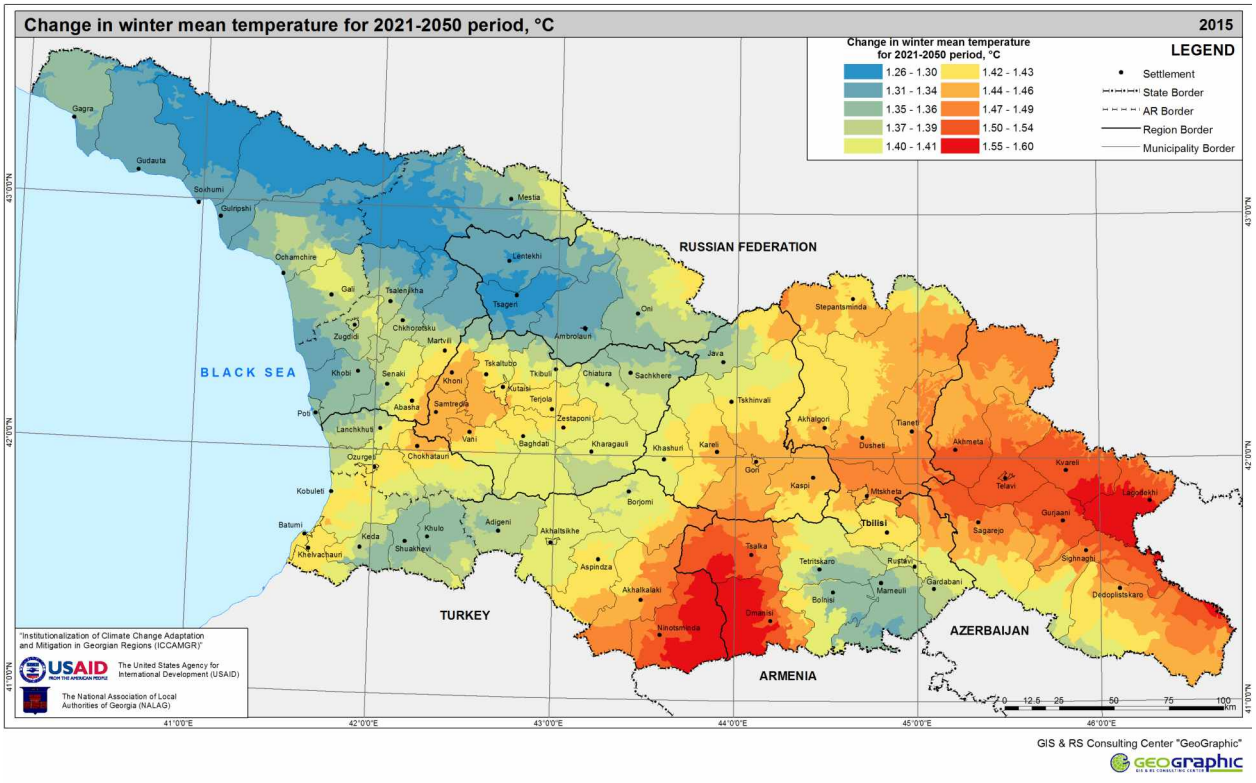
Map 1. Average annual air temperature change at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), the average annual air temperature throughout Georgia will presumably have an increase in the range of 1.3°C to 1.6°C. Since the change is stated as an average, the difference may seem insignificant, however greater extremes are present. The most intensive warming will take place in the Sagarejo, Sighnaghi and Dedoplistskaro municipalities of Kakheti region. The lowest increases in temperature will be observed in the Black Sea coastal area.



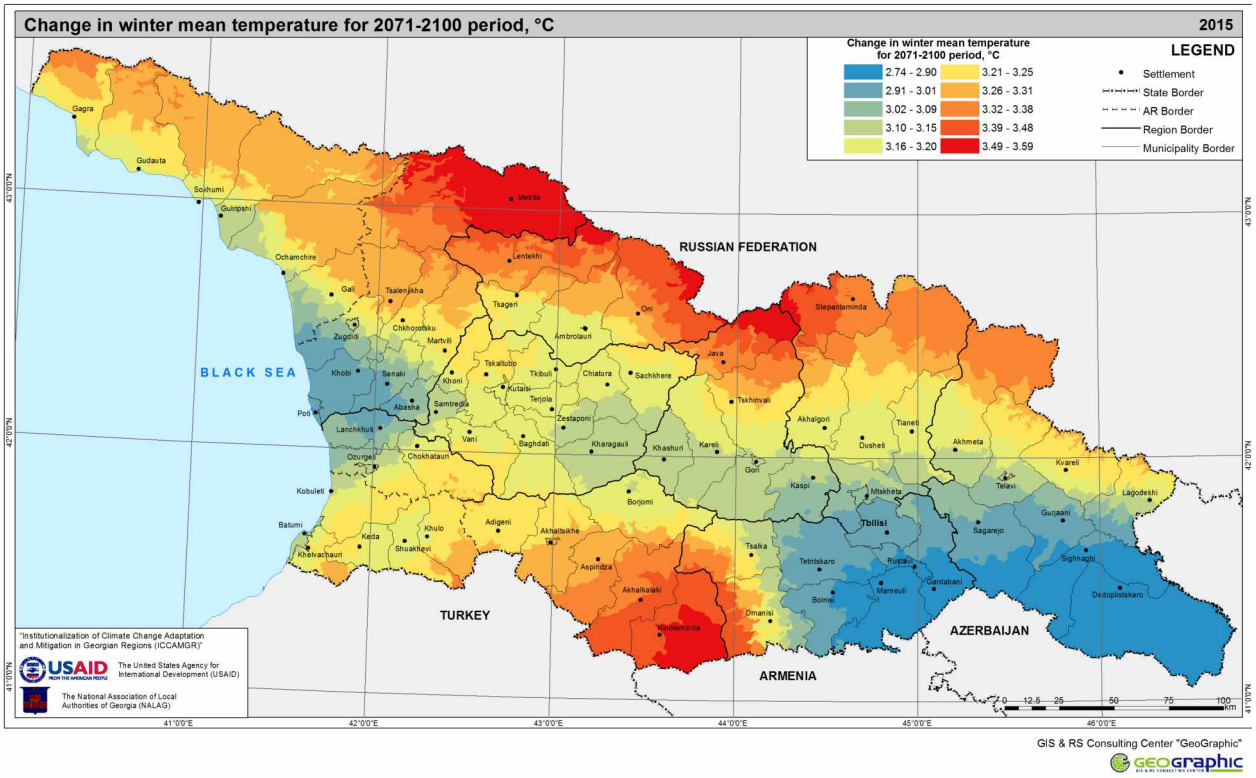
Map 2. Average annual temperature change at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the average annual air temperature will increase from 3°C to 4°C. The average annual air temperature for the period increases most of all on the slopes of the Lesser and the Greater Caucasus – in Mestia, Khulo, Aspindza and Akhalkalaki municipalities. The least warming is again expected in the Black Sea coastal area and Kolkheti Lowland of Georgia.



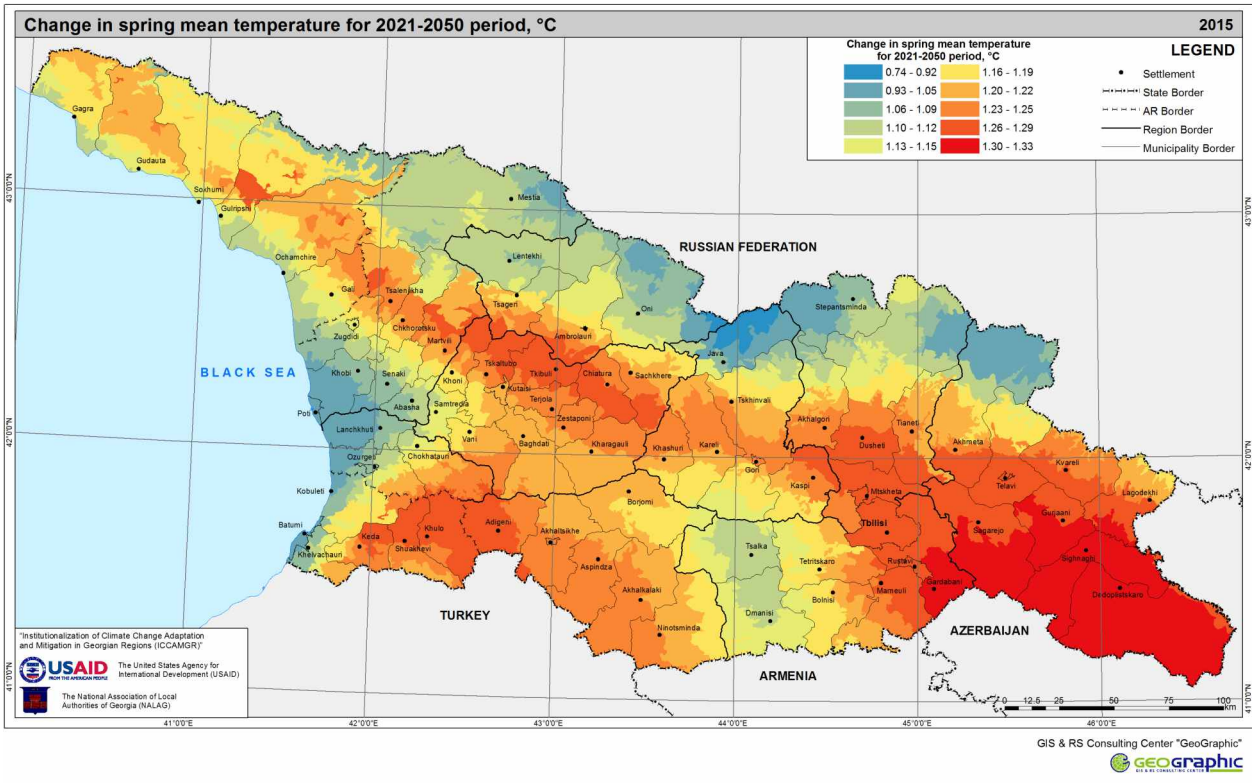
Map 3. Average annual winter air temperature change at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The average annual air temperature change in winter at a height of 2 m, for Future 1 (2021-2050) compared to the baseline period (1961-1990), will vary within almost the same interval (from 1.3°C to 1.6°C), as the average annual temperature change. In this season the average annual winter temperature will show the least increase in West Georgia, mainly within the Caucasus mountains of West Georgia, than in East Georgia. The highest warming value is expected in the Kvareli, Dmanisi and Ninotsminda municipalities.



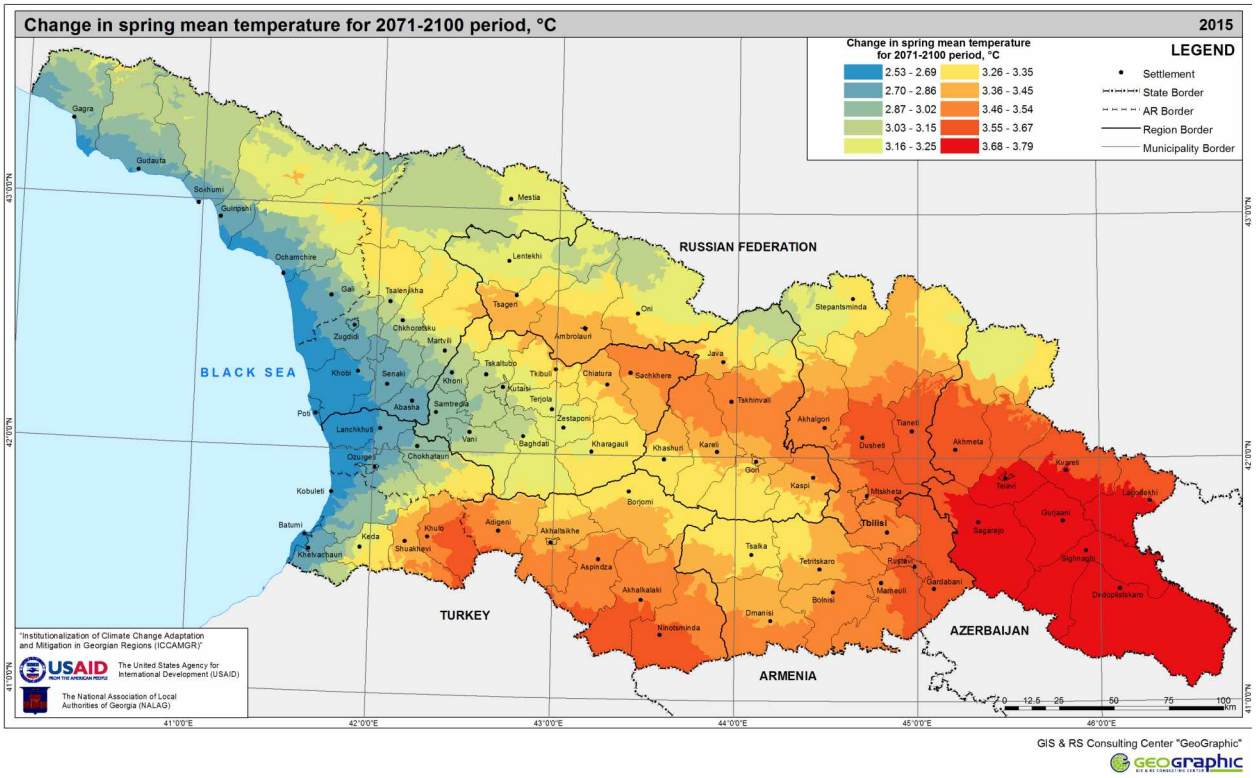
Map 4. Average annual winter air temperature change at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the average annual air temperature will increase from 2.7°C to 3.6°C. The highest increased value of the average annual air temperature is again most likely in the territories of Mestia and Ninotsminda municipalities. In contrast to the previous projected period, the lowest temperature increase (2.7°C) is expected in Sagarejo, Sighnaghi and Dedoplistskaro municipalities of Kakheti region and in Marneuli and Bolnisi municipalities in Kvemo Kartli region.



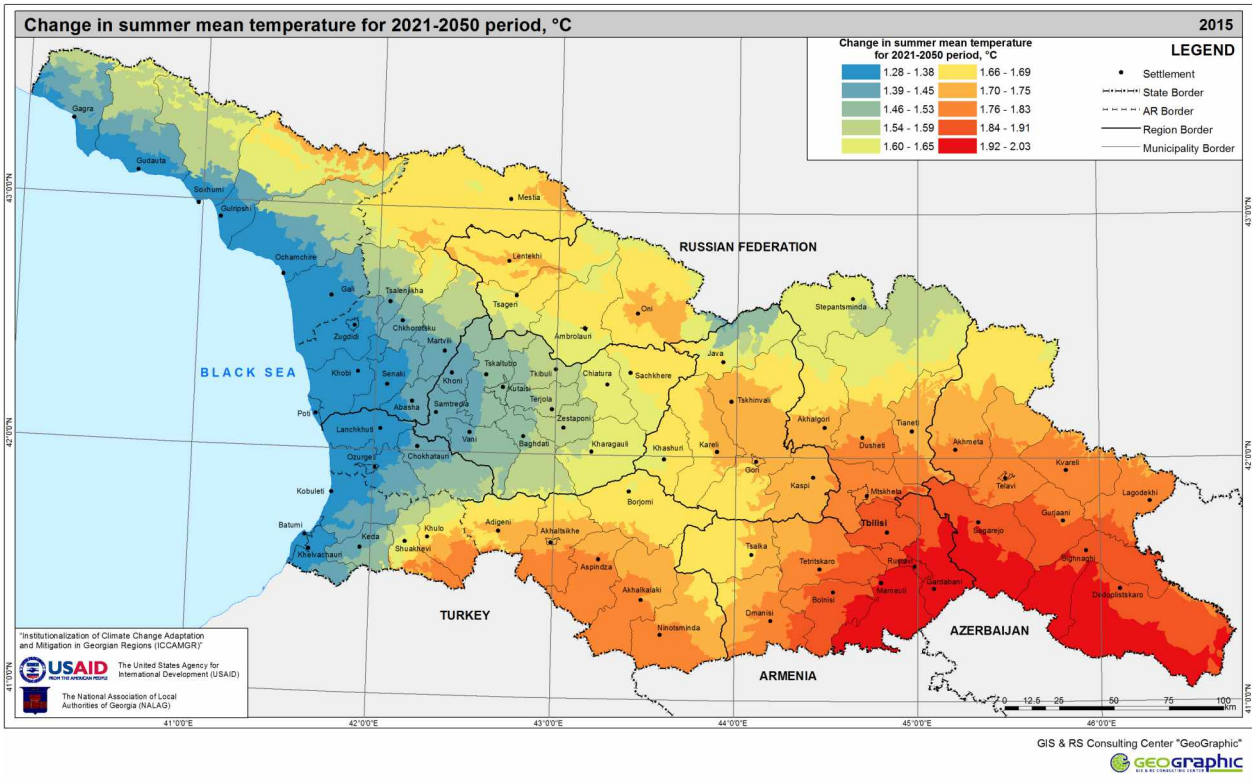
Map 5. Average annual spring air temperature change at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The average annual air temperature change in spring at a height of 2 m, for Future 1 (2021-2050) compared to the baseline period (1961-1990), will increase by 0.7°C to 1.3°C. This is the lowest warming value increase among the seasons. The spring temperature's highest increase will be observed in the southern part of Kakheti region and the lowest in Stepantsminda.



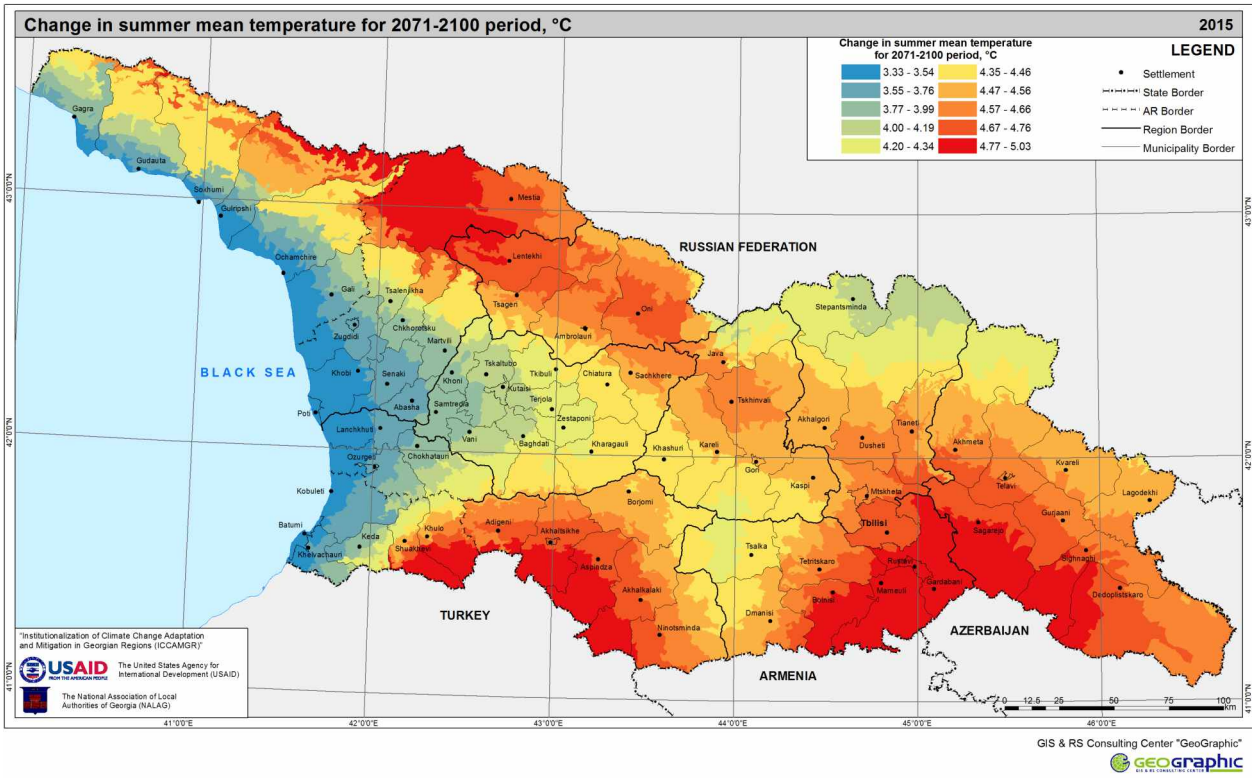
Map 6. Average annual spring air temperature change at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

The average air temperature in spring for Future 2 (2071-2100) compared to the baseline period (1961-1990) will increase rather intensively by between 2.5^{0}C and 3.8^{0}C. Like in the previous projected period (2021-2050), the greatest warming will again take place in the territory of Kakheti, while the lowest warming figure will be observed in the Black Sea costal area and Kolkheti Lowland.



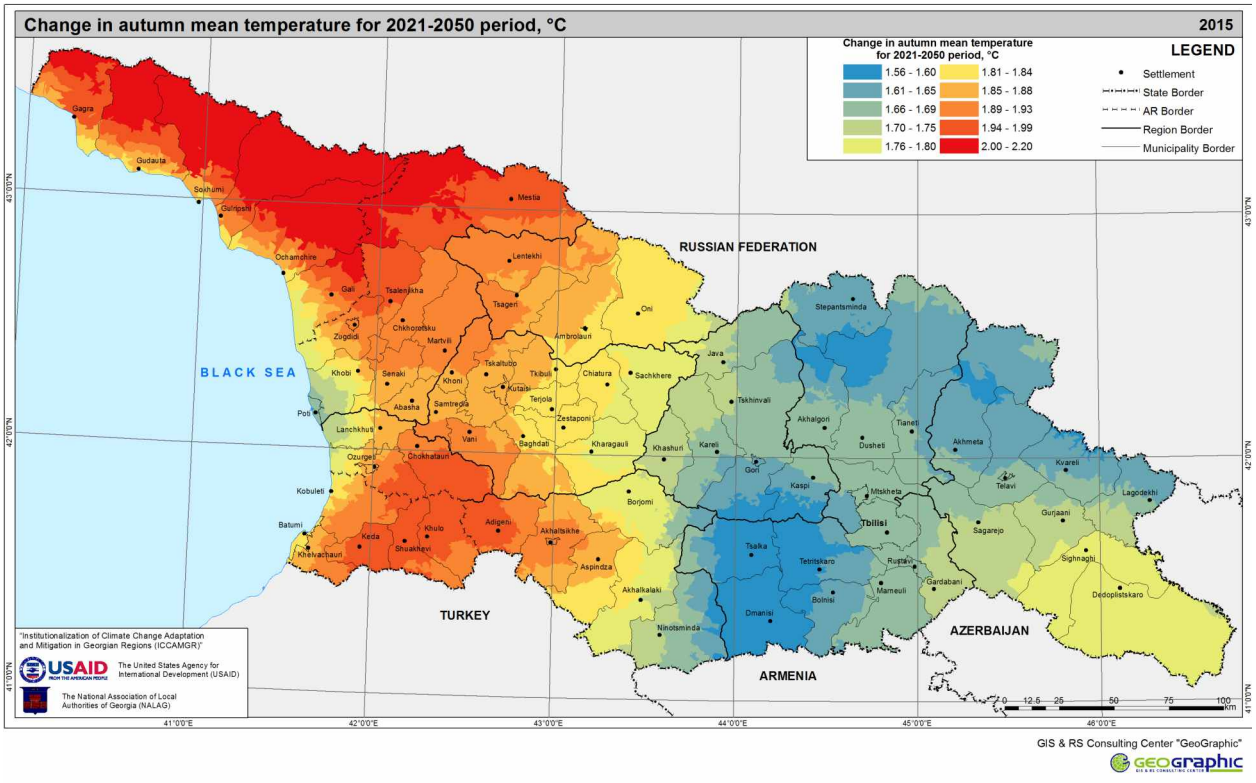
Map 7. Average annual summer air temperature change at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The average annual air temperature change in summer for Future 1 (2021-2050) compared to the baseline period (1961-1990) is expected to be within 1.3°C to 2°C. The highest warming value is expected in the municipalities neighboring Azerbaijan, while the lowest will be in the Black Sea costal area and Kolkheti Lowland.



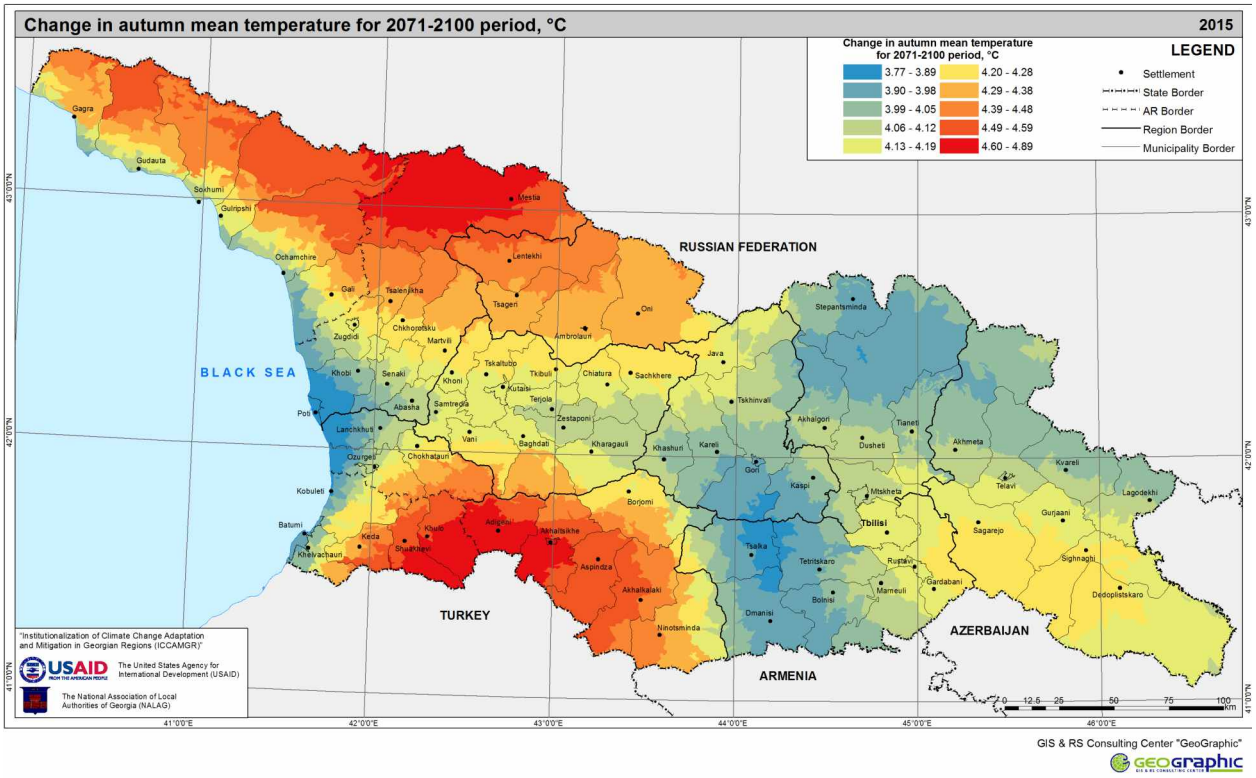
Map 8. Average annual summer air temperature change at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

The average air temperature in summer for Future 2 (2071-2100) compared to the baseline period (1961-1990) is expected to be within 3.3^{0}C to 5^{0}C. Also in this period the summer temperature will increase less in the Black Sea coastal area and Kolkheti Lowland, while the summer temperature warming is expected in the territories of Khulo, Aspindza and Akhalkalaki municipalities, in addition to the municipalities neighboring Azerbaijan.



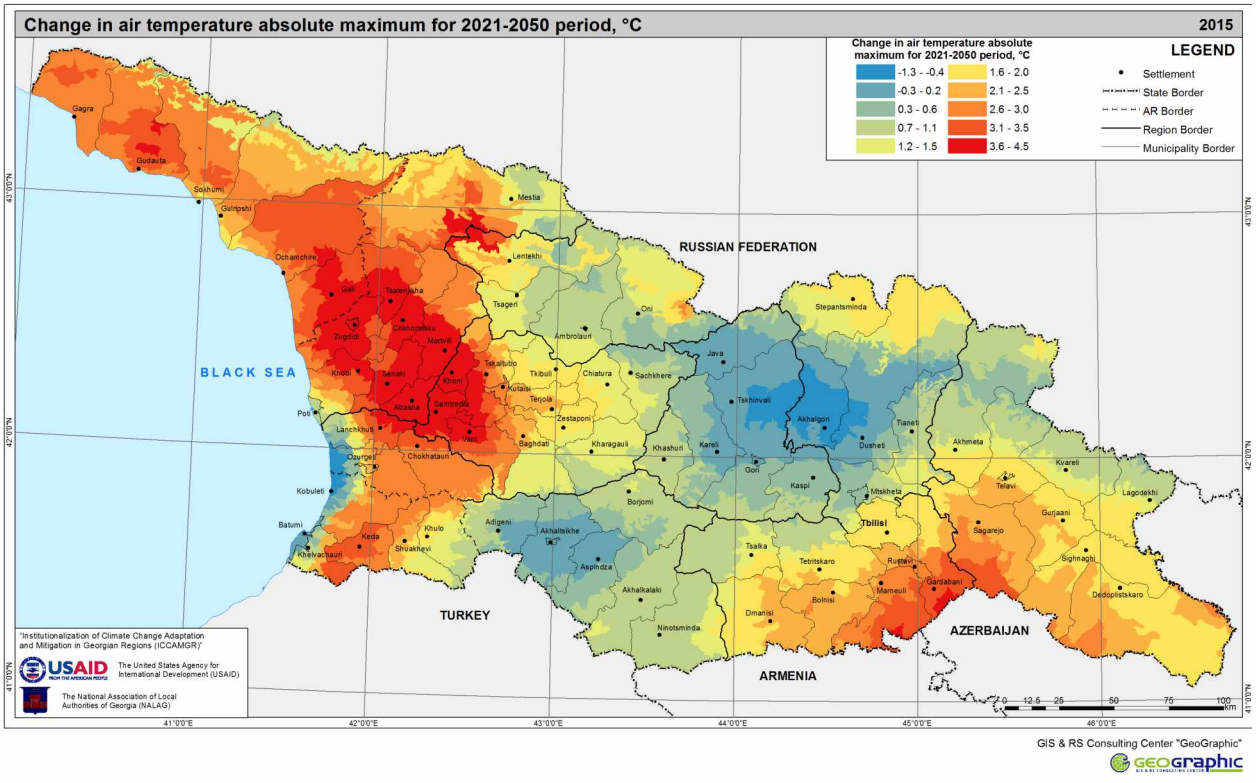
Map 9. Average annual autumn air temperature change at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The average air temperature in autumn for Future 1 (2021-2050) compared to the baseline period (1961-1990) is the most intensive in comparison with other seasons. This parameter will increase by 1.6°C to 2.2°C. In contrast to all other cases, the temperature increase in West Georgia, especially in the territory of Abkhazia, will be higher than in East Georgia. The average seasonal temperature will increase relatively less in Samtskhe-Javakheti, Mtskheta-Mtianeti and the northern part of Kakheti region.



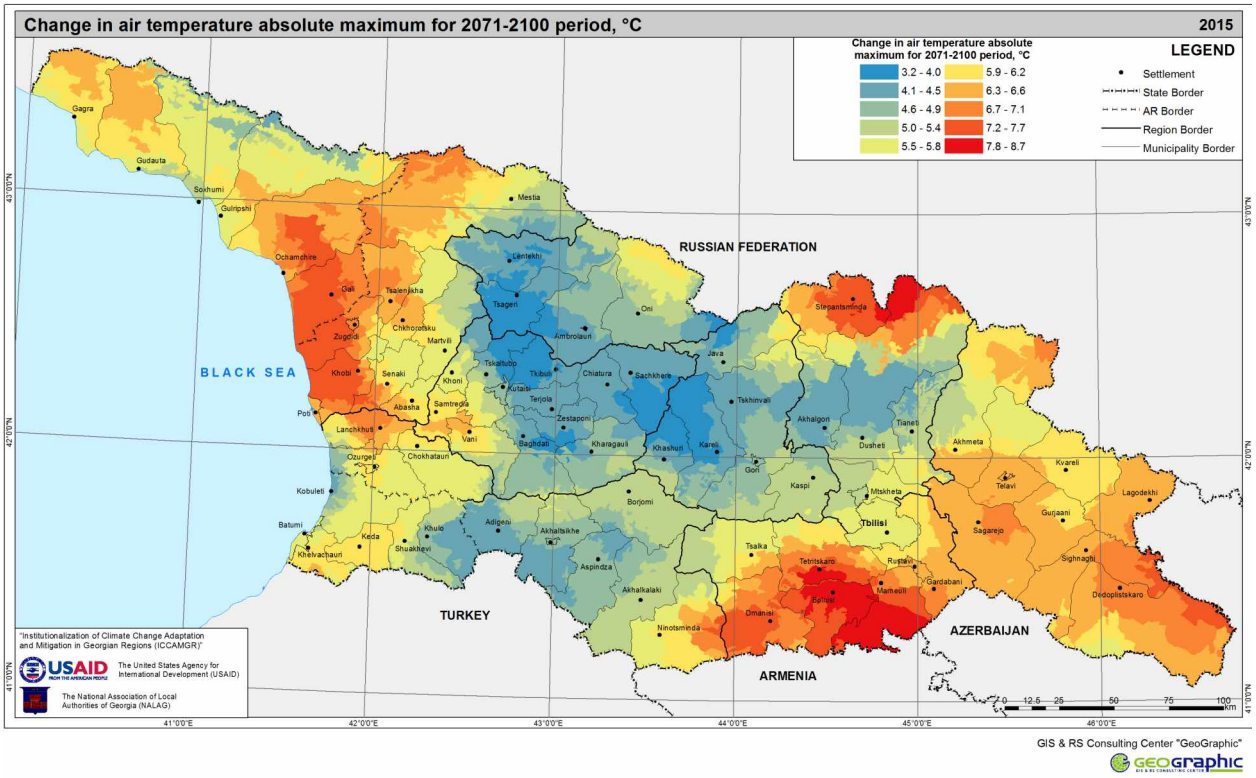
Map 10. Average annual autumn air temperature change at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

The average air temperature in autumn for Future 2 (2071-2100) compared to the baseline period (1961-1990) will presumably increase by 3.8°C to 4.9°C. The distribution of said increment throughout Georgia approximately replicates that described in the previous projected period (2021-2050).



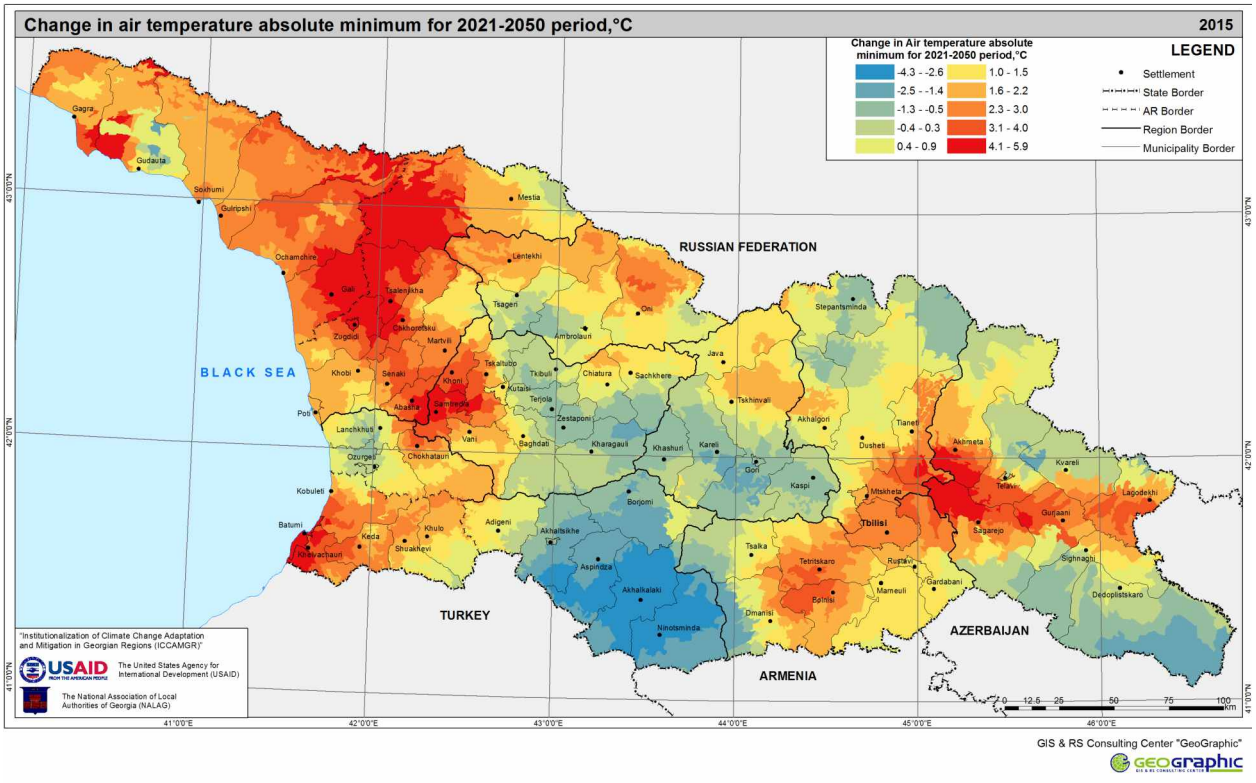
Map 11. Change in the absolute maximum air temperature at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

A change in the absolute maximum air temperature for Future 1 (2021-2050) compared to the baseline period (1961-1990) will be most observable (4.5^{0}C) in the territory of Kolkheti Lowland and Kvemo Kartli. In the rest of the territory of Georgia the temperature increase will be less pronounced; moreover, a decline in temperature is expected in some places: the most pronounced decline will be in the littoral area of Adjara (-1.3^{0}C) and in the territory of Mtskheta-Mtianeti.



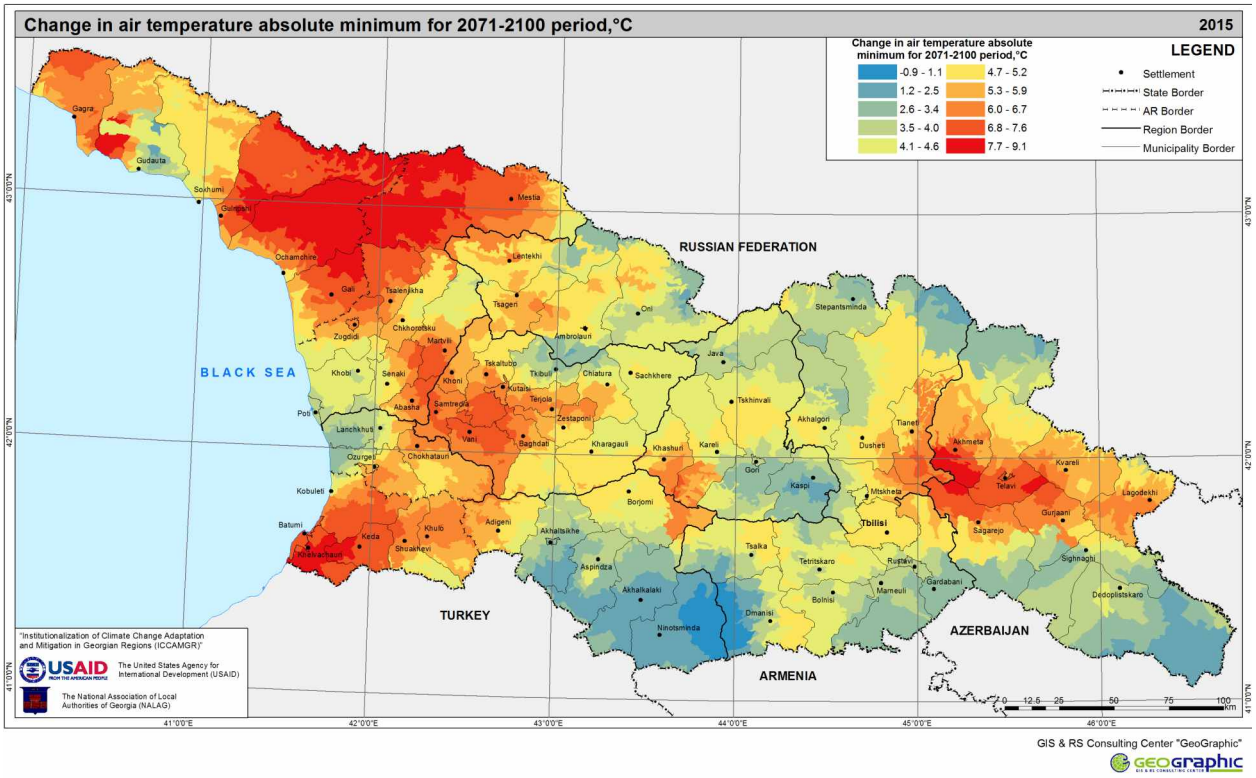
Map 12. Change in the absolute maximum air temperature at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

The change in the absolute maximum air temperature for Future 2 (2071-2100) compared to the baseline period (1961-1990) will be within 3°C to 8°C. The maximum change is expected in the territories of Kazbegi, Marneuli and Bolnisi municipalities. An increase of up to 5°C is expected in Kakheti region and in the lowlands of West Georgia.



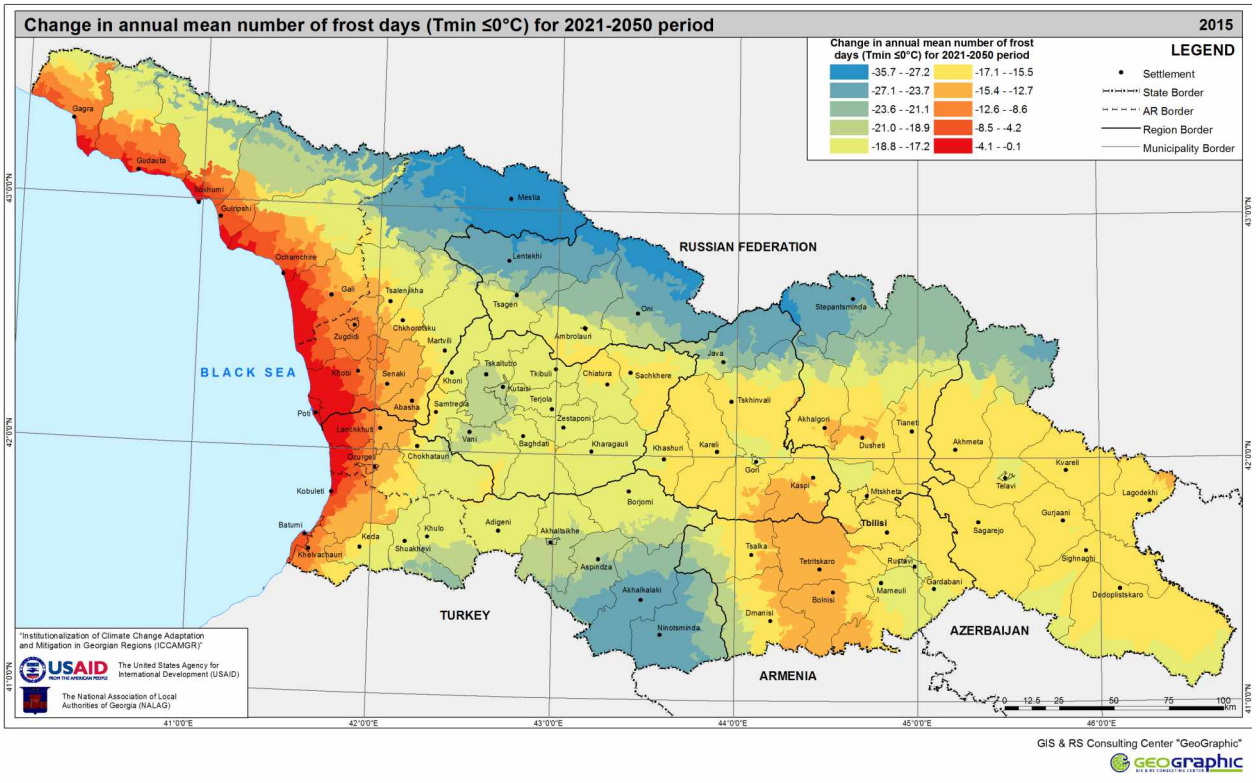
Map 13. Change in the absolute minimum air temperature at a height of 2 m for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The change in the absolute minimum air temperature for Future 1 (2021-2050) compared to the baseline period (1961-1990) has the same tendency for declines and increases in temperature in different regions of the country. The minimum decline in temperature will occur in Samtskhe-Javakheti, Shida Kartli, Imereti Highlands and the southern municipalities of Kakheti.



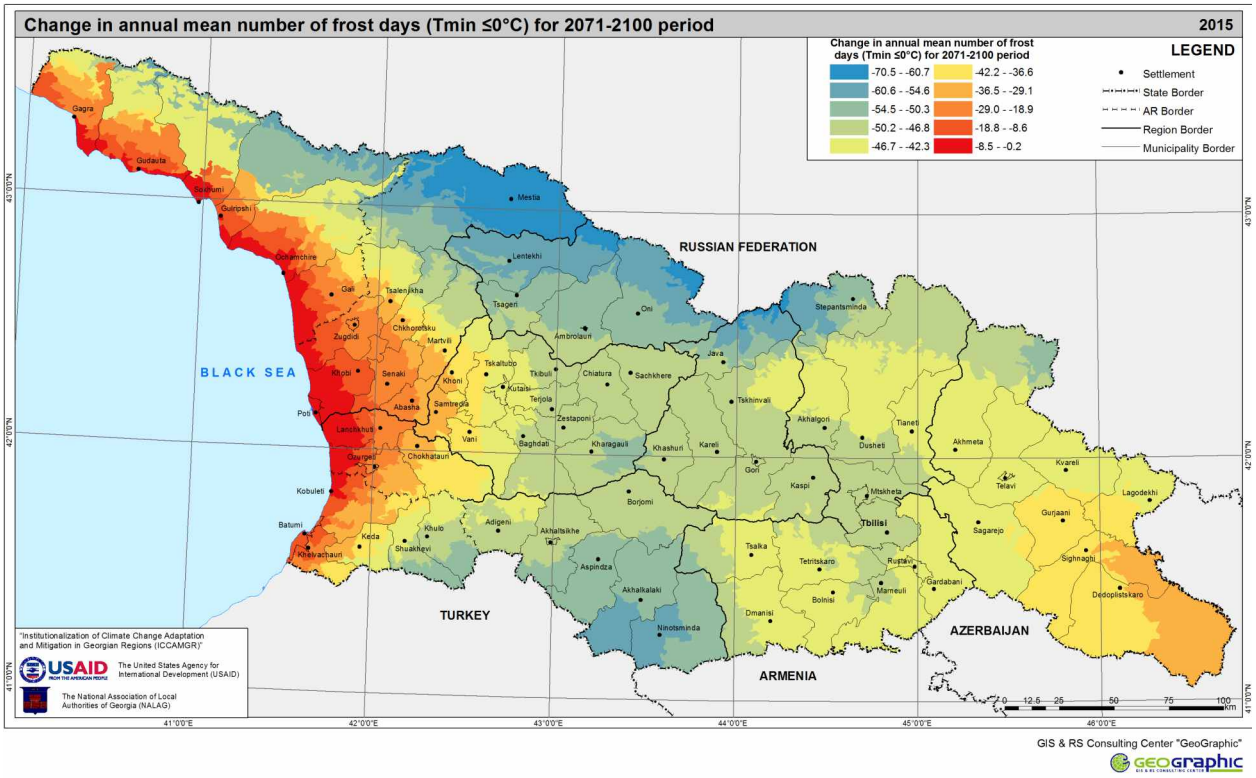
Map 14. Change in the absolute minimum air temperature at a height of 2 m for Future 2 (2071-2100) compared to the baseline period (1961-1990)

A change in the absolute minimum air temperature for Future 2 (2071-2100) compared to the baseline period (1961-1990) has a general tendency for warming; although a fall in temperature by 1°C is probable in the mountain zone of Dmanisi and Ninotsminda municipalities. The maximum positive change (+9°C) is expected in Khelvachauri, Gulripshi and Mestia municipalities.



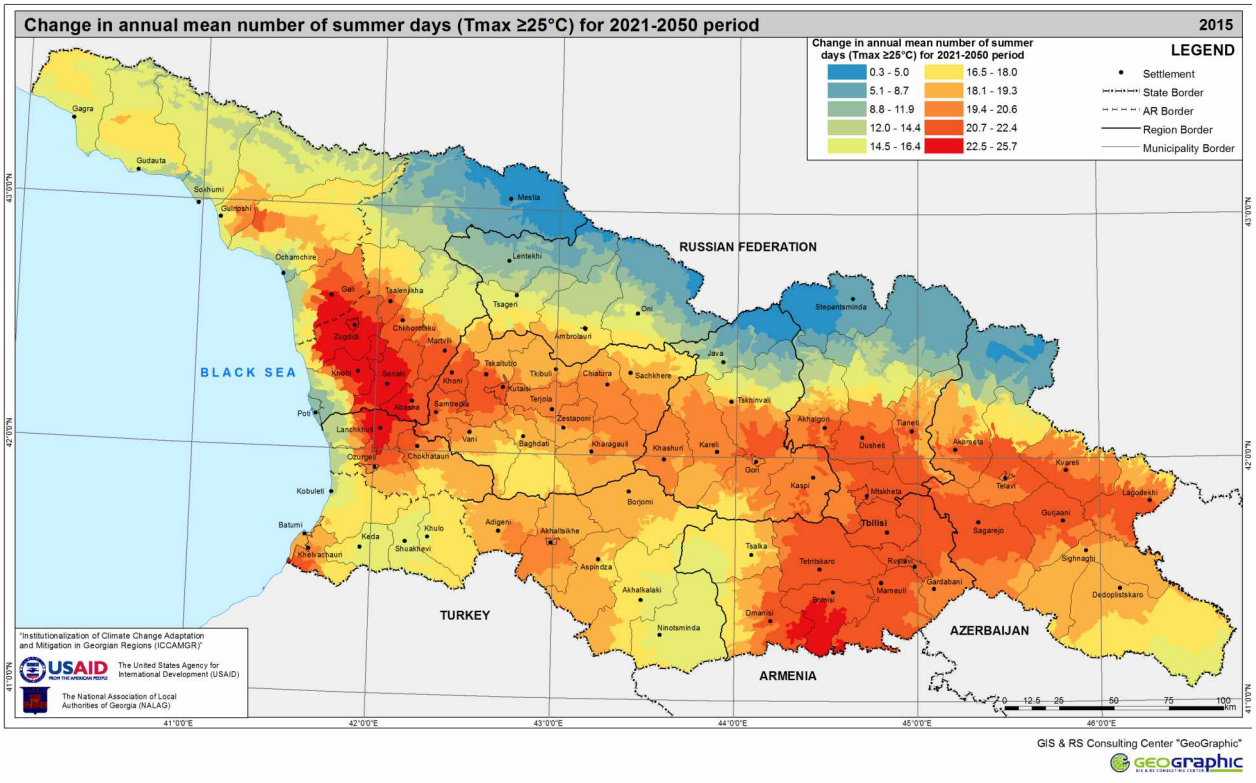
Map 15. Change in the number of frost days for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The number of frost days for Future 1 (2021-2050) compared to the baseline period (1961-1990) is decreasing throughout Georgia. This decrease is of special importance for mountain regions, where the number of frost days will decrease by 36 days per annum on average. The least decrease of this parameter is expected in the Black Sea coastal area, where the number of frost days in the baseline period is not significant.



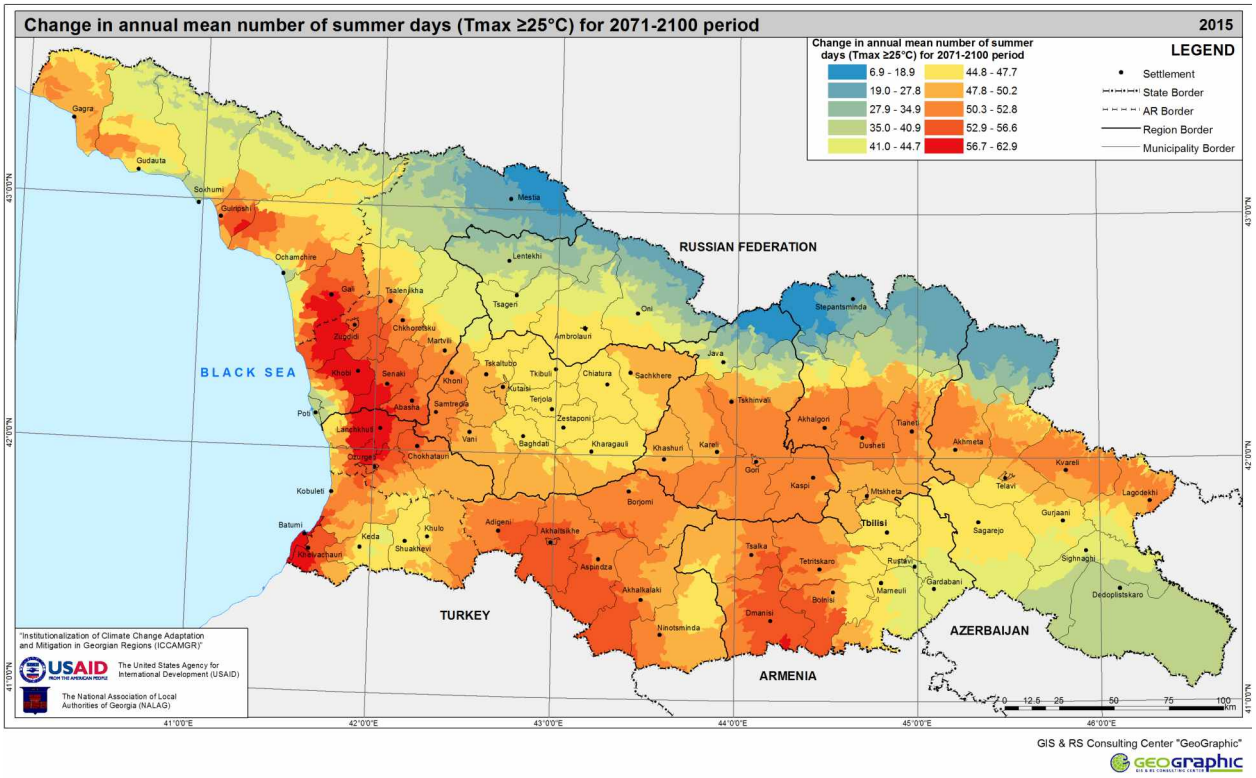
Map 16. Change in the number of frost days for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the maximum change in the annual number of frost days will double (71 days) compared with Future 1 (2021-20150) and the greatest decreases are on the slopes of the Lesser and Greater Caucasus, although the number of frost days significantly decreases (50 days) in other highland and lowland areas of Georgia. Frost days in the coastal zone and Kolkheti Lowland are a rare event.



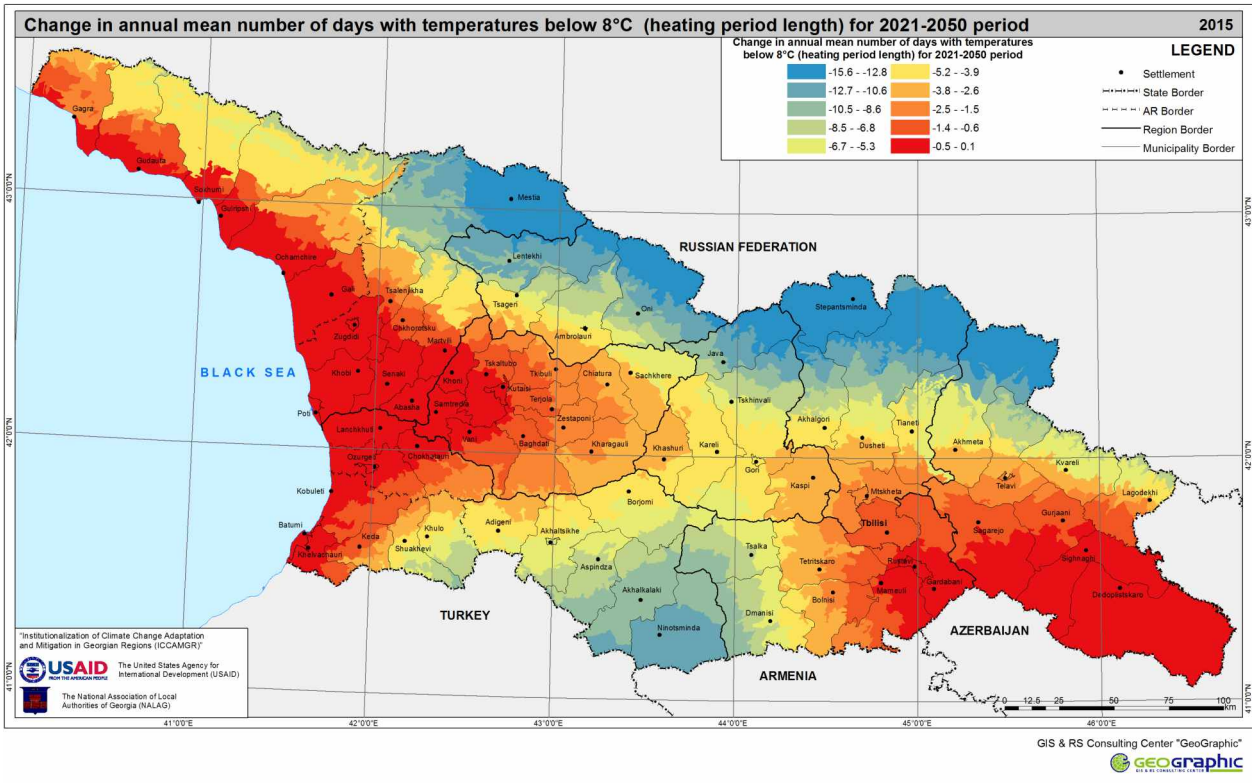
Map 17. Change in the number of hot days for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The number of hot days for Future 1 (2021-2050) compared to the baseline period (1961-1990), or the total days when the maximum temperature is over 25°C, is increasing throughout Georgia. The process is less observable on the Greater Caucasus slopes. In particular, the number of such days in Mestia, Lentekhi, Oni, Java, Stepantsminda, Dusheti and Akhmeta municipalities increases from 0.3 to 5, while in some Bolnisi and Samegrelo municipalities (Zugdidi, Senaki and Khobi) the contemplated maximum increment reaches 27 days.



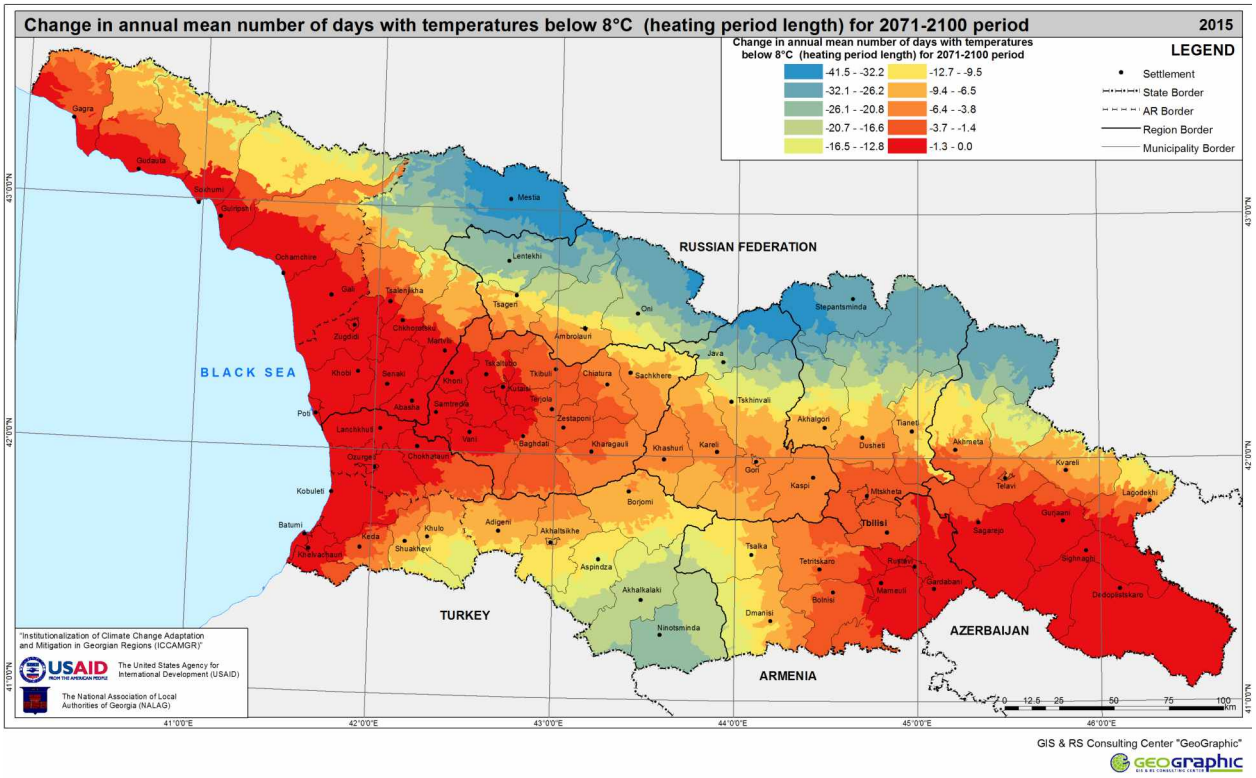
Map 18. Change in the number of hot days for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the annual number of hot days will increase about 2.5 times more than in the previous projected period (2021-2050) almost according to the same pattern.



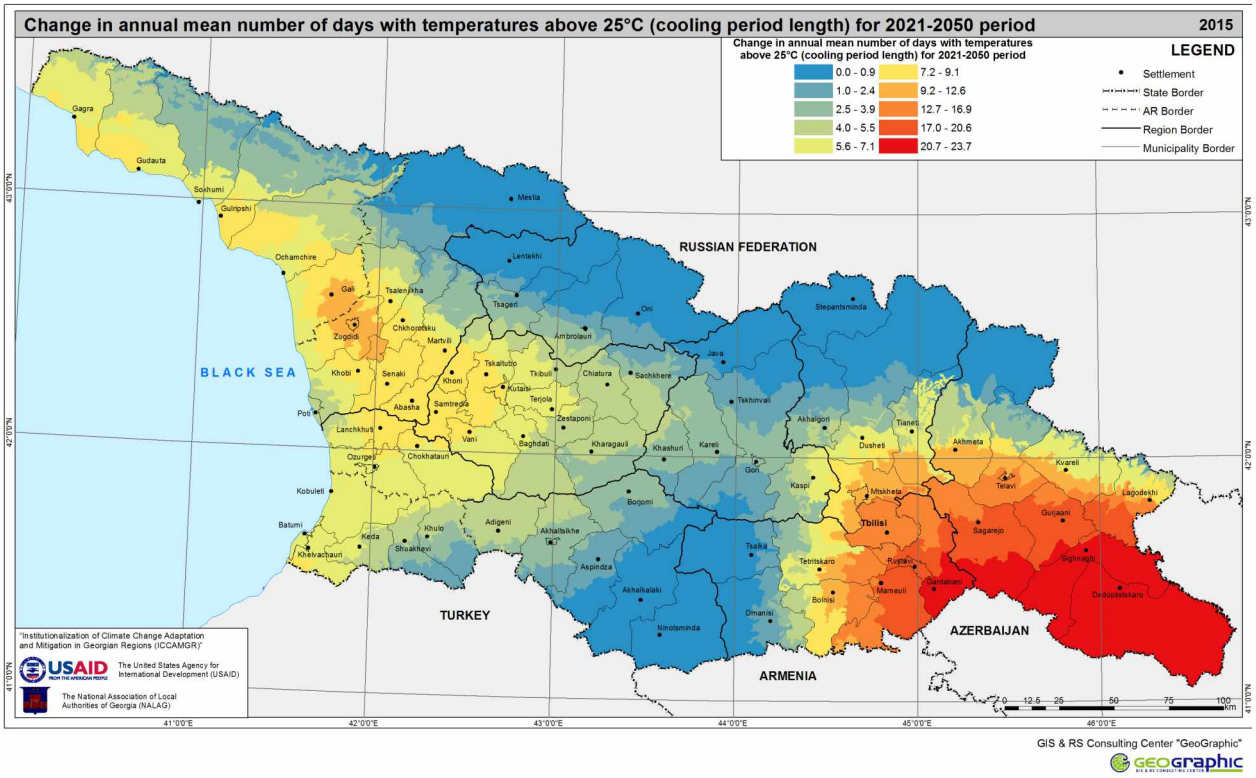
Map 19. Change in heating period length for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The heating period, or when the average temperature is less than +8°C and the population needs additional heating resources, tends to decrease throughout Georgia. The trend is particularly notable in mountain zones, where the heating period decreases by 15 days on average. In the Kolkheti lowland, Kakheti and Kvemo Kartli the heating period will decrease by 1-3 days.



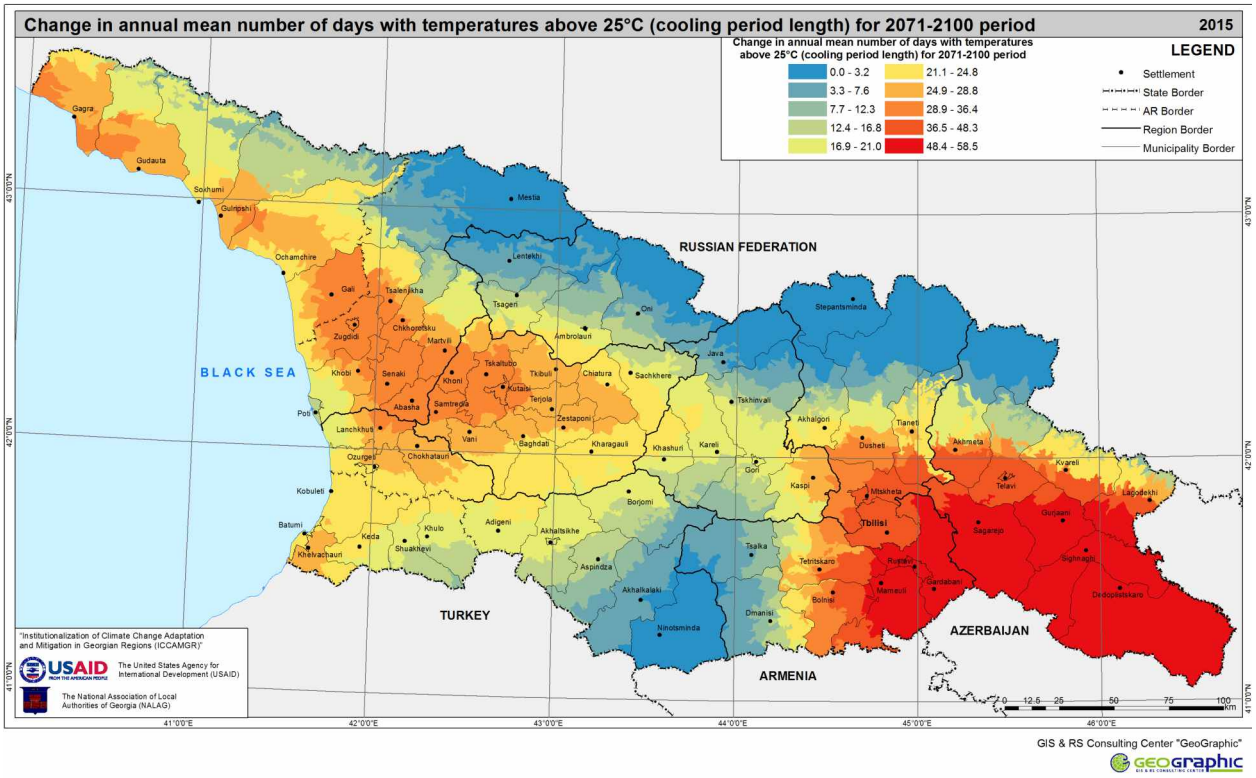
Map 20. Change in the heating period length for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), reduction in the heating period (or when the average temperature is less than $+8^{0}$C and the population needs additional heating resources) has the same character as in the previous projected period (2021-2050), it will decrease in the territory of the Lesser and Greater Caucasus, although more intensively (46 days).



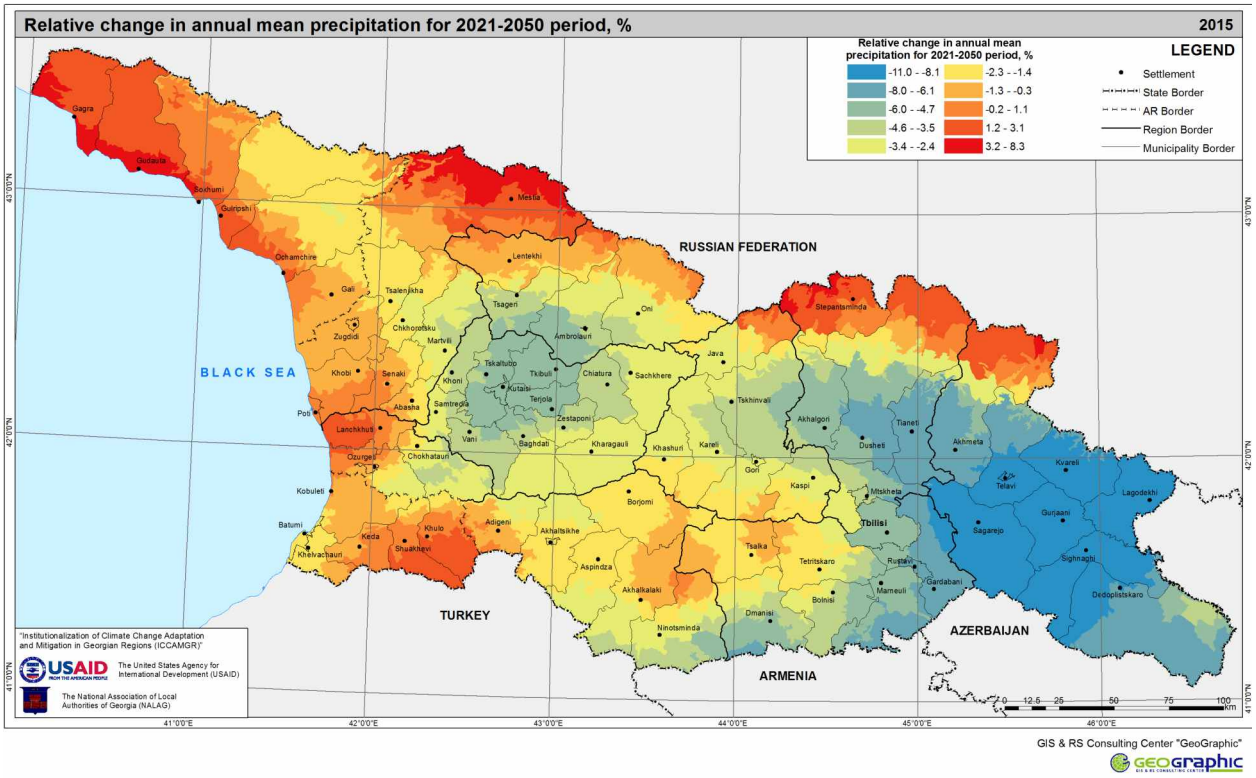
Map 21. Change in the cooling period length for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), change in the cooling period (number of days when temperature exceeds +25^{0}C and the population may use cooling equipment) has a trend opposite to a change in the heating period. In mountain regions it is almost unchanged, pronouncedly increasing in Kvemo Kartli and Kakheti (by 21-24 days) and increasing less in the Kolkheti lowland (by 10 days).



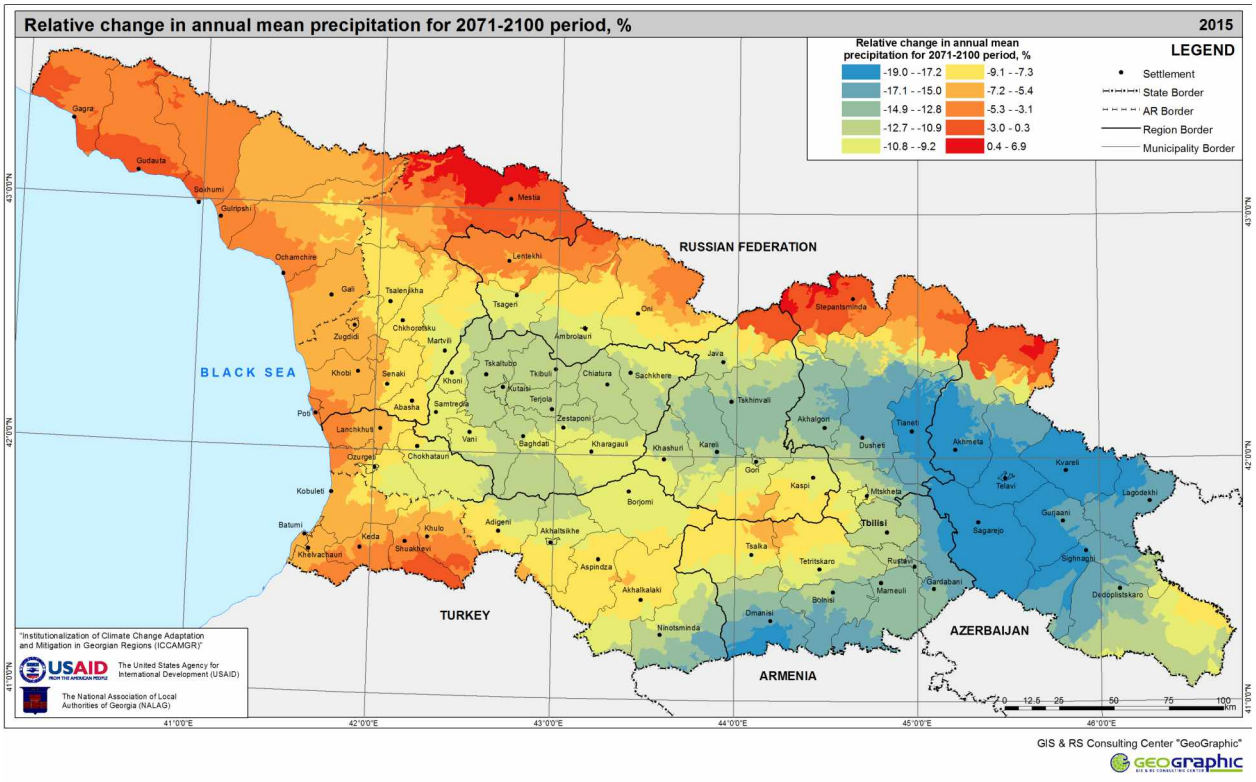
Map 22. Change in the cooling period length for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the cooling period (number of days when temperature exceeds +25^{0}C and the population may use cooling equipment) increases more intensively. As in Future 1 (2021-2050), the most pronounced increase (by 48-59 days) is again observed in Kvemo Kartli and Kakheti, although in the territories of the rest of the country, other than the mountain regions, the trend for the increase in such days will be retained.



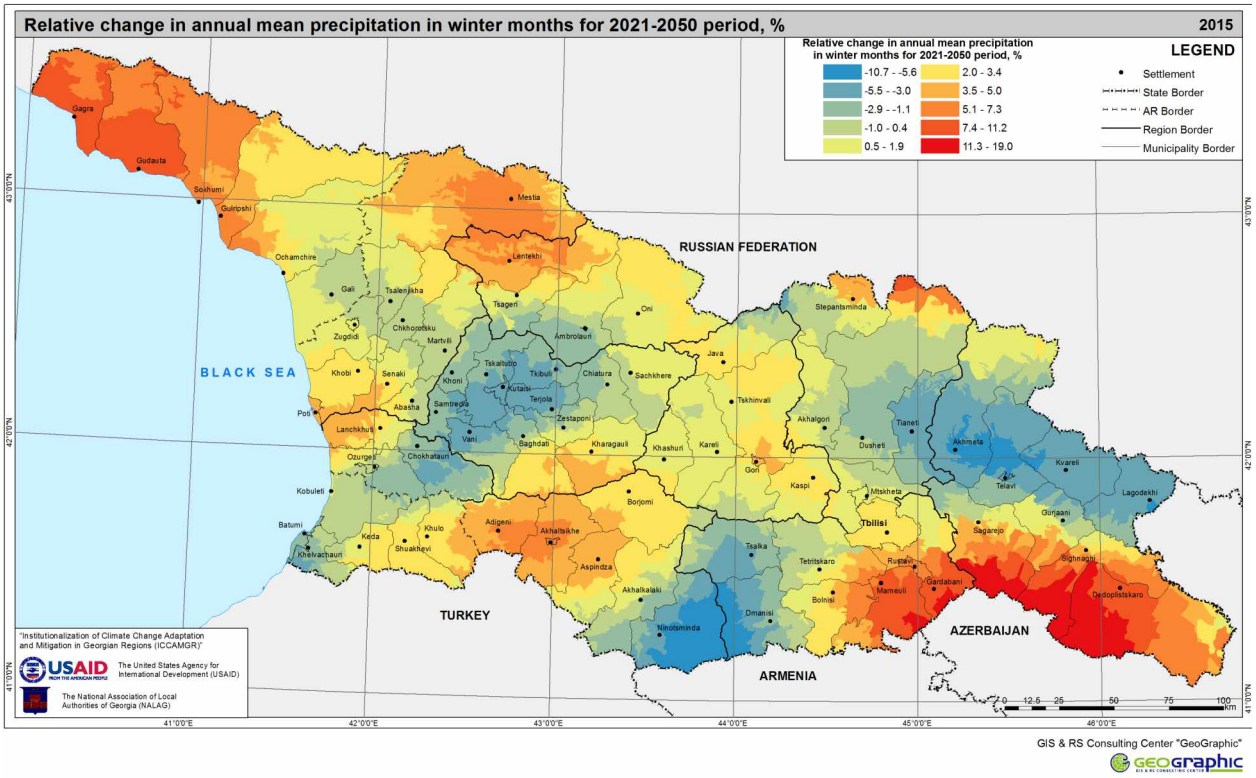
Map 23. Percentage change (%) of annual mean precipitation for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The percentage change of annual total precipitation for Future 1 (2021-2050) compared to the baseline period (1961-1990) is within a range from a 11% decrease to an 8% increase. The decrease is most observable in the territories of Kakheti and Kvemo Kartli. The largest positive change (increase up to 8%) is expected in Abkhazia, Mestia and Stepantsminda municipalities.



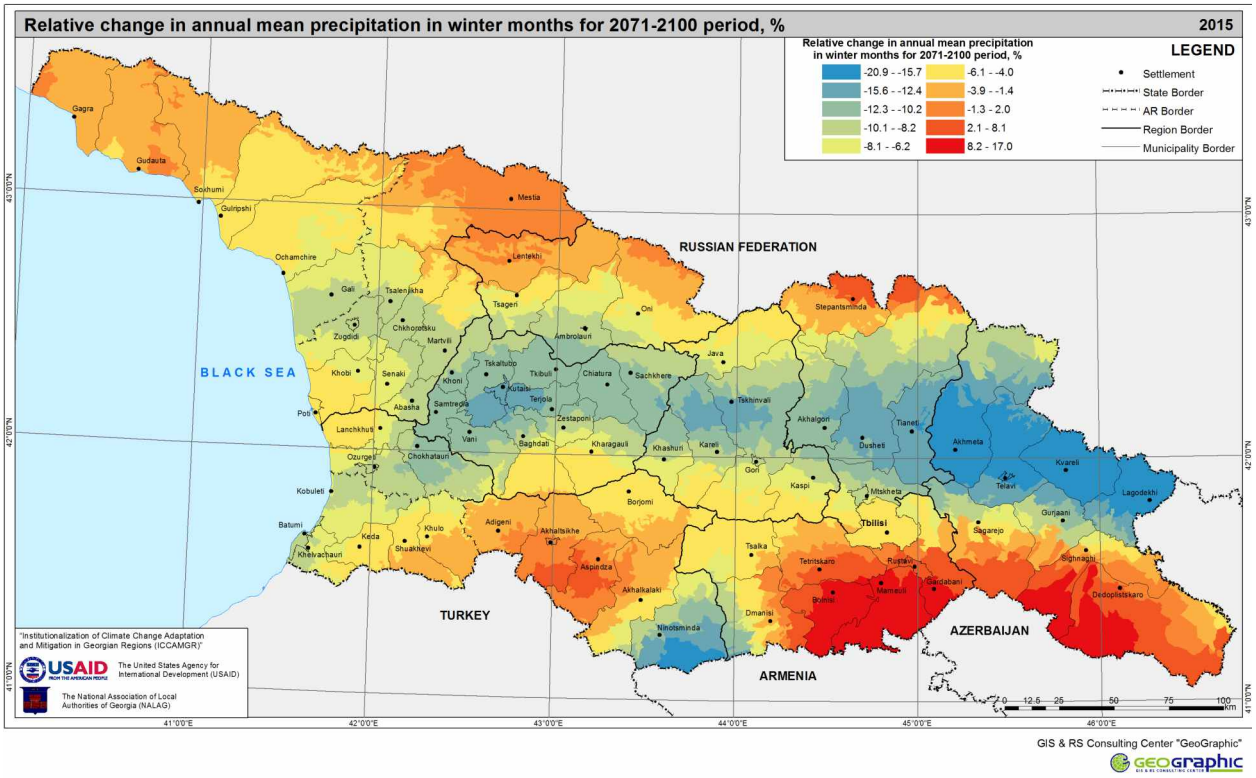
Map 24. Percentage change (%) of annual mean precipitation for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the range of percentage change of total annual precipitation will be within 19% to 7%; the percentage decline of precipitation in this period will be greater than in Future 1 (2021-2050). In general, precipitation in the territory of East Georgia will decrease, except for in the highlands. In the west, along the coastal zone and Imereti highlands precipitation will remain almost unchanged. The most pronounced decrease of precipitation in West Georgia will take place in the Imereti highlands, while in the territory of Mestia-Lentekhi precipitation will increase.



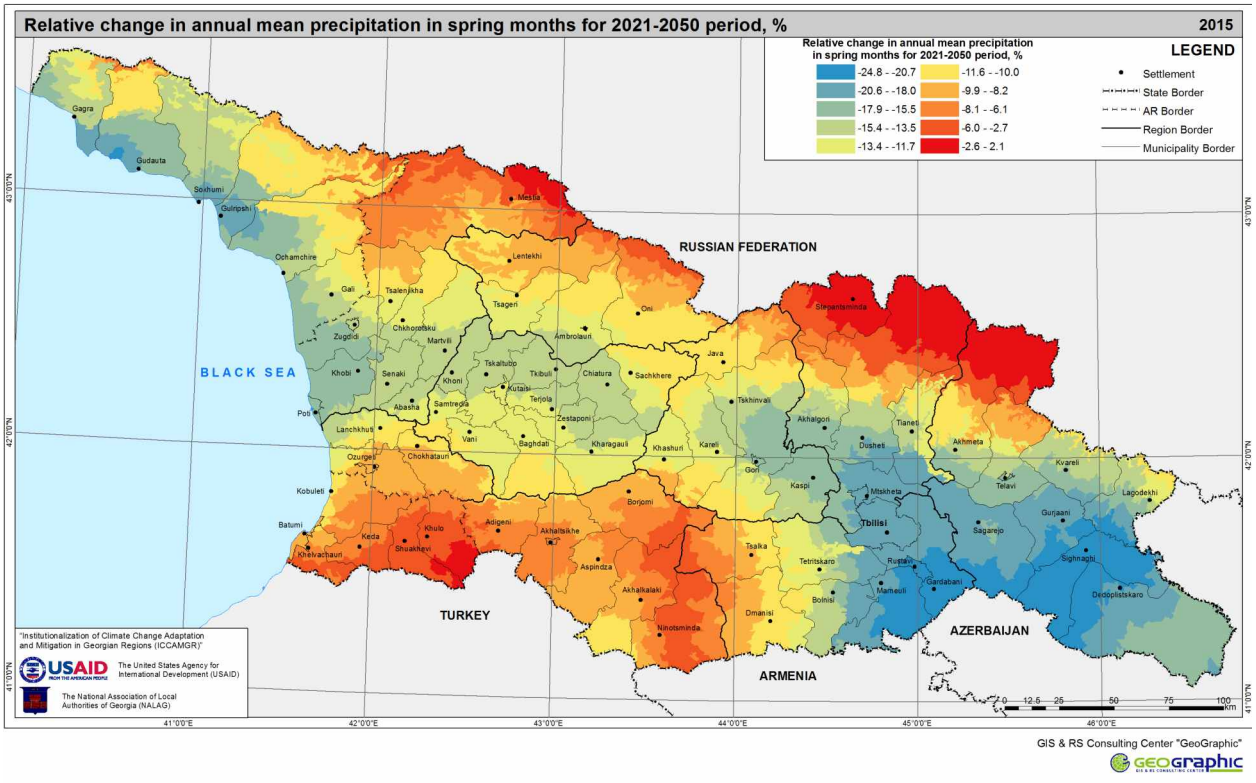
Map 25. Percentage change (%) of annual mean precipitation in winter for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), total precipitation change for the winter season has a rather wide range (from an 11% decrease to a 19% increase). A winter precipitation decrease is observable in Tianeti, Akhmeta, Telavi, Kvareli, Lagodekhi, Ninotsminda and Dmanisi municipalities; a comparatively lower decrease (6%) is observable in the Imereti region. Winter precipitation increases in the territories of the municipalities bordering Azerbaijan and in Gagra and Gudauta municipalities.



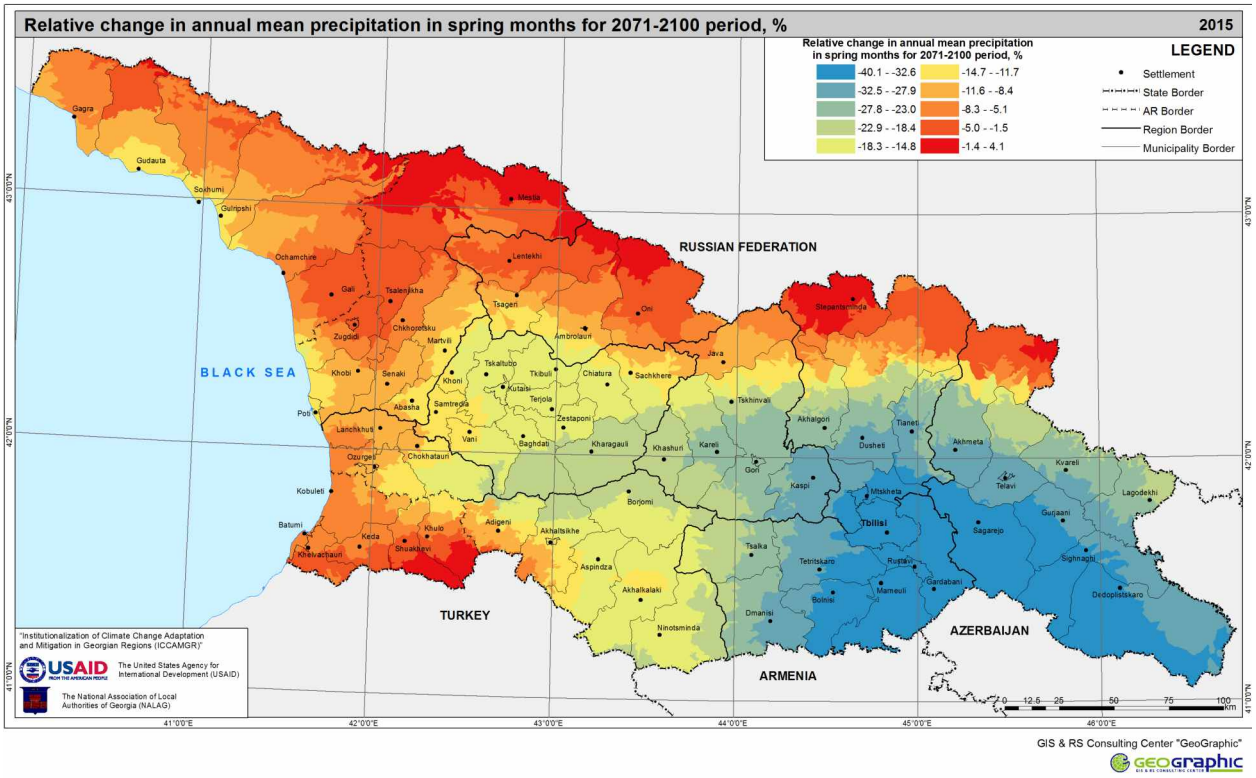
Map 26. Percentage change (%) of annual mean precipitation in winter for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), the winter precipitation change has the same tendency as in Future 1 (2021-2050), and it decreases or increases in the same municipalities, with the difference that the maximum decrease in this period is 20%.



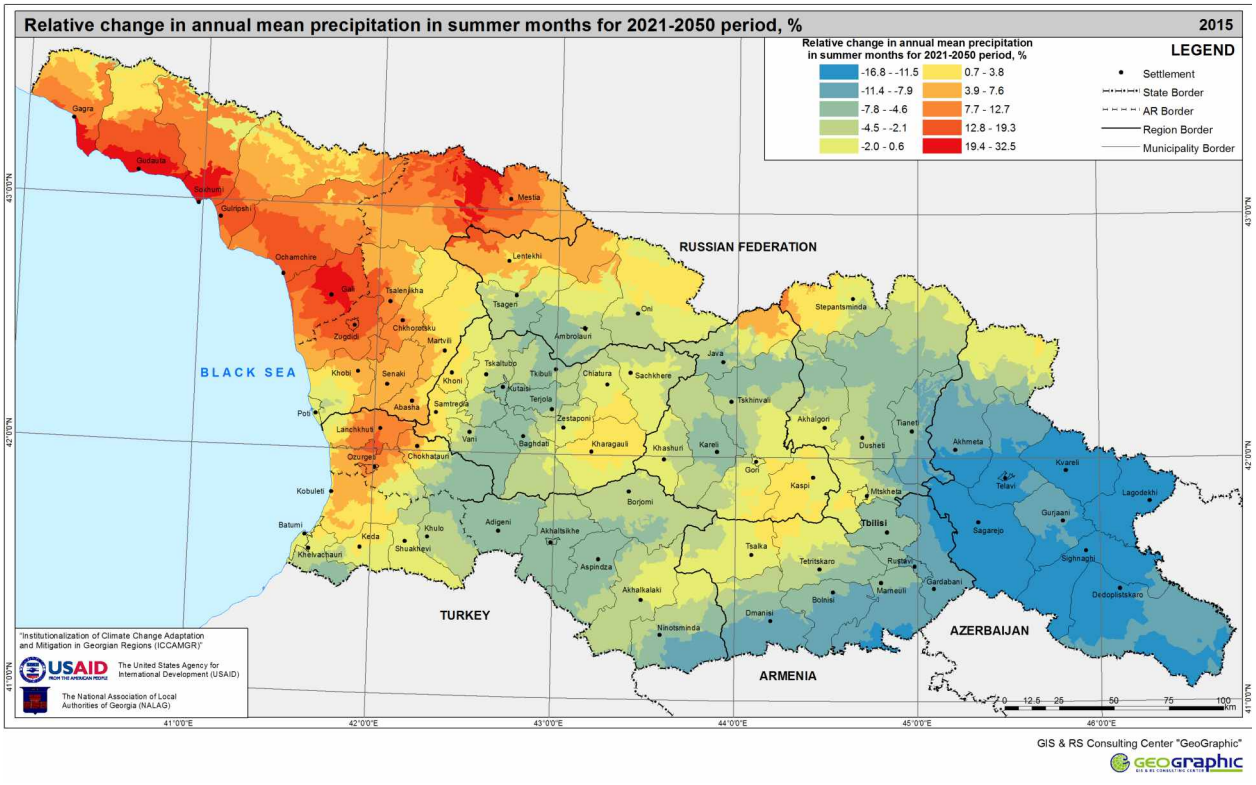
Map 27. Percentage change (%) of annual mean precipitation in spring for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The ratio of total precipitation in spring, for Future 1 (2021-2050) compared to the baseline period (1961-1990), significantly decreases (by 24%) in Kvemo Kartli and Kakheti (except Tusheti). This is the largest decrease between the seasons in this projected period. In the Kolkheti lowland and along the Samegrelo-Abkhazia coastal area the precipitation decrease will be half as much (by about 11%). In the remaining territory of the country as well, the total precipitation for the season will only decrease, but by much less.



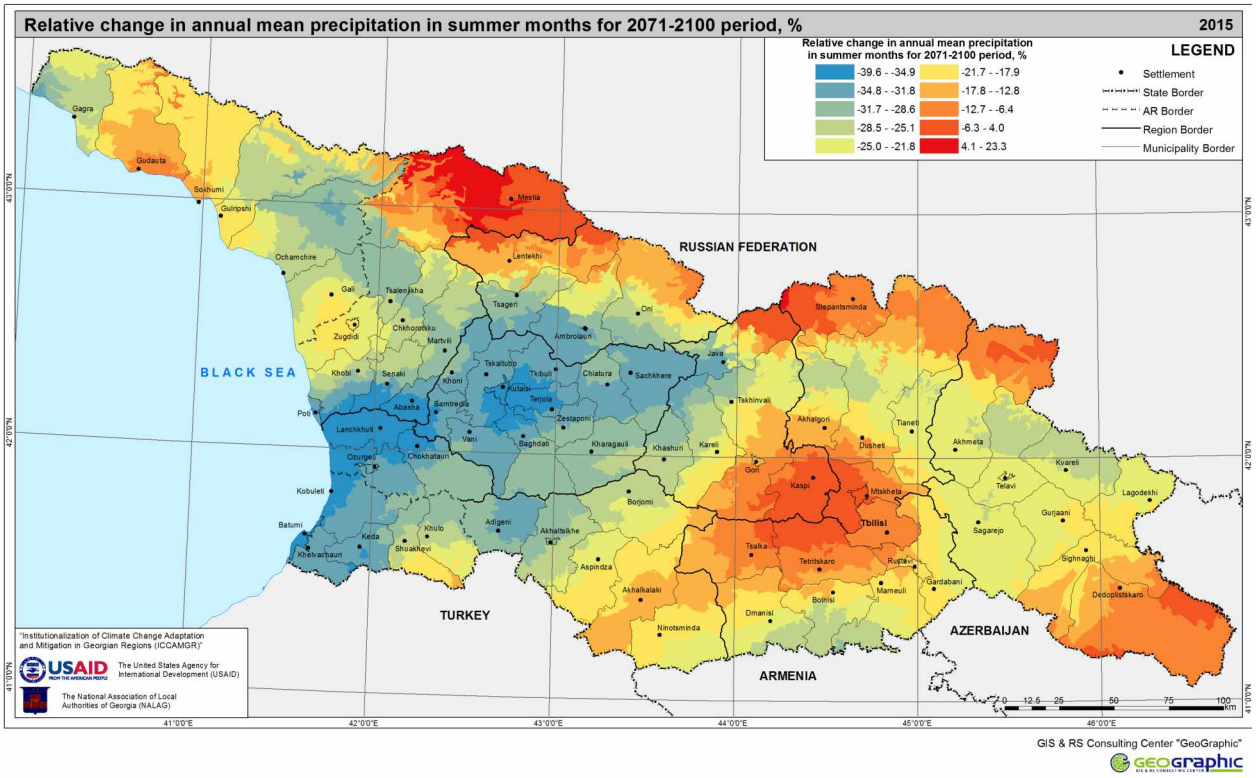
Map 28. Percentage change (%) of annual mean precipitation in spring for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), total precipitation continues to decrease and assumes a more pronounced character. In East Georgia, it will increase only on the slopes of the Caucasus by 4%. In the rest of the territories, especially in the Southeast, precipitation will decrease by 40%. In the West and in the lowlands the decline will be within 5%, except for the Kharagauli and Baghdadi municipalities, where precipitation falls by 25%, while a small 4% increase is expected in the highlands.



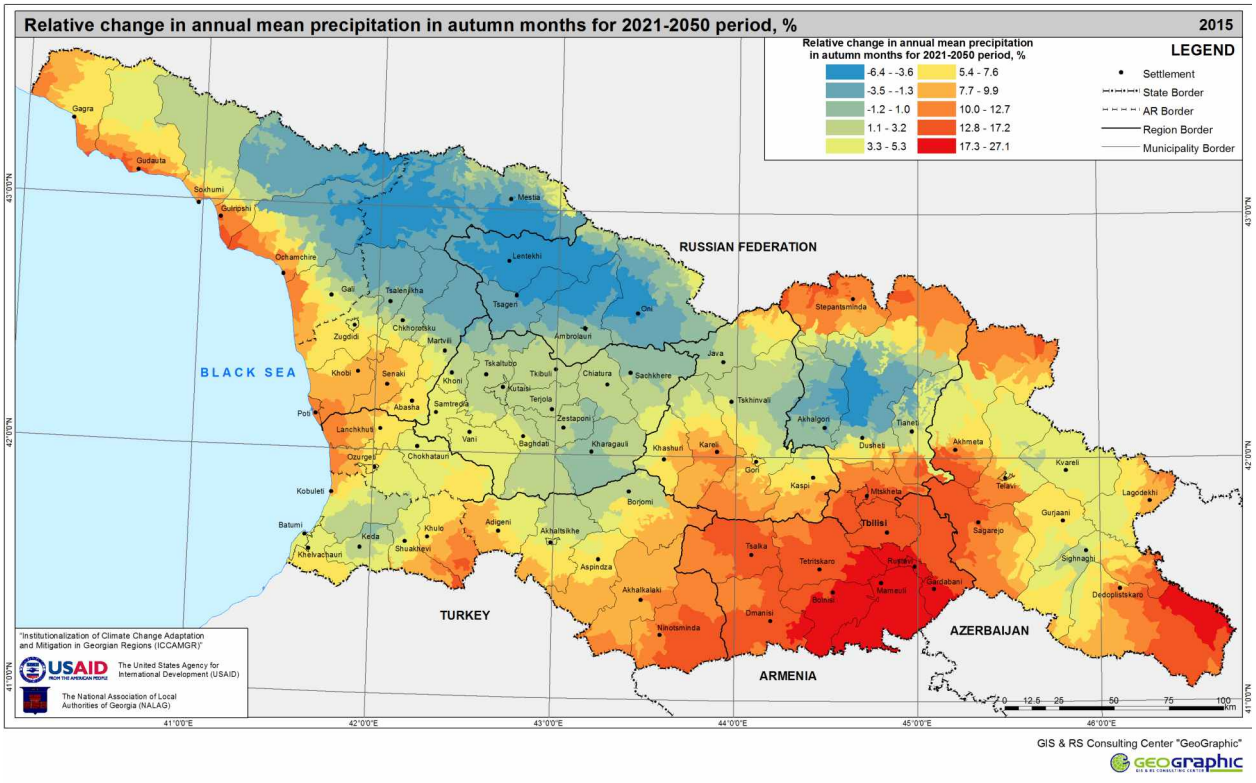
Map 29. Percentage change (%) of annual mean precipitation in summer for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), total precipitation in the summer period will decline in East Georgia, in the territories of Samtskhe-Javakheti and Imereti regions, most of all in Kakheti (17%). In Abkhazia, Samegrelo and Upper Svaneti a 25% increase in total precipitation on average us expected.



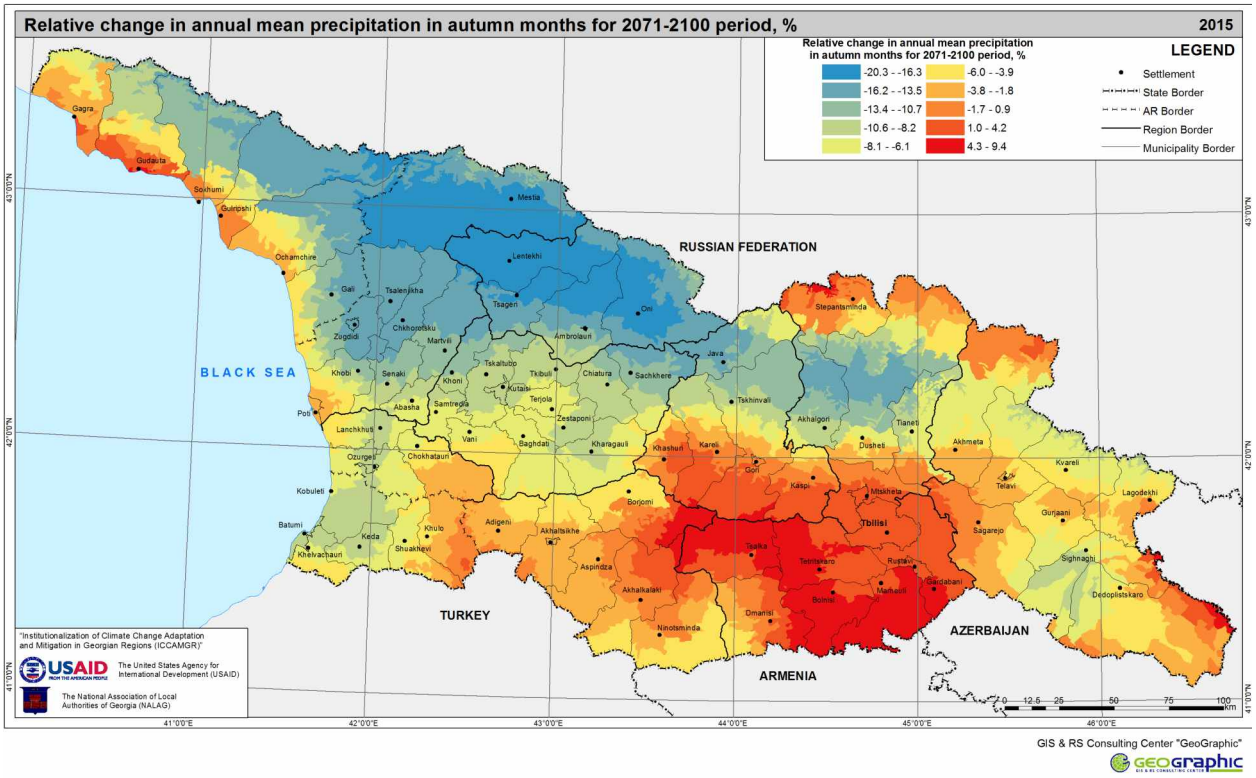
Map 30. Percentage change (%) of annual mean precipitation in summer for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), precipitation in summer will decrease as opposed to Future 1 (2021-2050), mostly in West Georgia. The largest decrease (up to 40%) will be observed in the Rioni gorge downstream, also in Terjola and Tkibuli municipalities. In West Georgia, an increase is observable only in Mestia.



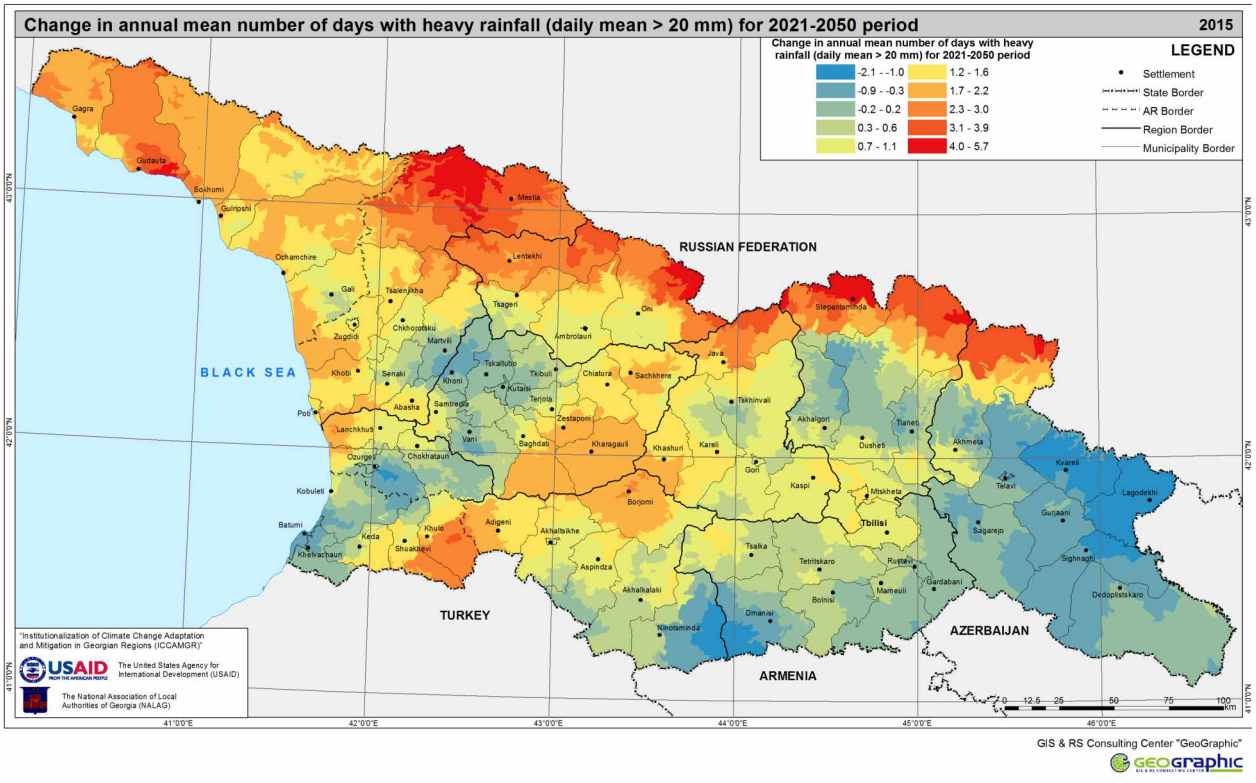
Map 31. Percentage change (%) of annual mean precipitation in autumn for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), the percentage change of total precipitation in autumn is not uniform, as it is in other seasons. The upward tendency is more evident in the southern regions of the country, and is most notable in the territories of Gardabani, Marneuli and Bolnisi (up to a 27% increase). A downward trend is more pronounced in the north of Georgia, although it is less intense (7% decrease).



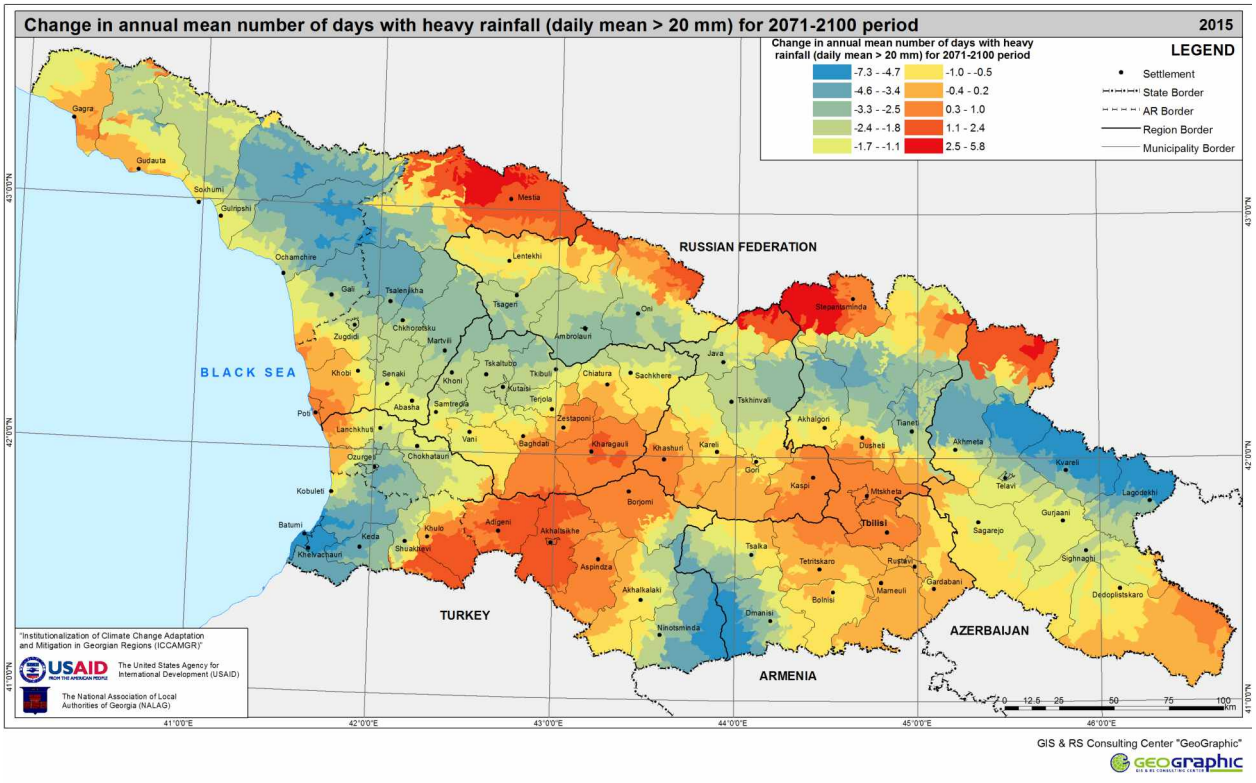
Map 32. Percentage change (%) of annual mean precipitation in autumn for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), trends for declines or growth in autumn precipitation will be retained from Future 1 (2021-2050) in all the regions of the country, although the intensity of these changes will be more significant. In particular, an approximately 20% decline is expected in the northern part of the country, while increases can be much less intensive. For example, the highest increase will presumably reach 9% in Kvemo Kartli.



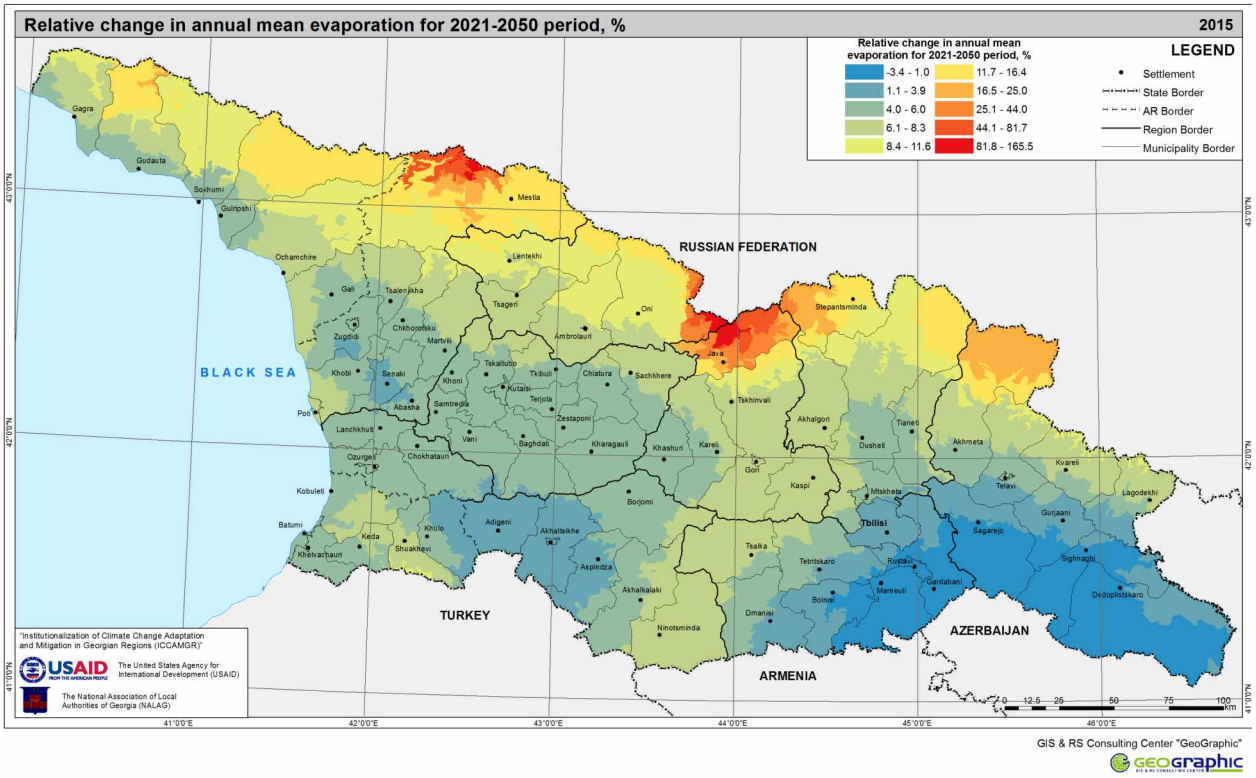
Map 33. Change in the annual mean number of days of heavy rain for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), a change in the number of days of heavy rain is not noted for large deviations. Its variation is within the range of 2 to 5 days. A decline is more observable in the Southeast, also in Adjara and a large part of Imereti. An increase will take place in mountain regions, mostly within the Greater Caucasus.



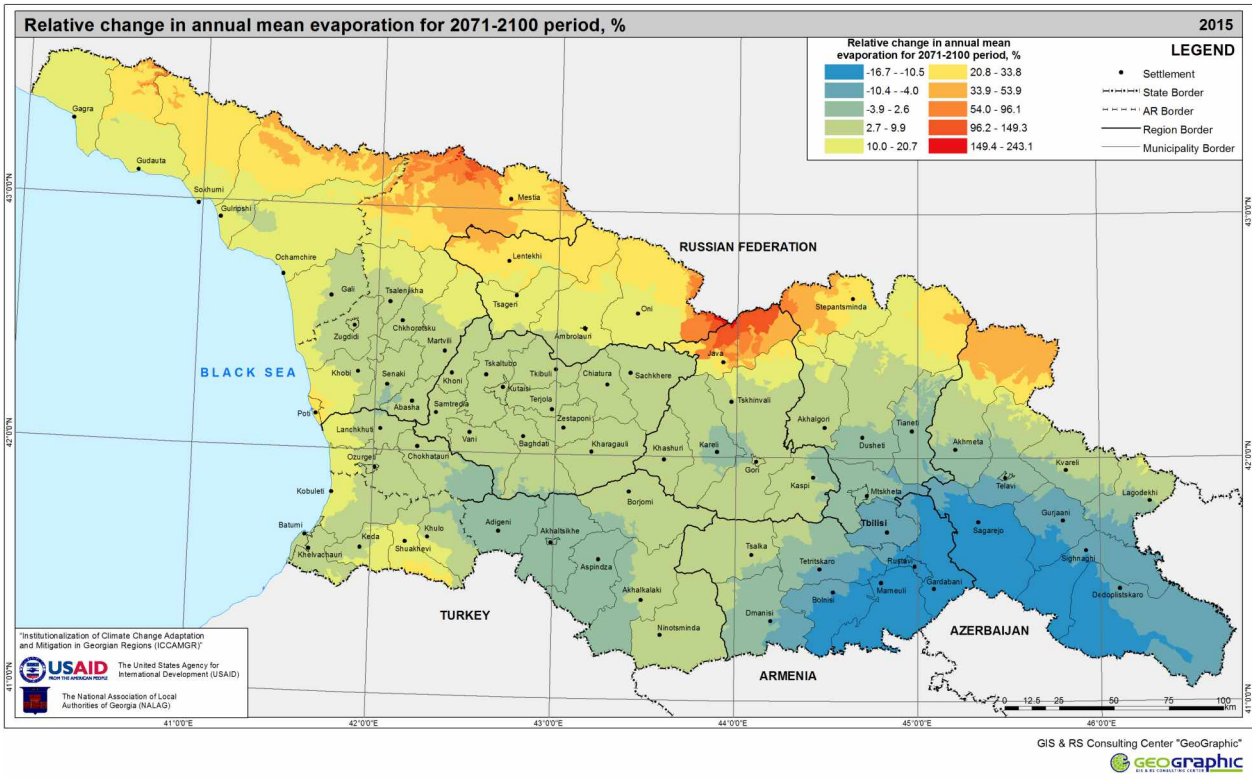
Map 34. Change in the annual mean number of days of heavy rain for Future 2 (2071-2100) compared to the baseline period (1961-1990)

A change in the days of heavy rain for Future 2 (2071-2100) compared with Future 1 (2021-2050) is retained on the Greater Caucasus and this number is close to 5 more days. As regards a decline, the annual number of days of heavy rain will decrease by approximately 6 to 7 days and it is expected to take place in the Greater Caucasus foothills and the middle mountain zones, in the territory of Adjara, in Dmanisi and Ninotsminda municipalities.



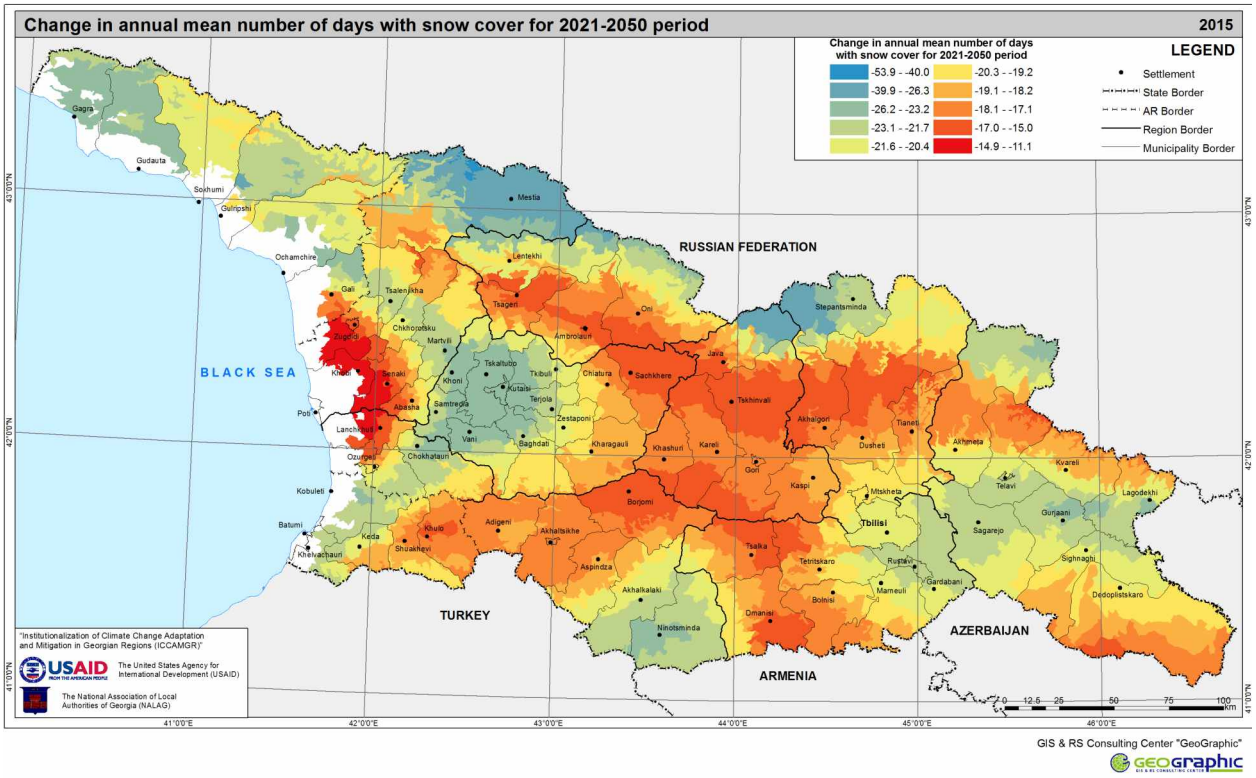
Map 35. Percentage change of average annual evaporation for Future 1 (2021-2050) compared to the baseline period (1961-1990)

The average annual evaporation for Future 1 (2021-2050) compared to the baseline period (1961-1990) will generally change from 4% to 10%. A decline takes place mostly in southern regions. To the north of the country and especially in the highlands a growth trend is observable. The change in the Great Caucasus within Oni and Java municipalities, where this indicator is to grow 1.5 times, is most notable.



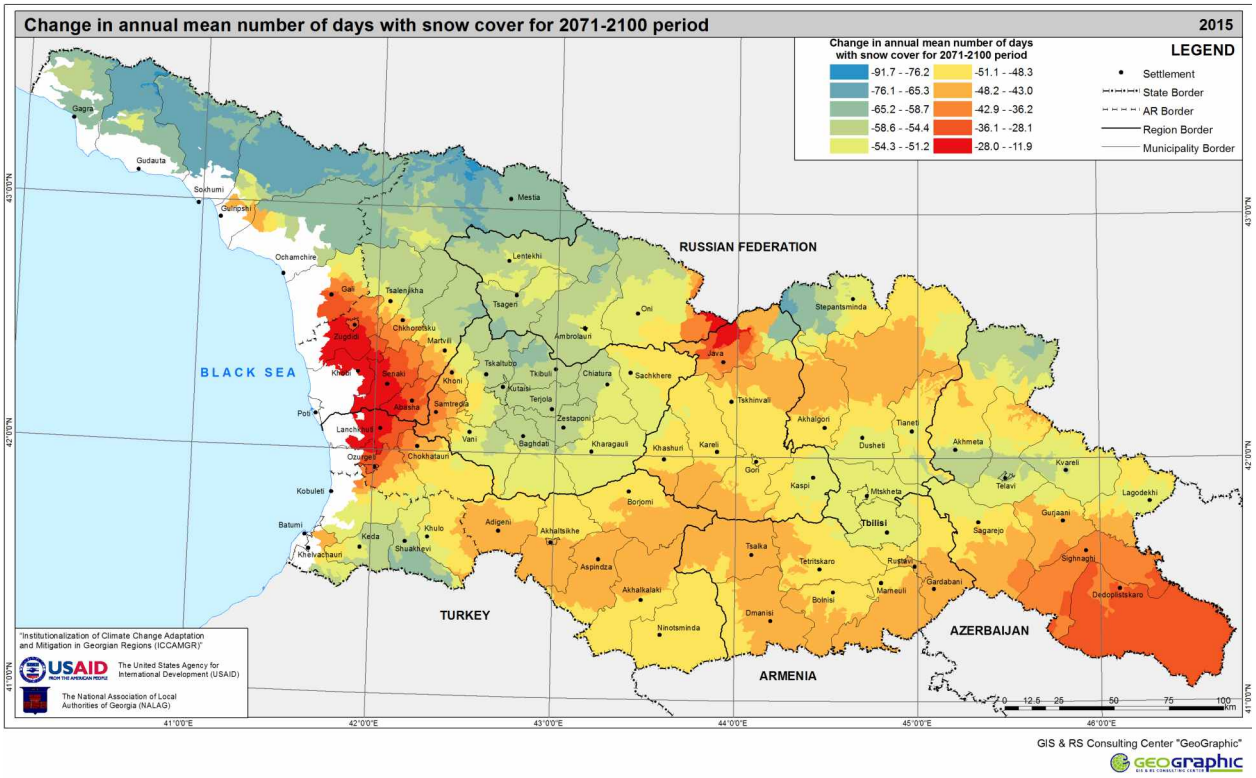
Map 36. Percentage change of average annual evaporation for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), evaporation will decrease in the municipalities bordering Armenia and Azerbaijan, a 30% increase is expected to the north in Mestia, Tusheti and Stepantsminda, while within Oni and Java municipalities located within the Greater Caucasus evaporation is to increase twofold and then some.



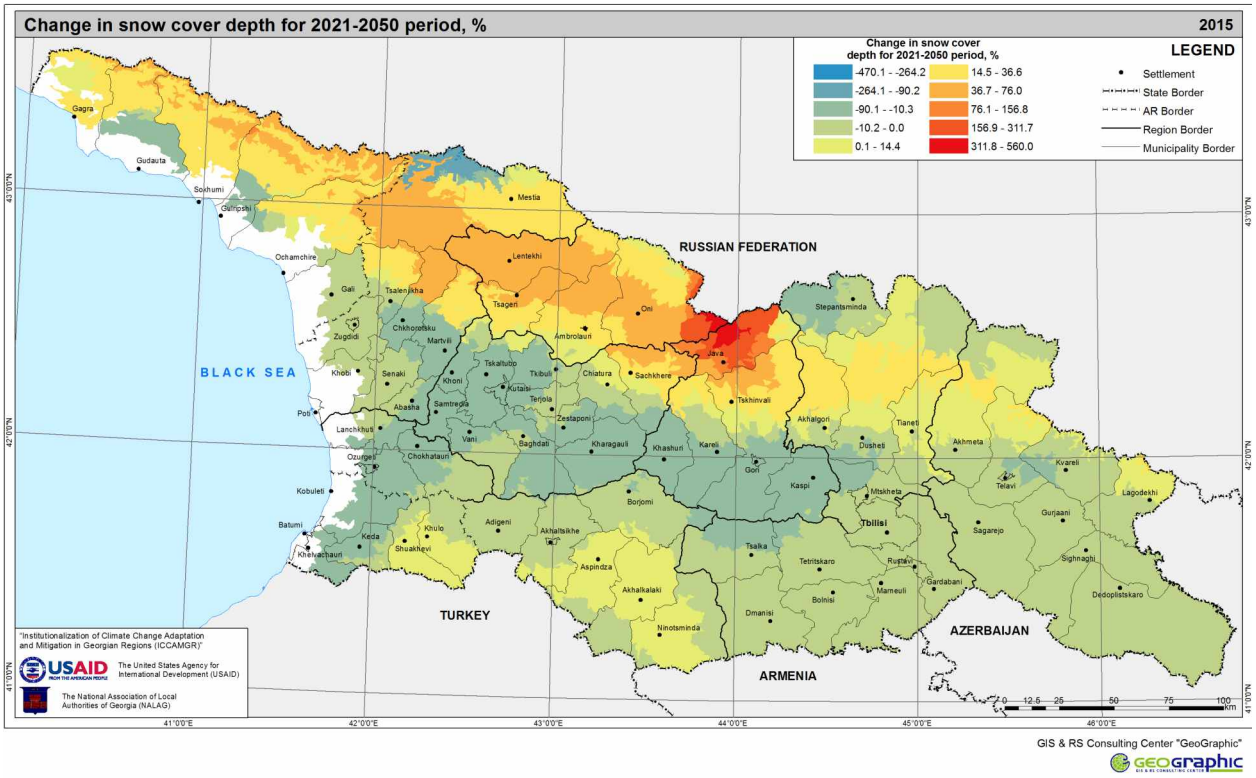
Map 37. Change in the avarage number of snow days for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), the average annual indicator throughout the country is declining. The change in highland areas is significant, where snow depth is retained for the majority of the year. In the Greater Caucasus, such change equals 50 days on average, while in the lowlands it falls to 11 days on average, because the number of snow days is insignificant there.



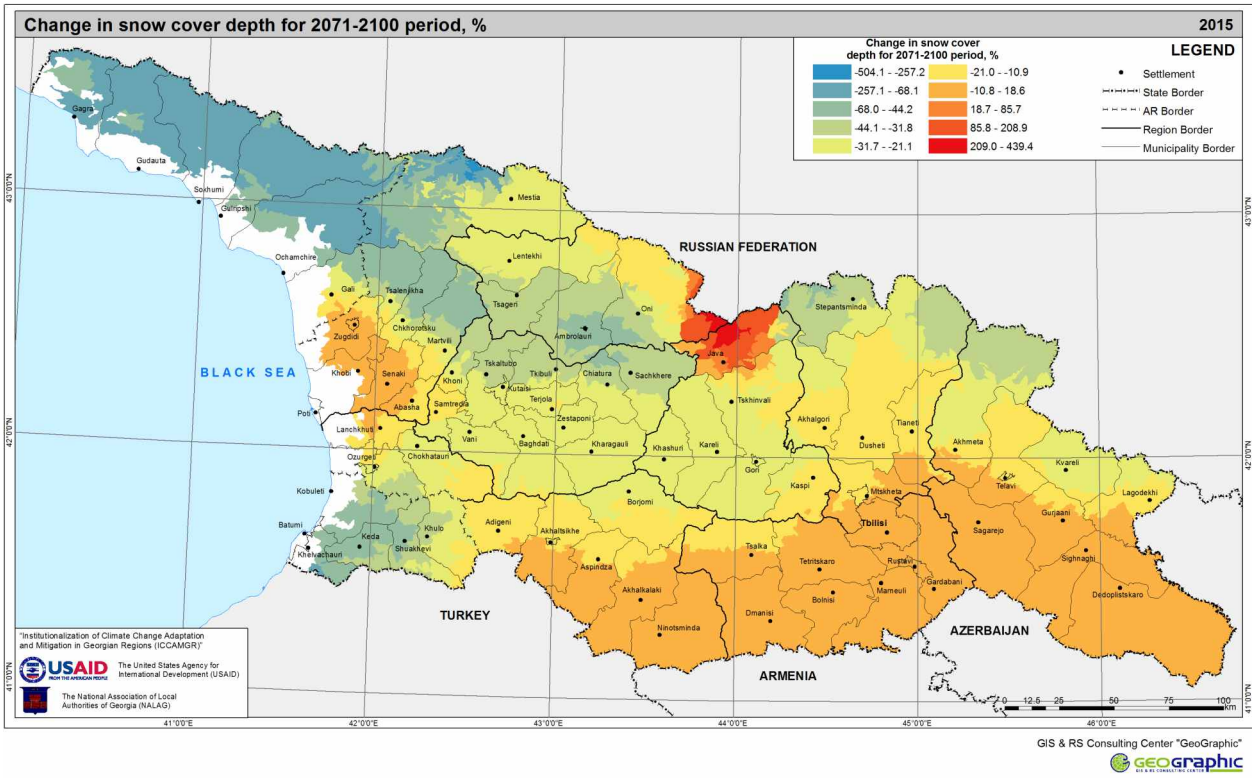
Map 38. Change in the average number of snow days for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), a tendency for decreasing the number of snow days will remain as in Future 1 (2021-2050), reaching 90 days in the highlands. The least decline in this parameter, by 11 days on average, will be observed within the Kolkheti lowlands, in the territories of Java and Kakheti.



Map 39. Percentage change of snow cover depth for Future 1 (2021-2050) compared to the baseline period (1961-1990)

For Future 1 (2021-2050) compared to the baseline period (1961-1990), a percentage change in snow depth is generally noted as a decline. The snow depth in the central part of the country will decline almost five times, relatively less in the southern territory (10%), while a 14% increase is expected in the north, for instance in Mestia and Lentekhi municipalities.



Map 40. Percentage change of snow cover depth for Future 2 (2071-2100) compared to the baseline period (1961-1990)

For Future 2 (2071-2100) compared to the baseline period (1961-1990), snow depth is declining again to approximate changes as in the previous projected period (2021-2050).

3. Sensitivity to climate change for socio-economic sectors

3.1 Sensitivity of the tourism sector, cultural heritage and protected areas

Tourism is one of the priority sectors of the Georgian economy, and it is growing in importance. Revenues from international tourism have increased by 12.4 times over the past 15 years, amounting to USD 1.4 billion in 2014. The number of international visitors is also constantly rising, increasing tenfold in the decade after 2005 to reach 5.5 million visitors in 2014[38].

Even so, the potential of tourism has not been fully realized in many municipalities. Local administrations should participate actively in the development of tourism, basing their efforts on the outcomes of scientific research and modern technologies. One urgent problem to address is the impact of climate change on the prospects for tourism, which is the focus of this report.

Georgian tourism depends to a substantial extent on the country's diverse natural recreational resources and rich cultural heritage. Therefore, this Road Map also focuses on the impact of climate change on Georgia's protected areas and cultural heritage.

The objective of this study is to establish the sensitivity of Georgia's tourism, protected areas and cultural heritage to climate change and to evaluate the impact of climate change on these areas, by municipality. The report also presents a number of maps to visually present the issues to decision-makers.

3.1.1. Tourism sector

RELEVANCE

Tourism is one of the priority sectors of the national economy. The share of tourism in the GDP of the country stands at 6 percent[39] for 2015. Tourism and related activities also play a significant role in the economy of individual municipalities. However, the prospects for developing this sector depend on a range of factors, chief amongst them is the environment, including preparation for climate change and the readiness of local governments to carry out adequate preventive and adaptive measures.

The evaluation of climate change processes, their impact on tourism, and the planning of appropriate measures are of particular importance for Georgia and its regions, as they have extensive natural areas with potential for tourist and recreational activities due to their diversity, attractiveness and recreational and curative properties.

[38] Georgian National Tourism Administration, 2015.
[38] Ibid.

The territory of Georgia is divided into two climatic regions: (1) a maritime subtropical humid climate region (western Georgia); and (2) a transitional subtropical-continental climate region (eastern Georgia). Under the first climatic region prominent is a one sub-region – a transitional subtropical to moderately humid climate sub-region (the central steppe part of the southern highlands). There are 12 climate types within these regions[40].

According to health spa and climate resort zoning[41], Georgia is divided into several zones: plain resort belts (up to 500 meters above sea level or m.a.s.l), lowland resort belts (500-1000 m.a.s.l), medium mountain lower resort belts (1000-1500 m.a.s.l), upper resort belts (1500-2000 m.a.s.l) and highland non-resort zones (2000 m.a.s.l.). The latter zones are mountaineering areas. The low and medium mountain resort zones provide favorable conditions for health recovery and recreation.

The Tourist Climatic Index (TCI) developed by Zbigniew Mieczkowski[42] is widely used as an effective mechanism to measure and evaluate the impact of climate change on tourism. This complex index consists of five total components in which are seven climatic variables:

1. Daytime Comfort Index (CID). Represents thermal comfort when maximum tourist activity occurs. Its parameters are: (a) maximum daily temperature and (b) minimum daily relative humidity. This component constitutes 40 percent of the general value of the TCI;
2. Daily Comfort Index (CIA). Represents thermal comfort over a full 24-hour period, including sleeping hours. Its parameters are: (a) mean daily temperature; and (b) mean daily relative humidity. This component constitutes 10 percent of the general value of the TCI;
3. Precipitation (P). Represents total precipitation during the considered period. This component constitutes 20 percent of the TCI;
4. Sunshine (S). Represents total hours of sunshine during the considered period. This component constitutes 20 percent of the TCI;
5. Wind (W). Represents average wind speed. This component constitutes 10 percent of the TCI.

Using the above components, the TCI is calculated with the following formula:

TCI = 2[(4xCID) CIA (2xP) (2xS) W]

The tourism-friendly climate conditions per each location are evaluated according to the TCI scale and are categorized as follows: Ideal (90-100), Excellent (80-89), Very Good (70-79), Good (60-69), Acceptable (50-59), Marginal (40-49), Unfavorable (30-39), Very Unfavorable (20-29), Extremely Unfavorable (10-19) and Impossible (-20-9).

Georgia's Third National Communication to the UNFCCC presents the results of a study of tourism climate conditions that changed with the warming in three Georgian regions (Adjara, Kakheti and Upper Svaneti).

[40] M. Kordzakhia, The Climate of Georgia, Tbilisi, 1961.
[41] The Georgian SSR Resorts, Tbilisi, 1987.
[42] Z. Mieczkowski, "The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism", The Canadian Geographer / Le G ographe canadien. Vol. 29 (3), September 1985, pp. 220–233.

The research was carried out using the Tourist Climate Index[43]. An analysis made on four weather stations in Adjara the results of a 50-year observation (1961-2010) demonstrated a positive change (upper movement of the TCI category) in the coastal area as a result of air warming in the spring (April-May), and a definite negative change (cooling) in autumn (November). Positive changes (warming) took place in the Alpine zone for all the seasons, while no significant change in the Khulo district (mountain zone) took place[44].

In that study, the TCI was calculated for the period of 1961-2010 using data from the Mestia weather station. As a result, only summer tourism was analyzed. As indicated in the study, the TCI parameters are not sufficient to evaluate the climate conditions of winter tourism. In particular, evaluating the climate conditions for alpine skiing requires the use of different indicators and indices. The TCI in Mestia region for the said period was measured by month, the results were as follows: June, July, August and September fell into the category "Very Good"; May into the category "Good"; April and October were categorized as "Pleasant"; March and November were categorized as "Acceptable"; and the winter months – December, January and February – were categorized as "Unfavorable".

The study also forecast the TCI change in Mestia for the period 2071-2100. According to the project report, the average annual temperature is estimated to rise in that period by 4°C. However, the direction of the changes vary: for June, July and August, the estimated climate conditions for tourism will fall by one category to become "Good"; in May, September and October, they will rise one category to become "Very Good"; December and February go up by a category to become "Acceptable"[45], while March remains in the "Acceptable" category.

TCIs were more widely analyzed in some municipalities in the Kakheti region. The analysis was based on observation data covering 1961-2010 from the weather stations in Sagarejo, Telavi, Kvareli, Sighnaghi and Dedoplistskaro. Changes in the TCI were assessed in two equal 25-year periods (1961-1985 and 1986-2010). According to the authors of the report, analysis of the TCI climate parameters showed "an insignificant variation of the monthly values of these parameters between these periods, although a change in individual parameters on a specific weather station is observable"[46]. Accordingly, the TCI within the area covered by these weather stations did not change essentially. In contrast, a change in the TCI categories was observed both in the coastal area as well as the mountainous zone in Adjara region over the same periods. In Adjara, only the winter period was devoid of changes.

According to the study, the TCI categories remained at the "Very Good" level over the same period in Gare, (Southern) Kakheti and Telavi, from May through September, but they dropped by a category in Kvareli and Sighnaghi. It is noteworthy that all the areas under study in Kakheti were assessed positively ("Acceptable" and above) for the winter season, which can be explained by the typically mild winters in the region[47].

A forecast of TCI changes for 2071-2100 for the same region indicated an improvement of TCI categories in the "cold and cool" periods (October-April), and deterioration in the hot period (May-September) in all five municipalities due to increased average temperatures. The greatest change is forecast for the peak summer months (July-August) in Telavi and Kvareli, which will shift to the "unfavorable" category.

Regrettably, the lack of weather station data prevents TCI calculations for all municipalities of Georgia. However, another method of assessing the impact of climate conditions on tourism is based on a different index, namely that of the Complex Climate parameter (K), which is calculated with the following formula:

$$K=\frac{Hf}{S\sqrt{A}}$$

[43] The Third National Communication of Georgia to the UNFCC, op, cit., p. 190.
[44] Ibid., p. 192.
[45] Ibid., p. 197.
[46] Ibid., p. 198.
[47] Ibid., p. 198.

Where H is the precipitation in the warm period of the year (mm); f is the relative humidity of the hottest month (%); S is the average duration of sunshine on a horizontal surface; and A is the annual range of air temperatures (January and July, ^{0}C).

The Complex Climate parameter indicators are divided into seven grades, from "excellent" (K>90) to "extremely unfavorable" (K<40).

L. Kartvelishvili and K. Rokva (2001) applied the Complex Climate parameter to observation data of 54 weather stations covering the period 1957-2006 in order to estimate climate conditions for tourism in different regions of Georgia[48]. The results of their research demonstrated that the Black Sea coastal region had the highest score in terms of climate comfort. The Complex Climate parameter method provides a clear understanding of the impact of climate on tourism. However, it is also characterized by a number of shortcomings: it lacks several important climate parameters; the index is capable of estimating annual values only; and it is overly general, and so does not provide for differences between types of tourism and local specifics. Therefore, while informative, this information was not integrated into this study.

SENSITIVITY INDICATORS

In order to assess the impact of climate change on tourism in the municipalities of Georgia, it is necessary to select a sensitivity indicator that will adequately reflect the economic importance of tourism for municipalities. Such an indicator should have a valid and reliable data set for each municipality. The most direct indicator – the share of tourism in the gross domestic product of a municipality – cannot be used at the level of municipalities because no such data exists. Instead, the research focused on hotel statistics, specifically the total number of beds in all types of accommodation. There is a successful precedent of using this indicator in similar research carried out in European regions[49]. In contrast to the European experience, however, this research focuses on the ratio of beds to population rather than the absolute value of the number of beds in a self-governing entity as an indicator of tourism sensitivity to climate change. This choice is conditioned by the significant differences in population between municipalities. For example, the populations of Batumi and Kutaisi are within a range from 150,000 to 200,000 and the population of Zugdidi municipality exceeds 100,000. Meanwhile, the population of Kobuleti is approximately 75,000; that of Oni is 6,100; Lentekhi 4,400; and in Kazbegi just 3,700. Consequently, the population's economic dependence on tourism is different in each municipality. This indicator better reflects not only the economic position of tourism in a municipality but also the possibility for employing the population in the tourism sector, which is important for developing the economy of Georgia.

Thus, the sensitivity of tourism to changes, including climate change, in the municipalities of Georgia (self-governing communities and self-governing cities) is calculated by the following formula:

$$TSI=\frac{B}{P}/100$$

Where TSI is the Tourism Sensitivity Index; B is the total number of beds in accommodation facilities; and P is the population of a municipality.

This formula was used to calculate tourism sensitivity in the municipalities of Georgia (see Map 41).

[48] L. Kartvelishvili, and K. Rokva, "Tourism and Climate Change", Modern Problems of Geography, Geoidi Publishers, Tbilisi, 2011, pp. 213-220.
[49] ESPON Climate report, 2011, op. cit.

RELEVANCE

Cultural heritage is part of a country's essential material and spiritual assets. It is both the basis for a local community's historical and cultural identity, and one of the main resources on which tourism and tourism revenue are based.

For our purposes, cultural heritage can be divided into two main groups: immovable historical and cultural monuments, such as spiritual and secular architectural monuments, fortifications and historic sites among others; and museums that store movable monuments, including historic documents, archeological artifacts, and remnants of earlier economies and ways of life. Furthermore, cultural heritage may be considered to be of international, national or local significance.

Climate change increases the physical vulnerability of both types of cultural heritage. The impact of climate change is associated with both the location of a monument as well as the structure and composition of its building material. For instance, if a change in wind speed is conducive to the physical deterioration (causing wind erosion of the monument surface, changes in humidity among others) of monuments built of sandstone (e.g. Uplistsikhe, David Gareji, Vardzia)[50], for wooden structures (e.g. some vernacular architecture objects), abundant precipitation and abrupt temperature changes that cause decay of structures[51] seem to be more hazardous. Therefore, it is desirable that the issue should be studied in greater depth to ensure appropriate conservation and restoration planning.

EXISTING STUDIES

The risks of physical damage to cultural heritage monuments significantly increase as a result of climate change. Destructive factors of climate change are seen in both direct impacts such as rising air temperatures, increased humidity and precipitation, changes of temperature and wind speed; and indirect impacts through increased frequency of natural disasters, such as landslides, mudflows, avalanches, landslips, floods and marine transgressions among others[52].

Georgia's Third National Communication to the UNFCCC contains the results of special research of the impact of climate change on the cultural heritage monuments in Upper Svaneti[53] (Mestia municipality), which has many cultural riches. Moreover, owing to the complicated relief and climatic conditions of the municipality, it constantly faces challenges posed by natural hazards. Accordingly, it was an evident example to assess the impact of climate change. A variety of forms of adaptation to natural conditions have been developed in Upper Svaneti – particularly when selecting where and how to design and build traditional towers. The same holds true for the religious temples in Upper Svaneti that date back to the 9th and 10th centuries that have stood the test of time. However, over the last decades, climate change has significantly altered long-term climate conditions, increasing its impact on these religious, secular and fortification buildings. This phenomenon is especially obvious in the frescoes both inside the churches and on church elevations, which are characteristic of Svaneti. In particular, as Georgia's Third National Communication to the UNFCCC indicates, the fa ade decorations of Ifrari Archangels (Taringzeli) Hall Church of the 11th century and of the Laghami Savior Transfiguration Church (from the 8th-13th centuries) were in better condition in the middle of the last century than they are today. The interior decoration of the Ienashi, Ipkhi and Chvabiani churches are seriously damaged. Climate change has also affected the conditions of the objects of worship and equipment kept there[54].

[50] "Vulnerability of Cultural Heritage to Climate Change. European and Mediterranean Major Hazards Agreement (EUR-OPA) – Report". Strasbourg, 2008, https://www.coe.int/t/dg4/majorhazards/activites/2009/Ravello15-16may09/Ravello_APCAT2008_44_Sabbioni-Jan09_EN.pdf (accessed March 20, 2016).
[51] Ibid.
[52] Ibid., p. 10.
[53] The Third National Communication of Georgia to the UNFCCC, op, cit.
[54] Ibid., p. 224

Since natural disasters such as avalanches, mudflows, and landslides have become more frequent, they pose more intense dangers because of the activation of erosive processes on slopes. According to the Communication, the main result of these processes is the intensification of erosion as a result of the mean annual and daily precipitation maximum growth, which is likely to continue in the future[55].

The adverse impact of climate change on the cultural heritage monuments of Georgia has not been thoroughly studied. Therefore, comprehensive research in this direction with the participation of restorers, art historians, climatologists, landscape experts and other relevant specialists should be continued.

SENSITIVITY INDICATORS

As mentioned above, climatic factors impact cultural heritage monuments differently. One group of negative factors leads over time to gradual physical and chemical decay and possible destruction, while another – acts of God – can cause immediate structural damage, destruction and flooding. Climate changes contribute to the acceleration and complication of both types of hazards.

The current document considers natural hazards (floods, avalanches, landslides, mudflows and debris flows, among others), future projections and the related risks in terms of the impact of climate change on cultural heritage (see also Sections, 3.5 and 4.1).

However, the specific focus of the study requires a homogeneous quantitative indicator to assess the relative sensitivity of cultural heritage in municipalities and further assess climate change impact by municipality. It was not possible to select such an indicator for most natural disasters, as they cannot be contained in specific coverage areas. Since it is only possible to assess their impact on cultural heritage monuments on a case-by-case basis, this requires additional research.

Therefore, a projection was made for those hazards that have spatial (non-discrete) characteristics, such as: river floods (flooding zone) and avalanches (avalanche run-out zone). Given the above, only these factors were used for assessing the climate change impact on immovable cultural heritage monuments and museums. A similar indicator was selected for the ESPON Climate Scientific report[56].

The sensitivity of cultural heritage to climate change differs between municipalities. It is therefore important to distinguish the municipalities where monuments of special value are located. Damage or destruction of monuments inscribed on the UNESCO World Heritage and Tentative Lists, for example, causes much greater material and non-material damage than that of monuments of local or national significance. In the case of museums too, the most important historic and cultural movable monuments are kept in regional branches of the national museum. Their damage would also be a special form of damage. Another criterion of sensitivity is the total number of monuments and museums. By aggregating these two criteria, i.e. (a) the number of objects in a municipality and (b) objects' importance, the sensitivity indicators for cultural heritage of municipalities were developed.

All monuments inscribed on the UNESCO World Heritage List (including the Tentative List) are categorized as "particularly sensitive". The sensitivity of other monuments is measured by using their total number in the municipalities, as in the following calculation:

$$IMSI = \frac{1}{IMmax} x IMra$$

[56] ESPON Climate report, 2011, op. cit.

Where IMSI is the Immovable Monuments' Sensitivity Index to changes; IMmax is a quantity of monuments in a municipality with the maximum number of objects in Georgia; and IMra is the total number of immovable monuments in a specific municipality.

Accordingly, the sensitivity categories are: Very High Sensitivity (0.60-1.00); High Sensitivity (0.48-0.59); Average Sensitivity (0.33-0.47) and Low Sensitivity (0.01-0.32). Different levels of sensitivity of historic and cultural immovable monuments are reflected on a special map (see Map 42).

The sensitivity of museums to climate change is measured by using their total number in the municipalities, as in the following calculation:

$$MSI = \frac{1}{Mmax} x Mra$$

Where MSI is the Museums' Sensitivity Index to changes; Mmax is a quantity of museums in a municipality with the maximum number of objects in Georgia; and Mra is the total number of museums in a specific municipality.

The sensitivity of regional branches of the national museum is categorized as "particularly sensitive". The rest of the categories are: Very High Sensitivity (0.60-1.00); High Sensitivity (0.6 and above); Average Sensitivity (0.4-0.5); Low Sensitivity (0.2-0.3); and Very Low Sensitivity (0-0.1).

The different sensitivity of museums is reflected on Map 43.

3.1.3. Protected areas

RELEVANCE

The Law of Georgia on the System of Protected Areas (1996) defines a protected area as "a terrestrial and/or aquatic space of special significance for the preservation of biological diversity, natural resources and cultural phenomena included in the natural environment, which is protected and managed on a long-term and solid legal basis"[57].

Currently, it is widely recognized that biological diversity and climate change are interrelated. This is evidenced by recent studies according to which climate change can be viewed as the fifth key factor contributing to biodiversity loss together with habitat degradation, unsustainable use, environmental pollution and invasive species[58]. The vast majority of experts agree that the global climate is becoming warmer as a result of increased concentrations of carbon dioxide and methane in the atmosphere from the burning of fossil fuels, deforestation and livestock farming. The higher temperatures, and the decreased levels of precipitation that are predicted for some parts of Georgia, will severely affect ecosystems, especially those that are at the limit of their natural range. Major changes will occur in such ecosystems and in the distributions of plant and animal populations that depend on them. Shifts in vertical ecological zones will have a great impact on Georgia's biodiversity due to its mountainous terrain. Some species may disappear from Georgia because of their inability to adapt to new conditions. Some experts believe that with the changing climate, some plant species, such as pines, may become more susceptible to certain pathogens. The maintenance of robust ecosystems, such as forests, benefits biodiversity and serves as an important tool for both climate change mitigation through carbon sequestration and climate change adaptation[59].

[57] Law of Georgia on Protected Areas, Parliament of Georgia, https://matsne.gov.ge/ka/document/view/32968 (accessed March 25, 2016).
[58] Global Biodiversity Outlook 3, 2010, https://www.cbd.int/gbo3 (accessed March 19, 2016).
[59] Resolution of the Government of Georgia #343, "On the Approval of the 2014-2020 Biodiversity Strategy and Action Plan of Georgia", 2014, https://matsne.gov.ge/ka/document/view/2342057 (accessed March 19, 2016).

Given that biodiversity supports the sustainability of ecosystems and represents, correspondingly, the main component of ecosystem services, protected areas, play an essential role in biodiversity conservation and ecosystem protection. Protected areas have only recently been recognized as an integral part of the global response to climate change. They play a significant role in mitigating and adapting to climate change, in particular by reducing the effect of greenhouse gas emissions and assisting society in coping with the impact of climate change by preserving the ecosystem services, on which it depends. It is estimated that protected areas capture and store at least 15 percent of carbon dioxide. It should also be noted that protected areas maintain essential ecosystem services, which can increase resistance, resilience and reduce the vulnerability of livelihoods against climate change. Protected areas are frequently a source of both pure water and increased water flow. It is noteworthy that 33 of the 105 largest world cities receive water from catchments located within protected areas. In Georgia, a good example of this is the seaside resort of Batumi, on the Black Sea, which is supplied by water from Mtirala National Park[60].

To date, Georgia's protected areas include 11 national parks, 14 state reserves, 19 managed reserves, 2 protected landscapes and 41 natural monuments, making a total area of 5,984 km^2 or 8.58 percent of the country's territory.

Due to Georgia's biological diversity, the protected areas that have been established throughout the country differ significantly by natural landscape, ecosystems, biological species and relief forms. They include ecosystems characteristic of humid subtropics such as the Mtirala and Kolkheti National Parks and arid landscapes such as the Vashlovani National Park. The Borjomi-Kharagauli National Park is noted for its unique ecosystem of coniferous forests, while the Tusheti National Park is known for the diversity of endemic biological species, which includes 230 species of endemic Caucasian plants, 11 of which are only found in Georgia.

Protected areas constitute the basis of Georgian ecological tourism. Ecotourism is a growing sector in the country. From 2008 to 2014, the total number of visitors was multiplied 34 times from 12,200 to 417,800 per annum. The largest annual increase was 240 percent in 2011. The number of visitors declined slightly in 2012, but grew again thereafter[61].

EXISTING STUDIES

Global climate warming makes protected areas established within arid and semiarid areas especially vulnerable. Above all, this affects protected areas in the Dedoplistskaro municipality: the Vashlovani State Reserve, the Vashlovani National Park, the Chachuna Managed Reserve and natural monuments (Alazani flood plain, Takhti-Tepa, Artsivi (Eagle) Canyon. According to projections, the air temperature in these regions will rise by 4-5°C by 2100, while average annual rainfall will decline by 15 percent. In addition, as already stated, climate change has doubled the drought periods in territories exposed to intense erosive factors such as drought a high temperature range and wind[62].

E. Salukvadze and T. Chaladze have studied the state of natural landscapes within Dedoplistskaro municipality in terms of the impact of negative factors, including climatic factors. As evident from their study, landscapes under the influence of a dry and arid subtropical climate (with average annual precipitation of 350-400 mm) face the threat of desertification[63]. In particular, this affects the Pistachio and Juniper sparse forests, which are protected by purposefully created Vashlovani Nature Reserve and National Park.

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[60] World Database on Protected Areas, IUCN, http://www.protectedplanet.net (accessed March 19, 2016).

[61] Agency of Protected Areas of Georgia web-page: http://www.apa.gov.ge, Statistics Data on Visitors (accessed March 26, 2016)

[62] M. Shvangiradze, B. Beritashvili, and N. Kutateladze, "Identified and predicted climate change and its impact on the economy and natural ecosystems. Proceedings of the International Scientific Conference" in Climate, Natural Resources and Natural Disasters in the South Caucasus, Tbilisi, 2008, pp. 90-96

[63] E. Salukvadze, and T. Chaladze, "Landscapes of Critical Ecoregions: Problems and Current State" (in Russian), in "Modern Problems of Geography and Anthropology", Tbilisi, 2015, pp. 123-128.

The bird species protected in the Chachuna Managed Reserve – partridges, black francolins, pheasants and imperial eagles, are included on the IUCN Red List of Threatened Species. As a result of climate change, populations of such species characteristic of the hot and arid regions of Iran and Pakistan, separate populations of Indian porcupine and single individuals of five-toed jerboa (earth rabbit) – can now be observed within the protected areas of the Dedoplistskaro municipality[64].

The impact of climate change leads to different, but equally negative, processes in the humid subtropical landscapes of the western regions of Georgia. Georgia's Second National Communication to the UNFCCC[65] states that, as a result of climate change over the last twenty years, the temperature and precipitation conditions in the Adjaran forests have changed, which has led to a more widely spread area of previously known forest diseases (chestnut cortex cancer, great spruce bark beetle, European spruce bark beetle, engraver beetle and bacterial wilt-causing fungi) and the emergence of relatively new diseases such as: horse chestnut leaf miner, Cameraria ohridella Deschka and most importantly, the box blight fungal disease or leaf burn. During the last two to three years, box blight disease has begun to cover almost 60 percent of the box tree population of Kintrishi protected areas and Mtirala and Machakhela National Parks.

Since most of the basins of Adjara's rivers are also located within the boundaries of protected areas, they have also been affected: recently, for example, the population of trout has decreased by about three times because of increased water temperatures, which cause a reduction of the concentration of dissolved oxygen in the water. The optimum temperature for trout is between 9 and 16^{0}C. In response to increased temperatures, trout move to cooler places in upper parts of the river where their feeding resources are sharply reduced and their reproduction capacity declines.

According to the data given in Georgia's Third National Communication, by the end of this century, the rise of average temperature by 2-4^{0}C and increase of precipitation by 5-10 percent are expected throughout the whole territory of Adjara, according to which, presumably, the predicted climate warming will change the composition of species, due to the spread of more heat-loving species as well as the change in the upper boundary of forest by hundreds of meters[66].

SENSITIVITY INDICATORS

As in the case of cultural heritage, a homogenous, uniform quantitative indicator was selected within the framework of the study, which makes it possible to compare the impact across municipalities. A similar indicator was selected in the ESPON Climate report[67].

Not all municipalities have protected areas. Moreover, in those municipalities that have protected areas, the degree of their importance varies. Municipalities with larger protected areas will suffer more from the damage caused by climate change than municipalities where the protected areas occupy less territory. Therefore, the sensitivity indicator for protected areas is calculated using the following formula:

$$PASI = \frac{Spa}{S}$$

Where PASI is the Protected Areas' Sensitivity Index in respect of potential changes; S_{PA} is the space of protected areas in a municipality; and S is the area of the entire municipality (see Map 44).

[64] The Second National Communication of Georgia to the UNFCCC, op. cit., p. 127.
[65] The Third National Communication of Georgia to the UNFCCC, op. cit., pp. 217-219.
[66] Ibid., p. 219.
[67] ESPON Climate report, 2011, op. cit.

Agriculture has traditionally been a key industry for Georgia. The country's fertile soil creates extremely favorable conditions for both farming and livestock breeding. Agricultural land makes up 43.4% of the country's territory[68]. Traditional Georgian crops include grapes, wheat, maize, fruit, citrus fruit and tea[69]. The main types of livestock breeding are sheep and cattle breeding, while beekeeping is also well established in Georgia.

As part of the reforms of the 1990s, most of the country's agricultural land was transferred into private ownership (farmers)[70] and today the majority of agricultural land remains privately owned. At present, the most developed branches of the agricultural sector are winemaking, poultry keeping, fruit- and vegetable-growing, and fish farming. Since 2000, there has been a notable expansion of livestock farming within animal husbandry. Increasing crop capacity in agriculture generally depends on the quality of fruit, grape and citrus yields[71].

Agriculture is directly associated with climatic conditions, which determine the types of agricultural production in different regions of Georgia. These climatic factors such as humidity and temperature have a significant bearing on soil fertility and, correspondingly, yield stability.

Forestry is also an important industry for the country. The total land area with forest resources in Georgia amounts to 3 million hectares or about 40% of the entire area of the country. Of this, 2.8 million ha are covered with forests, the forest reserves amounting to 454.5 million cubic meters[72]. Most of Georgia's forests have a protective function due to most of them covering complicated mountainous relief, only 587,000 ha of forests are currently available for economic activity. The forests are public property. The existence of forests conditions the mitigation of the climate, water resources regulation, and the recreational potential of both regions and municipalities.

Regarding relief conditions, Georgian forests are divided into mountain and lowland forests. Mountain forests represent the significant majority (97%) of forests in Georgia, of these areas, 69.32% are deciduous forests, 15.98% are coniferous and 14.7% are mixed. Almost half of the forests in Georgia are beech forests. Of the lowland forests, which account for 3% of national forests, Kolkheti forests make up 2%, while Alazani and Iori forests, which are generally riparian, make up 1%. Despite the high percentage of forest-covered area, the spatial distribution of forested areas in Georgia is uneven.

Within the framework of this study, based on quantitative indicators and taking into account the available information, the potential sensitivity of agriculture and forest ecosystems to climate change and the impact of climate change on them for two projection periods (2021-2050 and 2071-2100) have been analyzed for each municipality in Georgia.

As a result of this work, relevant maps have been compiled that will assist the relevant municipality authorities in their decision-making.

[68] The Initial Communication of Georgia to the UNFCCC, Tbilisi, 1999.
[69] O. Giorgobiani, "Prospects of Solving Food Problems in Georgia", Collection of Scientific Works of the Institute of Economics of the Georgian Agricultural Academy III (XXVI), Tbilisi, 2001.
[70] Ibid.
[71] Resolution of the Government of Georgia #167 "On the Approval of the Georgian Agriculture Development Strategy for 2015-2020", 2015.
[72] Unless another source is indicated, the quantitative data are taken from "The Global Forest Resources Assessment concerning Georgia", FRA 2015, http://www.fao.org/forestry/20336-069418a0bd1928b55be0827f44dd1d915.pdf (accessed March 20, 2016).

RELEVANCE

The agricultural sector has traditionally held a significant position in the country's economy. Its share in the GDP of 1999 amounted to 25%, with roughly half of Georgia's population engaged in the sector[73]. According to 2014 statistics, again roughly half of the population was engaged in the agricultural sector, which encompassed 9.4% of the country's GDP[74]. This indicates the sector's low productivity and technological shortcomings. As a country develops, less of its population is involved in the agricultural sector[75] but productivity increases with greater use of technology. For example, the contribution of agriculture to GDP in developed countries, such as member states of OECD[76] and the EU varies from 2% to 12%, while the population involved in the sector is generally lower compared to Georgia. Of these countries, Romania (30%) has the highest proportion of its population involved in agriculture. Among the best performing countries in agriculture in the EU are France, Belgium, Germany and Denmark[77].

For Georgia, as is the case for other countries, a developed agriculture sector is a guarantee of food security rather than just another sector of the economy[78]. Of course, agricultural products and their places of origin are important representations of the country's cultural and social identity. Agricultural products, plant varieties and animal species frequently represent a country's cultural heritage[79].

In 2015, the Government of Georgia adopted an agriculture development strategy. The policy document treats climate change as a risk factor for the development of the agricultural sector and covers many important issues such as productivity, plant breeding, application of quality seeding and planting stock, creation of an optimum water and air regime for the soil and implementation of special land treatment measures[80]. Indeed, climate change can pose additional challenges to the agricultural sector that already faces various social, technological and economic issues.

Climate change has a direct impact on agriculture. An increase in temperature and a decrease in precipitation during the growing season automatically cause an increase in the irrigation rate (amount of water supplied to agricultural crops by farmers) or the frequency of watering[81]. At the same time, an increase in irrigation rate should consider changes of climatic variables to avoid excessive watering as well as shortage of moisture, both of which are equally harmful for the growth and development of plants.

Of similar importance is the impact of the variability of climate factors on soil erosion processes[82]. While a reduction in precipitation decreases the risk of water erosion, the resulting increase in the frequency of watering or in the irrigation rate enhances the threat of irrigation erosion. At the same time, a temperature increase and a decline in precipitation will contribute to soil desiccation, which, against the background of wind speed variability change, determines the risk of wind erosion occurrence or enhancement.

Currently, the agricultural land area in the country totals 3.17 million ha. Of this, 791,900 ha is plow-land, 269,800 ha perennial plantations, and 1.9 million ha are pastures and grassland. In 1990, of the total land area, 312,000 ha were irrigated, while 105,000 ha were equipped with drainage systems. However, through the past few decades, the complicated economic and social situation that emerged in the country resulted in the destruction of the majority of the infrastructure of this sector. In 2012, only 45,000 ha had a water supply, whereas the removal of excess water (drainage) took place on just 14,000 ha. As a result of the measures (rehabilitation and maintenance work) taken in 2012-2014, the irrigated areas and those with drainage nearly doubled[83].

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[73] Collected statistics from Georgian Agriculture, Tbilisi, 2000.
[74] GeoStat, 2014, http://www.geostat.ge/index.php?action=page&p_id=428&lang=eng (accessed March 20, 2016).
[75] Our World in Data Project, Oxford Martin School, http://ourworldindata.org/data/food-agriculture/agricultural-employment/ (accessed March 20, 2016).
[76] List of OECD member states, 2015, http://www.oecd.org/about/membersandpartners/list-oecd-member-countries.htm (accessed March 20, 2016).
[77] European Council, "Agriculture in the European Union and the Member States: Statistical factsheets", 2015. http://ec.europa.eu/agriculture/statistics/factsheets/index_en.htm (accessed March 20, 2016).
[78] Resolution of the Government of Georgia #167 "On the Approval of the Georgian Agriculture Development Strategy for 2015-2020", 2015.
[79] M. Lenzi, "Agricultural and food heritage", 2015. http://www.expoitaliasvizzera.it/img/schede/patrimonioagroalimentare_eng.pdf (accessed March 20, 2016).
F. J. Sundstrom et al. "Identity Preservation of Agricultural Commodities", University of California at Davis, 2002. http://www.plantsciences.ucdavis.edu/bradford/8077.pdf (accessed March 19, 2016).
[80] Resolution of the Government of Georgia #167, "On the Approval of the Georgian Agriculture Development Strategy for 2015-2020", 2015.
[81] N. Modebadze and G. Chechelashvili, "On predicting the yield of agricultural crops", Tbilisi, 1988.
[82] V.M. Sinytsin, "Natural Climatic Conditions as a Risk Factor in Farming", NR, 2005.
[83] Data of the United Reclamation Commission of the Ministry of Agriculture, 2015.

Based on the above-mentioned factors, it is clear that the available land-reclamation and other adaptive technologies will not ensure proper protection of agricultural land from climate change risks. This, in turn, suggests the necessity of: (a) continuation of further scientific research in the agricultural sector; and (b) planning and implementation of effective measures by using modern innovative technologies and knowledge gained from advanced international experience.

EXISTING STUDIES

The current climate change impact on agriculture is an important subject of study both abroad[84] and in Georgia. In Georgia, such studies have been carried out since 1994[85]. The results of key research papers in the sector are considered below.

According to Georgia's Third National Communication to the United Nations Framework Climate Change Convention, an internationally recognized official report[86], the average annual temperature in lowland regions and the Black Sea coastal area of Georgia is 14-15°C[87], while total annual precipitation varies from 1,500 mm to 2,700 mm. In the lowlands of eastern Georgia, the average annual temperature reaches 11-13°C and the annual precipitation totals 400-600 mm, increasing up to 800-1,200 mm in mountainous regions. In the last 25 years, as a result of climate change, the average annual temperature in western Georgia has increased by about 0.3°C, while in eastern Georgia the increment reached 0.4-0.5°C[88].

The main challenges facing agriculture were determined in the studies carried out in Georgia[89]. In eastern Georgia, these are drought, hail and land degradation, while in western Georgia the main challenges are the spread of plant diseases and land erosion.

It should be noted that the agricultural sector itself also contributes to climate change: greenhouse gas emissions in the agricultural sector of Georgia[90] (except the land tenure sector) made up 17% of total emissions in 2011.

Studies that are not directly associated with climate change, but that are still important for adapting the agricultural sector to climate change are listed below:

- Ts. Mirtskhulava of the Institute of Water Management of the Georgian Technical University in 2014-2015 carried out studies[91] concerning land-improvement systems and their efficiency based on data produced by the United Amelioration Systems Company LLC under the Ministry of Agriculture of Georgia. The study revealed that state irrigation systems are established across 40 municipalities of Georgia – in Kakheti, Kvemo and Shida Kartli and partially in Mtskheta-Mtianeti, Imereti and Samtskhe-Javakheti regions. Drainage systems are mainly located in western Georgia, and only a few, currently inoperative systems, are located in eastern Georgia. Irrigation in other municipalities is carried out through free flooding when and if required by farmers. In comparison with the irrigation systems, the functioning of drainage systems is more restricted. The condition of the land-reclamation systems (irrigation and drainage) indicates that the sensitivity of the agricultural sector to climate change is high in Georgia, which is frequently conditioned by the insufficient or excessive amount of water supplied to agricultural plants during their growing period. This, in turn, becomes one of the causes of the spread of plant diseases and their growth retardation, which adversely affects the sector's productivity.

[84] EEA, Climate change, impacts and vulnerability in Europe 2012. op. cit.
[85] The Initial National Communication of Georgia to the UNFCCC, op. cit.
[86] Other studies on the climate change impact on agriculture, with rare exception, are "armchair" studies based on national communications.
[87] The Third National Communication of Georgia to the UNFCCC, op, cit.
[88] Ibid.
[89] Ibid.
[90] Ibid.
[91] Ibid.

- Damage to topsoil by water and wind erosion[92] was assessed through the volume of barren areas on a national scale. Water erosion was recorded almost everywhere, except Adigeni, Akhalgori, Kazbegi, and Khobi municipalities. Factors causing erosion were revealed as the following: frequent precipitation, temperature change, overgrazing and excessive and improvident use of water for irrigation (cause of irrigation erosion). Since irrigation erosion represents one of several types of water erosion, identifying causes of water erosion of agricultural lands is not possible except in cases when non-agricultural lands are affected. However, the study conducted covered only eroded areas of plowland[93]. Wind erosion[94] is observed in Akhalgori, Akhalkalaki, Akhaltsikhe, Bolnisi, Gardabani, Gori, Gurjaani, Dedoplistskaro, Dmanisi, Tetritskaro, Kaspi, Marneuli, Mtskheta, Sagarejo, Kareli and Khashuri municipalities[95]. Its causative climatic factors are strong wind, temperature, precipitation levels, and some other non-climatic factors, while the absence of windbreaks can be taken as a conducive factor. The Climate Change and Technology Needs Assessment (TNA) report by the Ministry of Environmental Protection and Natural Resources[96] states that the cause of land degradation in western Georgia is soil water erosion, which is due to mountain relief and excessive precipitation. The main causative factors of land degradation are slope grades and raindrop kinetic energy, which depends on rain intensity. The total area of arable land in the region amounts to 186,800 ha, 33.7% of which is eroded. The cause of land degradation in eastern Georgia is mostly wind erosion. Of the total 486,400 ha of cropland, 21% is eroded. Both agricultural productivity components are defined in the same report, namely (a) the supply of insufficient or excessive moisture to plants; and (b) soil protection against water and wind erosion, caused by frequent flash floods, downpours, droughts and other negative factors, all of which require more attention and further study in relation to climate change[97].

SENSITIVITY INDICATORS

The sensitivity of the agricultural sector can be assessed through application of different, non-climactic indicators. It is worth mentioning that sensitivity indicators are interrelated with different climate change exposure factors. Examples of agricultural sector sensitivity indicators are as follows:

A report by the European Environment Agency (2012) lists indicators of soil sensitivity to climate change, including:

a) Soil moisture; and
b) Soil erosion[98].

Agriculture sensitivity in the same report is assessed by:

a) Growing season for agricultural crops;
b) Water-limited crop productivity; and
c) Irrigation water requirement.

In the ESPON climate change report[99], the content of moisture in soil is taken as a sensitivity indicator.

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92 "Protection of Georgian Soils against Erosion: the 1999-2005 State Purpose-oriented Program", Tbilisi, 1998.

93 Ts. E. Mirtskhuklava, O.G. Natishvili, V.I.Tevzadze, G.V. Gavardashvili, et al. "On nano-retaining and anti-corrosive capacity of vetiver plants". Collected Scientific Works of the Institute of Water Management of Georgia, No. 63, Tbilisi, 2007.

94 G.P Gogichaishvili, and T.T. Urushadze "Estimation of Erosion Danger, Lands of the Reclamation Fund in Georgia". Journal of Agriculture and Rural Development in the Tropics and Subtropics. Kassel University Press, Vol. 107, #1, 2006.

95 Georgian Climate and Agroclimate Atlas. Tbilisi, 2011.
E. Sukhishvili, Average annual wind speed. Tbilisi, 1985.

96 The Ministry of Environmental Protection of Georgia. "Climate Change and Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation", Tbilisi, 2012. http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNR_CRE/e9067c6e3b97459989b2196f12155ad5/30147bf67c1c4b97afe057fbb149a2fc.pdf (accessed March 21, 2016).

97 "Reducing the Vulnerability of Georgia's Agricultural Systems to Climate Change", EBRD/World Bank.

98 EEA, "Climate change, impacts and vulnerability in Europe", 2012, op. cit.

99 ESPON Climate report, 2011, op. cit.

In Georgia's Third National Communication to UNFCCC[100], when assessing climate change on agriculture, a change in the productivity of agricultural crops in two regions (Adjara and Kakheti) has been taken as a sensitivity indicator, and has been assessed under the impact of different factors.

Such methodology implies complex multicomponent modeling and takes into consideration the determining of the dependence of different regions on specific agricultural crops. No uniform data for the whole of Georgia were available for applying such methodology within the framework of the given research, while the research aimed to conduct a comparative study in municipalities on the basis of accessible homogenous quantitative indicators. Therefore, only the indicators that are supported with appropriate data from official national sources were selected.

Against the background of ongoing climate change in Georgia, the stable advance of the agricultural sector is unimaginable without land-reclamation development, which would ensure the necessary moisture conditions for agricultural plants. The appropriate amount of moisture should be secured with irrigation in arid areas of the respective regions and with removal of excessive moisture (drainage) in humid areas[101].

In order to assess agricultural sensitivity to climate change in Georgia's municipalities, first of all, climate sensitivity indicators that adequately reflect the economic importance of this sector in each municipality should be selected. Such indicators should rely on valid and consistent statistical data[102]. The following components can be used for measuring and assessing the agricultural sector's sensitivity to climate change:

Water supply to agricultural land and agricultural crops comprises, and is measured by, the area of the reclaimed land, state of air and water regime of soil, amount of consumed or removed water, (i.e. the irrigation and drainage rate), crop yield increase in the irrigated land, and some other factors.

State of soil cover is assessed by eroded land area, and the extent of land degradation encompassing desertification, salinization, and swampiness, among other conditions.

Based on the above-mentioned components and on the study objectives (a comparative appraisal of agriculture sensitivity to climate change and climate change impact on municipalities) as well as on international experience, the following non-climatic sensitivity indicators have been selected:

- Sensitivity of the irrigation rate (m^3/ha) of agricultural crops to moisture change;
- Utilization of the designed land-reclamation systems;
- Actual utilization of the land-reclamation systems;
- Sensitivity of agricultural land to erosion.

Sensitivity of irrigation rate of agricultural crops to moisture change[103] – the irrigation rate (M) in m^3 shows the amount of water applied per 1 ha during the entire period of vegetation, according to how frequently the given crop is irrigated.

[100] The Third National Communication of Georgia to the UNFCCC, 2015.
[101] S. Giorgadze, T. Katsarava, et al. "Drainage land-improvement", Tbilisi, 2010.
[102] Data of the United Reclamation Commission of the Ministry of Agriculture, 2015.
[103] Complies with the sensitivity indicator of agriculture as indicated in the report of the EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit.

The irrigation rate is determined by the following correlation:

$$M=\sum_{i-1}^{n} m_i=m_1+m_2+m_3+\ldots+m_n \ (m^3/ha), \qquad (1)$$

Where mi is the irrigation rate or the irrigation water amount to be supplied to a one-hectare area of agricultural crops through irrigation. The irrigation rate depends on soil characteristics, moisture, precipitation levels, and evaporation, among other factors. Eventually, the irrigation rate change in itself indicates a change of climatic conditions. The more arid a region is, the more obvious the irrigation outcome. At the same time, the effect of irrigation is greater when the root system of a plant is located at a shallower depth. Irrigation also has an impact on the microbiological processes taking place in the soil.

The purpose of irrigation is to minimize the difference between shortage of moisture in the soil and water consumption by a plant, which requires the selection of proper irrigation rates and periods. The irrigation rate (m) is the amount of water (m3) to be supplied to a hectare of land during regular irrigation.

Irrigation should establish requisite air and water conditions for a plant in the active soil layer (h) where the bulk of the plant's root system is found. The maximum indicator of moisture is where the boundary displacement reaches 90% of the complete displacement. Soil moisture in practice, like water holding capacity, is measured by special instrumentation and established under laboratory conditions.

Considering the above-mentioned points, the irrigation rate equals:

$$m=W_{max} - W_0=100\gamma h\ (r_{bou} - r_{sm})=100\gamma h\ (r_{bou} - 0,7r_{bou}) \qquad (2)$$

Where γ = the soil volume weight (kg/m3), h is the active soil layer and rbou is the boundary soil water holding capacity (%), which represents the amount of moisture the soil can retain. In general, when the moisture-holding capacity is higher, then more moisture, including atmospheric, is required by the plant for its development.

The soil moisture ratio (K)[104] is calculated by the following formula:

$$K=\frac{P}{F} \qquad (3)$$

Where P = the total of average annual precipitation, mm; F = evaporation (mm), being determined by the ratio:

$$F=0.0018\ (\ 25+t^2\ )x(\ 100-d\ ) \qquad (4)$$

Where t = the average monthly temperature ^{0}C; d = relative air humidity (%).

The foregoing formulas indicate the dependence of irrigation and the irrigation rate on climatic factors (P, t, d), the eventual alteration of which directly affects irrigation and the irrigation rate respectively. Fig. 7 shows the irrigation rates for 2015 (m^3) for each municipality.

[104] I. Anjaparidze. Soil Development Science, Tbilisi, 1977.

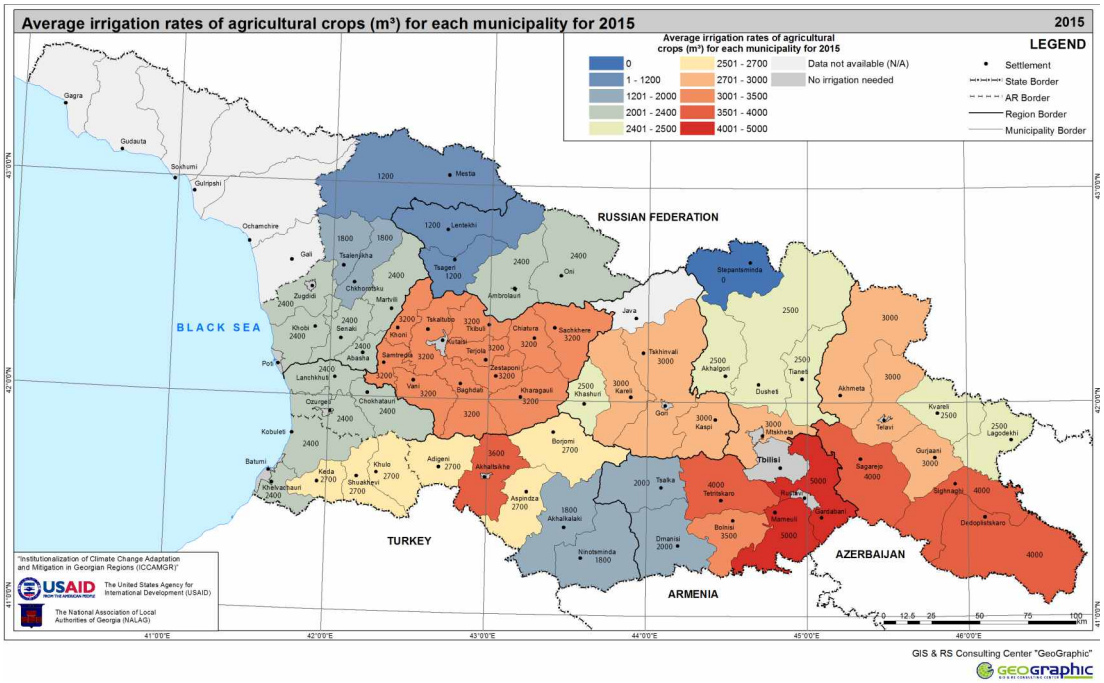

Fig. 7. Average irrigation rates of agricultural crops (m^3) for each municipality for 2015

Indicator of designed land-reclamation systems' utilization – the ratio of lands ameliorated[105] individually for irrigation of (see Fig. 8) and drainage to (see Fig. 9) agricultural land areas[106].

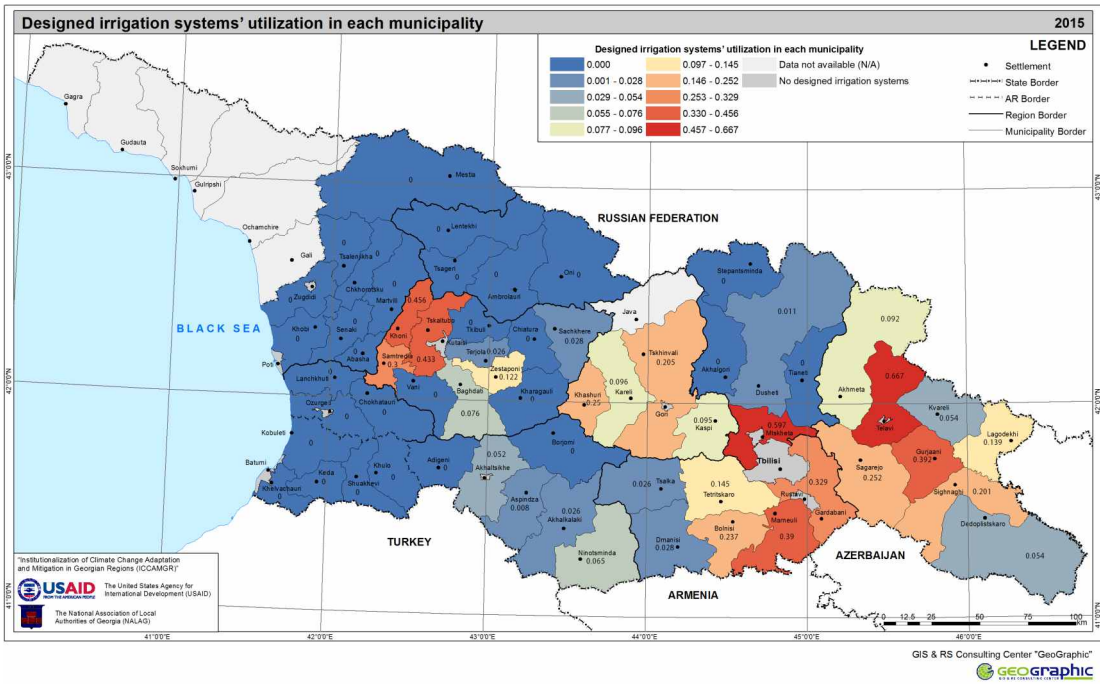

Fig. 8. Designed irrigation systems' utilization in each municipality

[105] Data of the United Reclamation Commission of the Ministry of Agriculture, 2015.
[106] Indicators 2 and 3 are additional indicators helping assess how efficiently agricultural lands are supplied with water

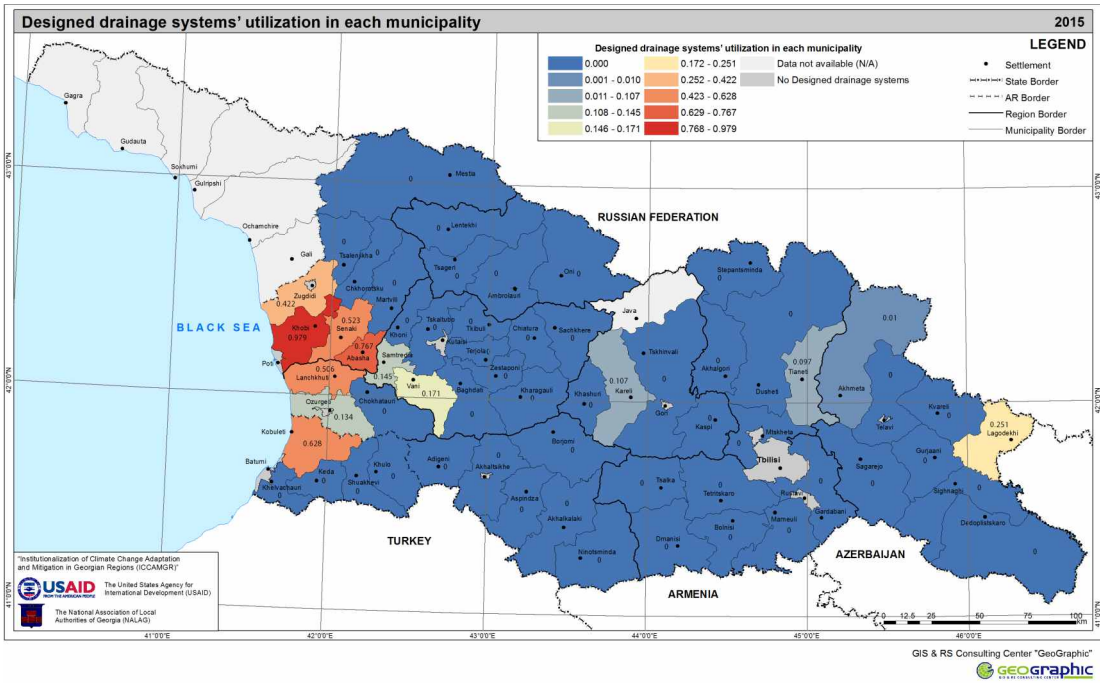

Fig. 9. Designed drainage systems' utilization in each municipality

Indicators of land-reclamation systems' actual utilization – the ratio of land areas equipped with the operating irrigation network for irrigation (see Fig. 10) and drainage (see Fig. 11) to the land areas covered by a designed irrigation network[107] for 2015.

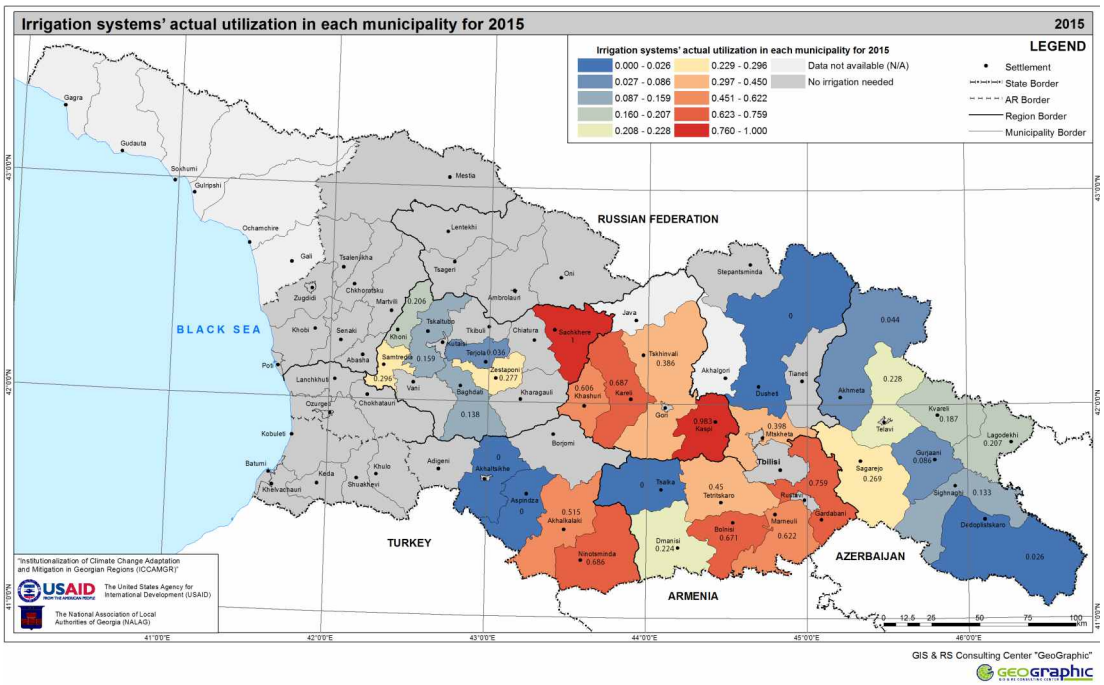

Fig. 10. Irrigation systems' actual utilization in each municipality for 2015

[107] Data provided by the United Amelioration Company of the Ministry of Agriculture, 2015.

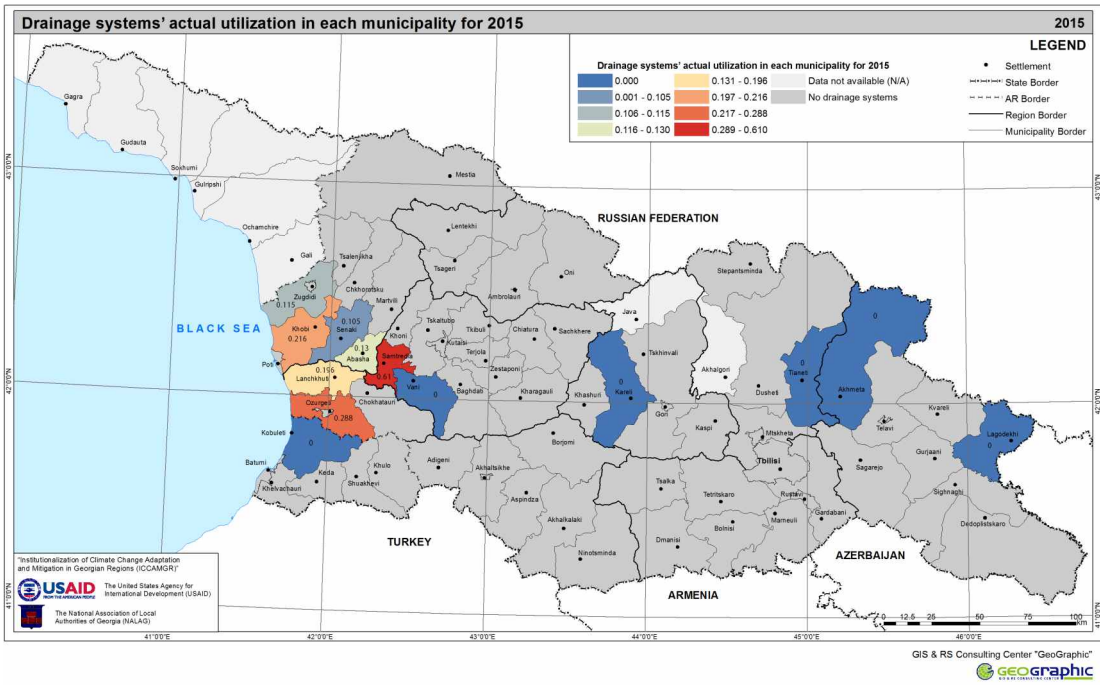

Fig. 11. Drainage systems' actual utilization in each municipality for 2015

Sensitivity of agricultural lands to erosion is measured according to the share of agricultural land areas eroded by water (see Fig. 12) and wind (see Fig. 13)[108]. The data are taken from the 1999-2005 purpose-oriented state program developed by the Water Management and Engineering Ecology Institute of the Georgian National Academy of Sciences under the leadership of Professor Ts. Mirtskhulava[109].

In Georgia[110], 54.1% of cropland is located on sloping land with slope of 2^0, 22.5% on slopes from 2^0 to 5^0, 14% on slopes of 5^0-10^0, up to 6% on slopes of 10^0-15^0, and 3.4% on slopes exceeding 15^0.

The foregoing agricultural land factor, together with rainfall intensity, determines water erosion occurrence and development. When implementing irrigation measures, the same factor creates a negative phenomenon that is known as irrigation erosion on the soil surface.

Sensitivity of agricultural lands to water erosion enhancement risk – water erosion arises from topsoil washing away during the irrigation of agricultural lands. One type of water erosion is linear erosion. This type entails erosion caused by concentrated runoff accompanied by scratching or scoring of the soil surface to various degrees. The runoff spreads across the soil surface during rainfall (i.e. when the infiltration rate has been exceeded) and may take various forms and degrees. The more humus the soil has and the lighter it is, the more permeable it is.

At the Water Management Institute of the Georgian Technical University, based on half a century of research, the academic Ts. Mirtskhulava[111] has developed a method for calculating the maximum allowable soil loss from erosion (G), the functional dependence of which has the following expression:

[108] Complies with the sensitivity indicator of agriculture as indicated in the report of the EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit.

[109] Protection of Georgian Soils against Erosion (the 1999-2005 State Purpose-oriented Program) Tbilisi, 1998.

[110] Order of the Minister of Agriculture of Georgia #2-277 of November 25, 2005, "On the Approval of the Recommendation on Complex Soil Protection Measures against Erosion".

[111] Ts. . Mirtskhulava, "Technical guidelines on the prediction of soil water (rainwater) erosion", . Vaskhnil, 1978.

$$G=f(R,S,I,\Omega,M,Y), \quad (5)$$

Where R = amount and intensity of rainfall; S = the physical-mechanical properties of the soil; I = soil sloppiness and shape indicator; Ω = share of area covered with vegetation; M = irrigation rate (to calculate the irrigation erosion), Y= eroded area indicator.

The said studies have served as the basis for approving the main document – the All-Union Standard – based on the calculations in the former Soviet Union of water erosion of agricultural land, including the intensity of irrigation erosion.

In 1998-1999, the Water Management Institute of the Georgian Technical University reprocessed the above-mentioned All-Union Standard, which served as the basis for preparing the 1999-2005 purpose-oriented state program aimed at protecting soil from erosion in Georgia[112].

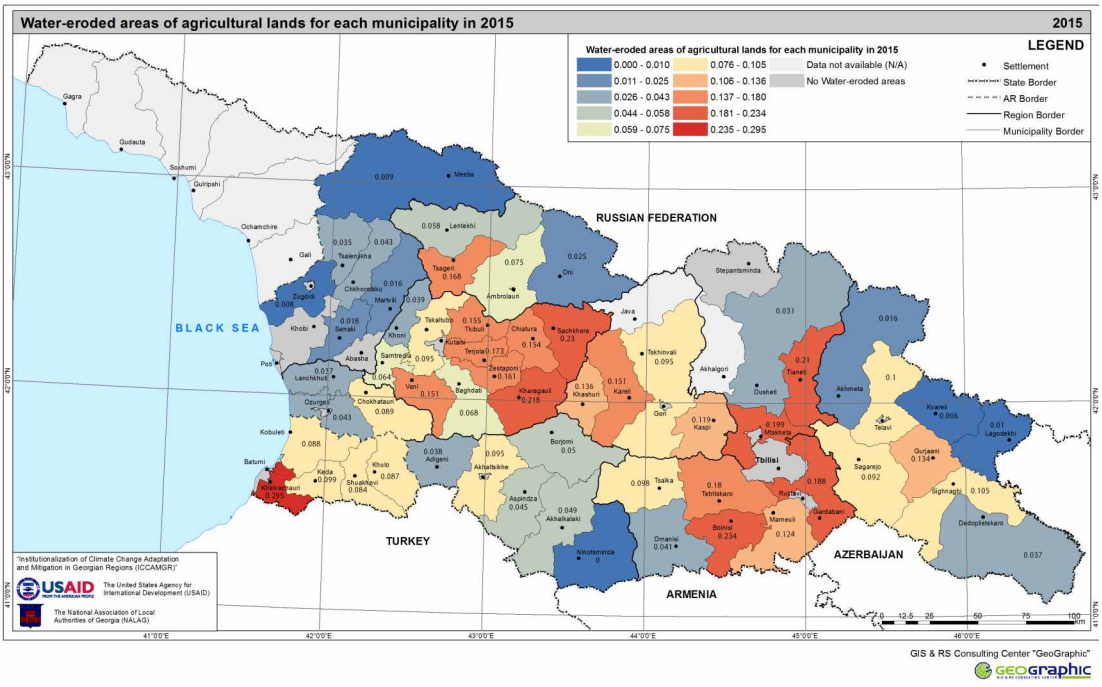

Fig. 12. Water-eroded areas of agricultural lands for each municipality in 2015

Sensitivity of agricultural lands to wind erosion enhancement risk: Wind erosion (soil deflation) is conditioned by the deterioration and transportation of topsoil and its forming substances. Water and wind erosion are both more or less observable in almost all regions of the country. To forecast wind erosion, the knowledge of the direction and speed of hazardous winds is necessary so that erosion prevention measures can be properly planned[113].

In addition to climatic conditions, among other factors, wind erosion processes are also predetermined by the mechanical and aggregate composition of soil, the content of organic substances, structural stability, and the cohesion of soil aggregates.

[112] Protection of Georgian Soils from Erosion (The 1999-2005 State Purpose-oriented Program), Tbilisi, 1998.
[113] Order of the Minister of Agriculture of Georgia ##2-277 of November 25, 2005, "On the Approval of the Recommendation on Complex Soil Protection Measures against Erosion".

The intensity of the wind erosion process is determined by several factors including wind speed in the region and the existence of side shelterbelts. Wind erosion intensifies in winter and early spring, when vegetation covers and protects less agricultural land, therefore leaving the soil bare. The intensification of wind erosion is caused by deep tillage with plowing, as a result of which the topsoil layer reinforced with plants' root systems is inverted and mixed with the subsoil[114].

The value of the amount of soil deposited by wind erosion (G) represents a multifactor function:

$$G=f(G_L, G_S, G_I, G_P, G_M, Y_W) \quad (6)$$

Where GL is the distance between windbreaks; G_s is the texture of soil, G_I is the soil surface inclination; G_P is the indicator of the vegetation cover impact on the topsoil; G_M is the climatic factor indicator. Taking into account each of these factors, the weight of the wind-deposited soil is calculated independently; Y_W is the wind-eroded area indicator.

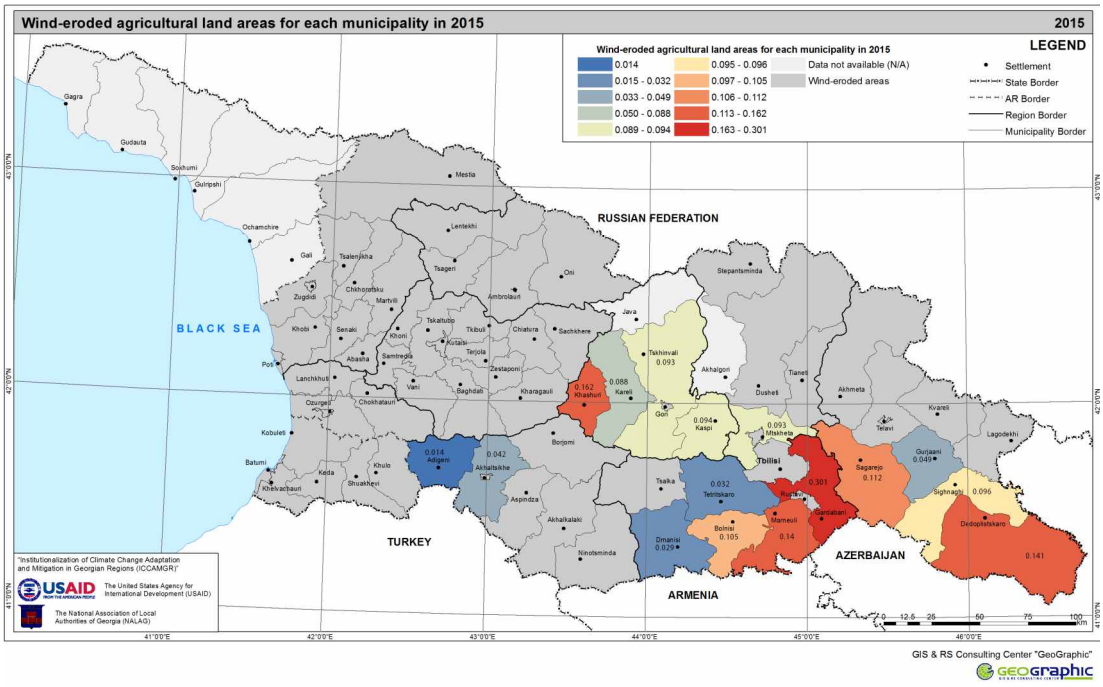

Fig. 13. Wind-eroded agricultural land areas for each municipality in 2015

By aggregation and normalization of the above indices and indicators, the following agriculture sensitivity aggregate indices have been derived:

Sensitivity of agricultural crops to moisture changes has been recorded using the following indicators: (a) sensitivity of the irrigation rate of agricultural crops to moisture variation; (b) utilization of the designed land-reclamation systems (irrigation and drainage); and (c) actual utilization of the land-reclamation systems (irrigation and drainage) – see Map 45.

Sensitivity of agricultural lands to water and wind erosion enhancement risk has been recorded by using the following indicators: share of water- and wind-eroded areas (see Map 46).

[114] G. Gavardashvili, Irrigation, drainage, erosion, Tbilisi, 2016.

RELEVANCE

Georgian forests represent a significant resource for the country. Currently, forests occupy about 40% of Georgia's territory as a whole. The total stock of wood in these forests amounts to 454.5 million m^3. Of this, 120.2 million m^3 are coniferous forests and 325.3 million m^3 are deciduous forests.

Over 800 tree species, shrubs, lianas, fern and other perennial plants, differently distributed within the country's territory according to climate and soil, have been registered in Georgian forests.

Table 3. Stock of major tree species of Georgian forests (million m^3).
(Source: Georgia's Report to Global Forest Resources Assessment /FRA 2015/)

	Species	Scientific name	2005	2010
1	Beech	Fagus orientalis	225.9	231.3
2	Fir	Abies nordmanniana	76.8	75.9
3	Spruce	Picea spp.	34.3	33.7
4	Hornbeam	Carpinus caucasica	24.9	24.6
5	Oak	Quercus spp.	23.8	23.6
6	Pine	Pinus spp.	16.4	14.6
7	Alder	Alnus barbata	13.9	13.8
8	Chestnut	Castanea sativa	13.4	12.7
9	Birch	Betula litwinowii	3.6	3.5
10	Maple	Acer campestre	3.7	9.2
Other			13.2	11.6
Total			455.9	454.5

The information presented in Table 3 is pertinent because climate change will most likely be followed by intersubstitution of these species and, accordingly, a change of their distribution areas and stock. Where and how said changes will occur should be the subject of future studies.

Forests and the climate are strongly interrelated. Forests create microclimates and their role is great in the establishment of the global climate. Forests represent the largest carbon accumulating and oxygen-producing ecosystem, which contributes to creating a climate favorable for human beings on Earth. Together with increased emission of greenhouse gases, the main cause of climate change has become the dramatic reduction in world forest cover. Due to the increased greenhouse gas emissions and reduced forest cover, the carbon accumulated by forests is no longer sufficient to maintain the right balance. Thus, the preservation of sustainable ecosystems, including conservation of forests, is of great importance not only in terms of biodiversity conservation, but also as an "instrument" of mitigation of the negative effects of climate change through the retention of oxygen and adaptation to climate change[115].

[115] V. Darakhvelidze, P. Metreveli, L. Chikhladze, Forestry, Tbilisi, 1981.

Georgian forests contribute to the country's ability to deal with climate change. To increase this contribution, it is necessary for both forest-covered areas as well as forest productivity to be increased, which is generally expressed in forest biomass growth. At present, the aboveground biomass of Georgian forests totals about 336.8 million metric tons (calculated per dry weight), while the underground biomass (mostly roots) amounts to 87.7 million metric tons (calculated per dry weight). This amount of biomass can accumulate about 212 metric tons of carbon. Hence, the role of Georgian forests in climate improvement is quite clear.

The impact on forests from climate change has been well researched. In developed countries of the world (e.g., in northern Europe)[116], a trend for increasing forest-covered areas as a result of climate change has been recorded for the last decade. The impact of climate change on forests has been studied less in Georgia than elsewhere, although from what has been carried out it appears that the intersubstitution of species and reduction of the size of their habitats will likely occur.

Another threat for forests due to climate change is the increase in temperature, which together with precipitation decline and evaporation growth can increase the risk of forest fires. In general, forest fires represent a global problem. During the last 15 years, forest fires have tended to cover about 280 hectares on average annually.

In addition, as a result of climate change, the risk of the spread of plant diseases caused by pathogens has also increased.

EXISTING STUDIES

In Georgia's Third National Communication to the UNFCCC[117] the impact of climate change on forest ecosystems was assessed based on examples of forest tracts in Adjara, Upper Svaneti and Borjomi-Bakuriani. The main impacts of climate change on Adjara forest ecosystems, which occupy 66% of the entire area of the region, are increases in temperature and precipitation, which for several decades have caused yearly growth in the spread of plant pests and diseases.

Currently, the total area of infected forests amounts to 6% of the forest reserves (192.5 thousand ha). Of phytopathological diseases, chestnut endotic cancer is the most widespread in the relatively low zone of the region, while the great spruce bark beetle (*Dendroctonus micans*), European spruce bark beetle (*Ips tipographus L*) and engraver beetle (*Ips acuminatus Eichh*) dominate the higher parts of the region. In the lower zone, where the temperature increment in the beginning of the century was 0.5^{0}C, the annual precipitation surplus amounted to 8%. A total of 28% of the total chestnut-covered area has withered and the damage is increasing every year. It has been established that with a gradual increase of the average annual temperature, the diseased area will advance to highland chestnut forests.

In addition, new plant pests such as horse-chestnut leaf miner (*Cameraria ohridella Deschka*), trumpet leaf miner (*Tischeria complanella Hb*), oak leaf mining moth (*Tischeria ekebladellia Bjerkande*), and boxwood blight (*Cylindrocladium buxicola*) emerged in the forests of Adjara in 2006-2011. They are expected to cause catastrophic damage to host relicts and endemic species under conditions of climate warming. In addition, the upper forest border has moved lower by 300-400 m during the last 50 years, which is mainly due to land erosion processes and anthropogenic pressure (overgrazing and deforestation) associated with heavy rainfall.

[116] EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit.
[117] The Third National Communication of Georgia to the UNFCCC, op. cit.

According to forecasted climate change, the temperature in Adjara will increase by 1.5°C in the middle of this century, and by the end of the century this figure will reach 4.2°C. In addition, the number of hot days and tropical nights will significantly increase, which will create a favorable environment for increased prominence of forest pests and diseases. Moreover, with a slight increase in precipitation in the medium term, a decline of approximately 10% is expected in precipitation by the end of the century. Based on this forecast, it could be said with high probability that the risks of fire and plant diseases will increase in the forests of Adjara. At the same time, the risk that the subalpine forests will disappear is also increasing and the downward movement of their upper distribution boundaries is being recorded. The Climate Change Strategy of Adjara has been developed in order to implement climate change adaptation measures discussed in this sector.

The study of the impact of climate change on the forest sector of Upper Svaneti revealed that boreal forest species (pine and birch) gradually occupied the areas vacated by glacier retreat. During the past 50 years, birch was replaced by a coniferous variety, namely spruce, on relatively large areas in the Mestia climatic zone. It was also revealed that on the northern mountain slopes, where the upper spruce-fir forest belt moved to the alpine zone, spruce-fir forests are now widespread. The analysis also demonstrated that climate warming, which in the last half-century amounted to 0.3°C, had a particular impact on the dissemination of birch forests in the Upper Svaneti region. It was recorded that the birch forests' upper boundaries are moving slightly higher.

By taking the future climate change forecast into account, a conclusion was reached that in the alpine zone, where anthropogenic pressure is lower, the forest area will increase. Meanwhile, in the forest tracts along alpine pastures, biomass stocks will increase with warming in proportion to capacity growth. It was also noted that negative manifestations of climate change, such as fires and increased incidence of pests and diseases, are not observed in Svanetian forest tracts, despite a tendency for these to increase in other regions of Georgia.

In the Khaishi climatic zone, unlike the Mestia zone, the impact of climate change on the forest tracts has not been clearly established. However, by taking into account the observed changes in the Mestia zone, it was concluded that in Khaishi zone, coniferous forest species may be replaced by deciduous species during the current century. As for the Borjomi-Bakuriani forest ecosystem, during the past 50 years, abiotic disorders (increase in fire incidences), as well as biotic disorders (the systematic recurrence of ictus of pests and diseases) were observed. The summer temperatures in the region increased by 10°C in the above-mentioned period, while precipitation decreased by 14%. Almost all time-scale droughts increased and the number of hot days increased by eleven-fold annually. At the same time, the number of days with abundant precipitation also increased.

It was concluded based on the analyzed materials that the current features of climate change facilitated the increase in fire hazard and the expansion of favorable areas and spread of pests in Borjomi-Bakuriani forests. This trend will be even further strengthened by future conditions of climate change.

Many studies have been carried out at the international level as well on the impact of climate change on forest ecosystems. Particularly noteworthy is a study carried out by the European Environment Agency (2012)[118], which underlines that forest biomass and the area covered by forests and other wooded land have increased over the past decade. It was recorded that forest growth will continue to increase in northern Europe and decrease in southern Europe in the future. The Third National Communication of Georgia to the UNFCCC also notes the tendency of northern European forest areas with regard to the mountainous regions of Georgia, namely for the Mestia municipality.

[118] Climate change, impacts and vulnerability in Europe 2012, op. cit.

Moreover, the same European study states that the number of fires in the Mediterranean region increased over the period from 1980 to 2000 and decreased thereafter. The impact of fire events is particularly strong on already degraded forest ecosystems in southern Europe.

Of particular significance is a study concerning forest fires carried out by the Caucasus Environmental NGO Network (CENN)[119]. The work presents Georgian maps with the existing forest fire risk classification, which states that the most fire-prone area in Georgia comprises southeastern Georgian municipalities. It should be mentioned here that a separate category of forest fires has not been outlined in the course of analysis. The document is also interesting as it uses geographic information systems (GIS) to make an analysis, although the mentioned study does not provide information on how the risk of fire occurrence would change under climate change conditions.

This issue is being considered in the present study, for which purpose, based on climate change modeling and assessment methodology, relevant sensitivity and exposure indicators and indices have been aggregated and visualized.

SENSITIVITY INDICATORS

As previously mentioned, the following quantitative indicators can be used to assess the sensitivity of forest ecosystems to climate change:

a) Change in the frequency and number of fires and the resultant fire-damaged areas;
b) Change in the areas covered by forests;
c) Change in the frequency and number of plant diseases caused by pathogens and infected areas.

Based on the given research objectives, which implied a comparative study of municipalities and required the collection of quantitative data per indicator, the sensitivity of forests to climate change was assessed by the number of forest fires (Forest Fire Danger Index) and the share of land area covered by forests (Forest Area Index).

Based on the available information, the following quantitative sensitivity indicators were used:

- Forest fire number indicators – the number of forest fires in a municipality (by normalization from 1 to 10).
- Forest area indicator – the ratio of the area covered by forests in a municipality to the municipality's total land area (by normalization from 1 to 10).

Since the data received from the Emergency Situations Management Agency of the Ministry of Internal Affairs of Georgia and the National Forestry Agency of the Ministry of Environment and Natural Resources Protection of Georgia covered only the period from 2010 to 2015 and was of poor quality (in the data for the past five-year period, basic information was available for only six municipalities), it was decided that satellite observation data would be used to detect forest fire danger and afforestation indices.

[119] GIS Wildland Fire Hazard Modeling in Georgia. I. T. Feliciano Santiago, N. Kheladze, CENN, 2011.

In particular, to determine the quantitative indicator of wildfires for each municipality, NASA's Fire Information for Resource Management System (FIRMS) was used[120]. The system encompasses the satellite observation data (5th version) of hotspots/thermal anomalies detected by the MODIS satellite to within 1 km during 2000-2015. The data naturally contains the fires observed both within forest and cropland areas.

From 2000 to 2015, a total of 6,000 fires were recorded in Georgia. To separate forest fires from the common database, the following sources of forest cover were used: a 350 m resolution map (with 2009 data from GlobCover of the European Space Agency)[121], a 30 m resolution map (with 2010 data (from Globeland 30)[122], and a forest cover map developed for Georgia within the framework of the GIZ project entitled "Sustainable Biodiversity Management in the South Caucasus" (2011, a 5 m resolution map). With the help of these three sources and the GIS vector analysis, respectively, 1019 fires (on 350 m resolution map), 789 fires (on the 30 m resolution map) and 644 fires (on the 5 m resolution map) were identified.

As accuracy of the observation of total fires was only within 1 km (NASA FIRMS), it was not possible to identify forest fires on low-resolution maps of forest cover. Therefore, the lowest number of fires (644) has been used to produce the map, as it complies with the best resolution forest cover maps (GIZ, 5 m resolution map) and gives a clearer picture of forest fires within the territories of each municipality.

Fig. 14 below shows all types of fires recorded in the period from 2000 to 2015 (red dots); and forest fires for the same period (black dots) are disaggregated; a GIS layer of the area covered by forests (source: GIZ) and the calculated and visualized quantitative indicator of forest fire numbers (for each municipality, normalized from 1 to 10).

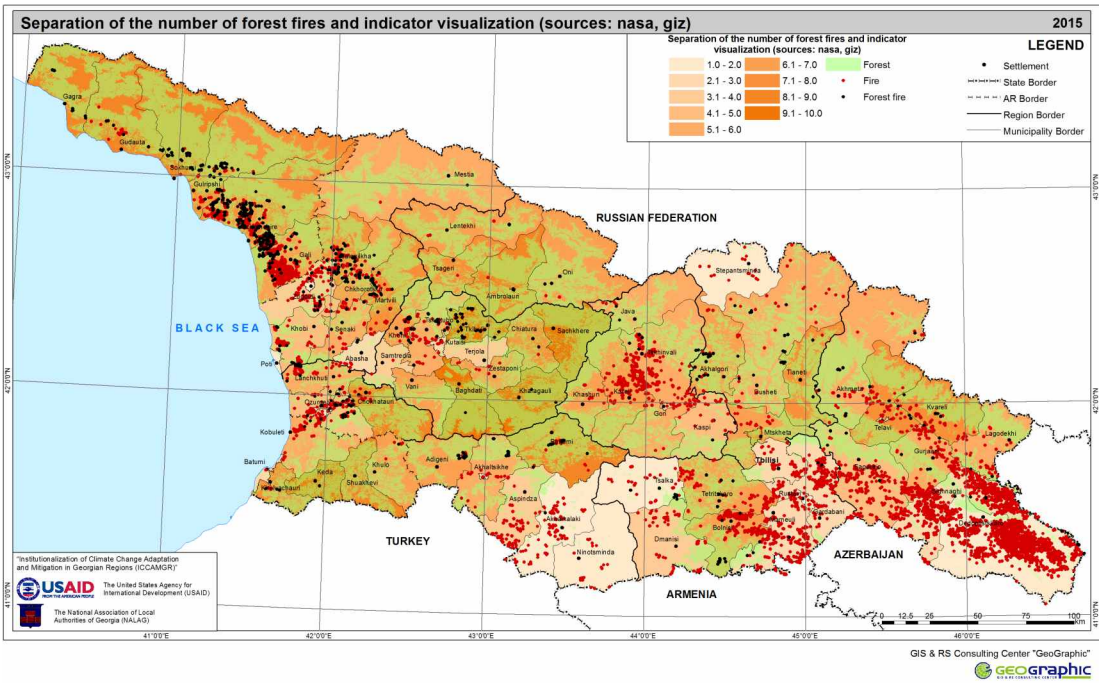

Fig. 14. Separation of the number of forest fires and indicator visualization (sources: NASA, GIZ)

[120] See http://earthdata.nasa.gov/firms (accessed March 18, 2016).
[121] See http://due.esrin.esa.int/page_globcover.php (accessed March 18, 2016).
[122] See http://www.globallandcover.com/GLC30Download/index.aspx (accessed March 18, 2016).

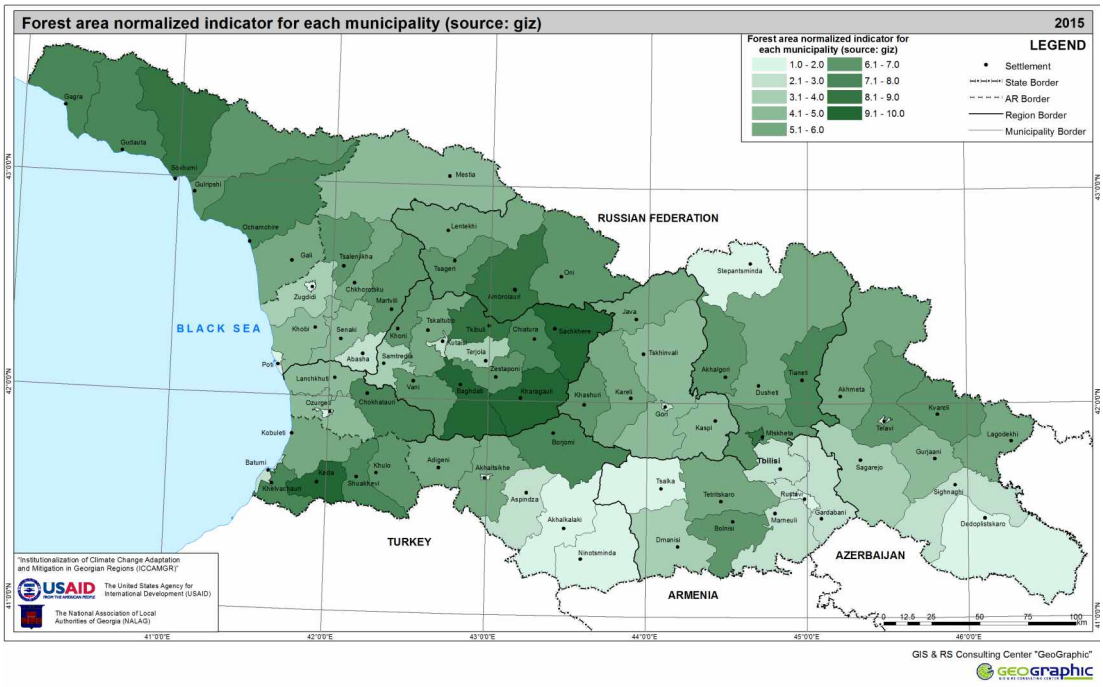

Fig. 15. Forest area normalized indicator for each municipality (source: GIZ)

Finally, in order to assess the sensitivity of forest ecosystems to fires, an aggregate sensitivity indicator has been derived for which a geometrical mean of forest numbers and of two forest areas (equilibrium index) has been calculated (see Map 47).

Each distinct industrial sector is uniquely vulnerable to varying climate change exposures. In order to evaluate both the rate and impact of vulnerability, the following information regarding the industrial sector's activities in the municipalities needs to be accessible to external parties:

- Data about the industrial processes in the municipalities;
- Data on the exact location of industrial plants;
- Data on numbers of employees in the industrial sector.

The accessibility to data sources is critical for assessing how the following factors of climate change can impact the overall operability of the industrial sector:

- Accessibility of water resources: Climate change can impact water availability and can thus affect the amount of energy generated by hydroelectric power plants therefore directly impacting industrial processes because the majority of industrial plants require a sustainable supply of water for production output;
- Agricultural production: Enterprises engaged in agricultural production or export enterprises are vulnerable to the following potential climate impacts: temperature changes and decreases in precipitation. These changes may impact the cultivation period, among others.
- Abundant precipitation: Precipitation can potentially increase the risks of various natural hazards, thus potentially impacting the physical safety of certain industrial infrastructure and individuals employed in those industries;
- Temperatures: One of the key climate change exposure factors – the increase in both temperature and the number of hot days – affects the overall capacity of individuals to work productively[123].

Based on the above, some industrial sectors are more vulnerable to climate change than others. In addition, these sectors respond to the same climate variables differently. The climate change effect can be simple and have only one climate exposure indicator or complex, having multiple climate exposure variables. For example, there are many textile factories in the Adjara Region built by Turkish investments, the number of which is projected to increase per annum. One of the attractive factors for investors is Georgia's comparatively low energy costs. Accordingly, a consistent supply of power is the crucial factor for the effective operation of critical industries and should be ensured by the government. Industries should also utilize alternative, renewable sources of energy and introduce energy-saving technologies. In the event Georgia's energy supply is restricted due to climate change, it will have negative economic outcomes such as a reduction in production revenues as well as adversely affecting the overall employment potential of these industries.

In addition to the textile sector, potential climate changes will have multiple impacts on agricultural processing and agro-industry plants. These changes, such as climate exposures, may include, but are not limited to the following: drought, wind speed changes, summer temperature increases and precipitation decreases among others. For example, frequent droughts will raise producers' vulnerability, resulting in smaller harvests, while summer temperature increases and on-going desertification will cause production and supply problems for the dairy and cattle-breeding sectors.

[123] United Nations Environment Programme (UNEP), The Outlook on Climate Change Adaptation in the Southern Caucasus Mountains, 2015, http://www.unep.org/roe/Portals/139/documents/Press%20Releases/Caucasus_screen.pdf (accessed March 18, 2016).

While assessing the potential climate change impacts on the overall industrial sector, the percentage of the population employed in a relative sub-sector is a critical economic factor to take into account. Thus, given that over half of the Georgian population is engaged in agriculture[124], any adverse effect on agricultural productivity will directly impact the wellbeing of employees. Given that the agriculture sector in Georgia is a low productivity and low technology sector, as is evidenced by the sector's contribution to the country's GDP, climate change can potentially have extremely detrimental impacts on the population employed by this sector. This study assesses the industrial sectors most vulnerable to climate change that are also vital to the country's economic growth and development including construction, mining and agricultural processing.

According to the most recent GeoStat data[125], the industrial sector contributes 17.4 percent to Georgia's GDP, followed by trade at 17.3 percent. The transportation and communications sectors contribute 11 percent, agriculture and fishing contribute 9.4 percent, construction contributes 8.9 percent, public administration contributes 7.6 percent, the real estate sector and consumer services contribute 6.9 percent while health care and public assistance contribute 6 percent. In addition, according to preliminary estimates of economic growth[126], the average actual economic growth of the first 11 months of 2015 was 3 percent, as compared with the same period in 2014. The statistical data of the previous period make it possible to assume that the growths trend in construction, the processing industry and agriculture sectors will continue.

RELEVANCE

Climate change and industry are interdependent. However, the majority of existing studies assess the impact of industrial activities on climate change (i.e. the role of emissions), while fewer studies are concerned with the negative and/or positive effects of climate change on industry.

The industrial sectors studied, according to their vulnerability to climate change, are the following: agriculture, forestry, energy and tourism.

The following industrial sectors have not yet been studied in depth in other studies: mining, cultivation, processing and export of agricultural products and construction. In order to address the lack of studies in the above-mentioned sectors, it is recommended that the following studies be carried out.

First, the climate change impacts should be assessed on:

- The agricultural sector as well as the potential industrial opportunities created as a result of climate change at the local municipal level;
- The construction sector, per municipality;
- The processing sector, including the potential capacity created as a result of climate change in the municipalities;
- The mining industry, per municipality.

[124] Central Intelligence Agency (CIA), World Fact Book, Georgia (2015), https://www.cia.gov/library/publications/the-world-factbook/geos/gg.html# (accessed March 18, 2016).
[125] National Statistics Office of Georgia. GeoStat, Industry, Construction, Energy Statistics. http://geostat.ge/index.php?action=page&p_id=284&lang=eng (accessed on March 22, 2016).
[126] National Statistics Office of Georgia, GeoStat, Preliminary estimate of economic growth, 2015 http://geostat.ge/cms/site_images/_files/english/economic/monthly%20economic%20statistics_november_2015.pdf (accessed March 22, 2016).

Studies should also be conducted to consider:

- Damage incurred by a producer and/or enterprise caused by climate change. In order to decrease production risks, prior to establishing an enterprise, the location of an industry should be compared to the respective GIS maps, which detail potential natural hazards.
- Potential losses. An inventory of enterprises located in municipalities should be carried out identifying their exact locations on respective maps. Also, an assessment of the industrial infrastructure should be made. In addition, information about the number of employees in each sector should be collected, in particular employees over 65 years of age; This information will allow for better calculation of these potential losses.
- Specific climate change exposure indicators, such as drought and heavy rain, in order to assess the particular impacts of each type of event on the overall industrial sector. It should be mentioned that this current study had to be based on assumptions due to a dearth of reliable quantitative data.

All of the above studies should be tailored to Georgia's needs and developing-country status. While climate change risks are taken into account in the industrial processes in developed countries, these potential risks are disregarded in Georgia. For example, as has been mentioned, temperature increases will exacerbate desertification and pasture degradation and negatively impact cattle breeding productivity, as Georgia mostly uses pasturelands to graze cattle rather than supplying artificial feed.

Given these many factors, studying industrial processes is complex, which can be explained by the diversity of the types of enterprises on the one hand and on the other hand, the dependence on the goodwill of the producers in selected enterprises to inform the study – the possibility that producers might cause problems for the conduct of said studies should not be disregarded. The search for an appropriate international approach suited to the Georgian reality will be necessary.

EXISTING STUDIES

The purpose of this study is to assess the potential impacts of climate change on the industrial sector. It should be mentioned that integrated cross-sectoral studies, or best practice material for Georgia, are unavailable. Most studies on the industrial sector describe the potential climate change impacts on the agricultural sector and mining. Several other studies review the construction and processing sectors, however the emphasis is often on the agricultural sub-components of both industries.

It should also be mentioned that existing source documents, which directly or indirectly describe the impact of climate change on Georgia's industrial sector are different in structure and therefore are not comparable. These documents describe problems in a fragmentary way; therefore it is difficult to identify the most vulnerable and risky aspects and areas in the industrial sector on a national scale. The available reference materials are included within national strategic reports, such as project documents, policy documents, action plans, and white papers as well as risk assessment studies. In their aggregate form, these documents are informative and helpful in analyzing existing climate change concerns. While several of these documents highlight the potential risks to the industrial sector in the event of climate change, there is no guiding document or baseline assessment to guide this study and future evaluations.

There are observable positive trends in Georgia's national construction policy direction as evidenced by the Ministry of Economy and Sustainable Development's new Building Code[127]. One of the objectives of this Code is to promote the development and introduction of modern technologies in the direction of construction safety and energy efficiency. In addition, a Deep and Comprehensive Free Trade Area (DCFTA) Agreement was signed with the EU[128], which amends labor-related standards to allow for adequate employment and labor conditions for all Georgian citizens. The agreement reflects basic labor standards as recommended by the International Labor Organization (ILO) in Georgian legislation.

Within the framework of the United Nations Environment Program (UNEP, 2009)[129], a summary document, Buildings and Climate Change. Summary for Decision-Makers was elaborated. The document describes the role of municipalities, non-governmental organizations and the private sector in construction activities, while also including specific recommendations for municipalities to develop climate change programs. The development of such programs would include monitoring and evaluation activities, design and implementation of an action plan and elaboration of a strategic document.

In order to raise awareness and build the capacity of local communities and municipalities, Mercy Corps and the Caucasus Environmental NGO Network (CENN) implemented a joint project entitled "Enhancing Local Capacity and Regional Cooperation for Climate Change Adaptation and Biodiversity Conservation in Georgia and the South Caucasus"[130] in 2014.

In order to introduce various agricultural practices, the Ministry of Agriculture (MoA) developed the Strategy for Agriculture Development in Georgia for the period from 2015 to 2020[131]. This document includes promoting climate-smart agricultural practices and underlines the necessity to conduct research in the development of national and regional programs.

Another relevant research document is entitled "Climate Change and Agriculture in Kakheti Region"[132], which was drafted while preparing the Third National Communication of Georgia to the UNFCCC. The study comprises all eight municipalities in the Kakheti Region and emphasizes the climate change impact on industrial production in the agricultural sector. In particular, the study reviews the existing types of enterprises in the Kakheti Region, such as winemaking, cattle breeding and dairy production among others. This study represents one of the first to review the impacts of climate change on the industrial sector and its critical subcomponents. The research presented the negative climate change impacts on agriculture while detailing a list of project proposals for mitigating potential climate change impacts. The recommendations are divided into both the activities to be implemented for the municipalities as well as activities to be implemented in the municipalities. It should be mentioned that in order to achieve the final project outcomes, local consultants at the municipal level were engaged in the data-collection process and according to the new data, concrete recommendations were provided. Without local expertise it is quite difficult to draft recommendations for the municipalities.

A noted international report that addresses the climate change impacts on energy and agricultural sectors, which also highlights the socio-economic and public health effects, was published by the European Environment Agency[133].

In addition, the majority of other studies acknowledges a definite sensitivity of different sectors to climate change and recommends interventions by the national government to mitigate the potential risks caused by climate change in the industrial sector. In addition, a particular emphasis in the studies is placed on both the potential risks as well as the new economic opportunities created by climate change, the latter can become one of the most important factors in the development of industry in the municipalities of Georgia.

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[129] UNEP. Buildings and Climate Change Summary for Decision-Makers. Georgia, 2014. http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf (accessed March 22, 2016).

[130] EEA projects http://eeas.europa.eu/delegations/georgia/projects/list_of_projects/221368_en.htm (accessed March 22, 2016).

[131] Resolution of the Government of Georgia 11/02/2015 # 167: On the Approval of the Strategy for Agriculture Development in Georgia 2015-2020. Georgian Legislative Bulletin: https://matsne.gov.ge/ka/document/view/2733545 (accessed March 22, 2016).

[132] Climate Change and Agriculture in Kakheti Region, UNDP, Georgia, 2014. http://www.ge.undp.org/content/dam/georgia/docs/publications/GE_UNDP_ENV_Climate_Change_and_Agriculture_Kakheti.pdf (accessed March 22, 2016).

[133] EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit. http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012

SENSITIVITY INDICATORS

As has been mentioned, different industrial sectors face varying vulnerabilities to climate change. Their unique profiles should be addressed appropriately in research – vulnerability assessments of agro-industrial enterprises require indicators different from those used in vulnerability assessments of mining enterprises.

Based on the above-mentioned issues and taking into account the purpose of the given study, the following indicators were selected for assessing the climate change impact on the industrial sector:

- Location of industrial sites (to assess the physical vulnerability of the industry's infrastructure), and;
- Number and age of employed workers in the selected sectors, such as construction, mining, processing and agricultural production (to assess the health and physical safety of the employees, by municipality).

Both data sets are not comprehensively available to external parties[134] and the researchers were only able to access the number of enterprises per municipality. Unfortunately, the total number of enterprises, as seen in Figure 16 below, did not provide sufficient data for researchers to analyze the sector's sensitivity towards climate change and potential climate change impacts on the sector.

If data were available on the activity and exact location of industrial enterprises in municipalities, it would be possible to compare the existing enterprises with mapped areas of natural disasters. Therefore, potential hazards that threaten industrial sites could be determined. It is necessary that this data become accessible, since the existence of an early warning system cannot fully prevent damage of industrial infrastructure in the event of natural disasters.

If researchers were able to estimate the number of employed workers per municipality, they would be able to assess the socio-economic dependence of a municipal population on a specific sector. If a sector were found to be vulnerable to climate change, the socio-economic vulnerability of the employed population groups would also increase. In addition, knowing the age of the employed individuals would enable researchers to assess and identify those individuals more vulnerable to climate change-related diseases, such as cardiovascular disease, respiratory-system pathologies, infectious diseases and vector disorders[135].

According to the collected information, which is based on the National Statistics Office's 2015 report, there are 7,584 registered enterprises in the above sectors, not including Tbilisi. There are 4,121 processing industries, 2,558 construction industries, 509 agricultural industries and 396 mining companies[136]. See Figure 16 for details.

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[134] According to the National Environmental Agency of the Ministry of Environment and Natural Resources Protection of Georgia, Revenue Service of Georgia and GeoStat, the information either does not exist or is a commercial secret requiring additional processing, or is available only for a fee.

[135] World Health Organization (WHO), Risk factors of ill health among older people http://www.euro.who.int/en/health-topics/Life-stages/healthy-ageing/data-and-statistics/risk-factors-of-ill-health-among-older-people (accessed March 18, 2016).

[135] National Statistics Office of Georgia, 2015. Report excerpt. Information was provided per an official request of the ICCAMGR project. Data was accessed in December 2015.

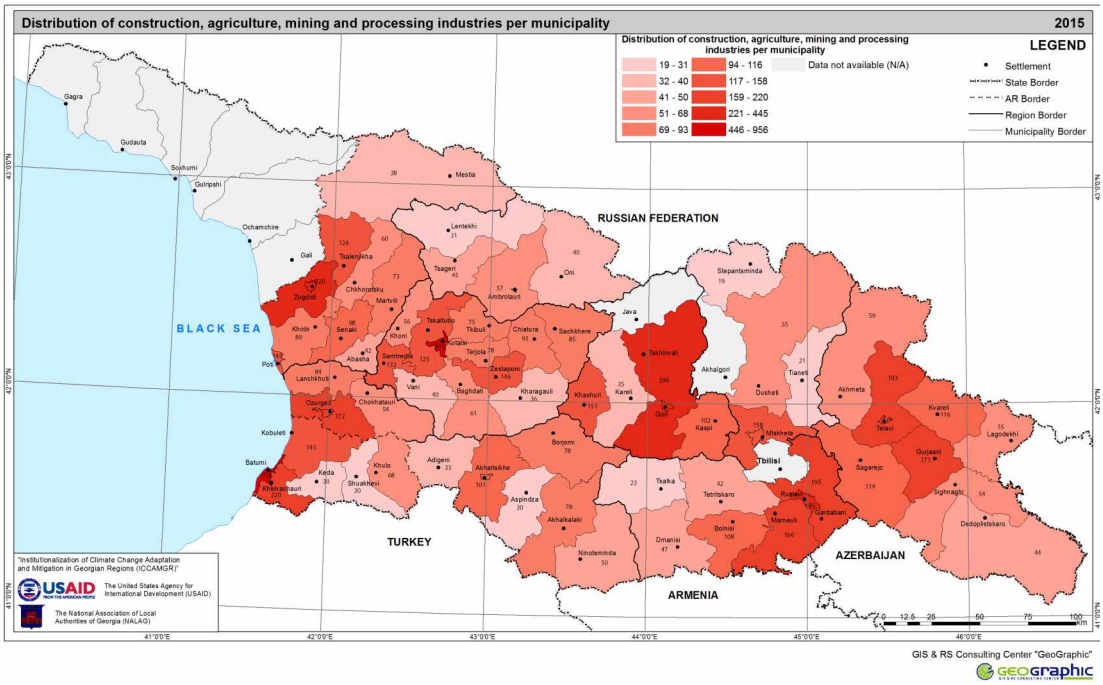

Fig. 16. Distribution of construction, agriculture, mining and processing industries per municipality

Within the current assessment, due to the lack of exact statistical data and in order to assess the sensitivity of the industrial sectors to climate change, municipalities were divided into two groups. The first group incorporated the municipalities with a less developed industrial sector, with a total of 100 enterprises in all the four sectors, while the second group incorporated municipalities with a developed industrial sector, with more than 100 enterprises. In this respect, based only on the number of enterprises, the projected impact of climate change was calculated quantitatively. In particular, the climate change sensitivity in each municipality demonstrated a weak sensitivity where industry is almost undeveloped, while the municipalities with developed industries all demonstrated a higher sensitivity. This assessment comprises the active enterprises rather than the sector as a whole, which are implied to be more or less vulnerable to climate change, the positive or negative climate impacts that may occur.

Understanding and analyzing the potential impacts of climate change on the energy sector is critical to planning an effective adaptation policy, which aims to reduce the impacts of climate change on the sector. Climate change has, potentially, a pervasive impact on the energy sector, in particular on energy generation and consumption, however the impact can be either positive or negative. For example, in some municipalities the demand for heating may be reduced due to climate change impacts, while in other municipalities an increased demand for cooling is expected. Climate change may also impact the existing energy infrastructure as extreme natural disasters can damage these sites resulting in a temporary suspension of the energy supply. Planned infrastructure can also be damaged in the future.

This study aims at assessing the climate change impacts on the energy sector by municipality. The study does not envisage assessing the quantitative impact of climate change on energy consumption. Within the frame of this study, researchers performed a comparative analysis of climate change impact on Georgian municipalities. To perform this study, the researchers analyzed the hydrological forecasts for certain rivers and assessed the potential climate change impacts on the generation of the hydro power plants located on these rivers while also evaluating the sensitivity of selected critical energy infrastructure sites towards climate change.

RELEVANCE

In Georgia, electricity is produced by hydroelectric and thermal power plants. The share of energy generated by hydroelectric power plants comprises an estimated 80 percent of total generation. The generation of electricity by hydroelectric power plants depends on the quantity of water available and climate change may impact the generation of Georgia's hydropower energy sector. The potential changes in outdoor temperatures will also impact energy consumption needed for heating and cooling. In Georgia, electricity is mainly used for cooling. In 2014, the residential sector consumed 2,465 kilowatt hours (kWh) of electricity, which is 25 percent of the total national electricity consumption, while electricity consumption in the commercial and state sectors was 2,567 kWh, which is 26 percent of the total national electricity consumption. On average, electricity consumption[137] in the residential sector increases about 5 percent per annum[138], while consumption in the non-residential sector increases about 14 percent per annum.

The majority of the rural population uses wood and natural gas for heating with only a small segment of the population using electricity, primarily as an additional heating source. An example of this is the split system air conditioners that can provide heating and cooling. In the large cities, the main source for heating is natural gas. Despite the GoG's active gasification program, wood is still widely used in villages and often in the cities for heating purposes. In 2014, the residential sector consumed 2.4 million m^3 of wood[139], which represents 98 percent of the total wood consumed for heating. In general, the commercial and state sectors use natural gas for heating, consuming 222 million m^3 in 2014, which is 14 percent of total natural gas consumption. In 2014, the residential consumption of natural gas was 597 million m^3, which is 40 percent of the total gas consumption. As such, the residential sector is the key consumer of natural gas. It is important to note that 99 percent of natural gas is imported from neighboring countries. Consequently, the sensitivity of energy consumption for heating purposes impacts Georgia's economic sustainability, its foreign trade balance and overall energy security, which depends in part on a sustainable supply of gas.

Climate change also influences the possibility for natural disasters, such as floods, snow avalanches, mudflows, landslides, etc. The mentioned natural disasters can threaten existing critical energy infrastructure while potentially endangering the security of Georgia's energy supply. Consequently, it is important to study the risks associated with natural disasters and their potential impacts to the energy sector.

[137] GeoStat, National Energy Balance of Georgia (2014), http://geostat.ge/?action=page&&p_id=2084&lang=eng (accessed March 22, December 2015).
[138] Based on information provided by electricity distribution companies for 2009-2014.
[139] GeoStat, National Energy Balance of Georgia (2014), op. cit.

The sensitivity of the energy sector is significantly influenced by the structure of energy consumption. Currently, no survey data exists detailing the consumption structure of the commercial sector, while several surveys were conducted for the energy consumption structure of the residential sector. Additionally, the current penetration rate[140] of end-user energy consumption technologies in the residential sector should be considered in the analysis of climate change impacts on energy consumption.

According to a municipal study[141], only 6 percent of the total Georgian population uses air conditioners. Mainly due to natural climate conditions, the highest penetration rate of air conditioners is in Batumi (30.3 percent of the population), in Kutaisi (22.6 percent of the population), in Poti (23.2 percent of the population) and in Tbilisi (13.7 percent of the population). Presumably, consumers will increase their usage of air conditioners as economic growth continues and household incomes continue to rise, which will increase the energy consumption for cooling purposes. In contrast to the low usage of cooling technologies, every family uses various technologies for heating. However, the majority of the Georgian population does not heat their entire house and energy consumption for heating is not at an optimal level. According to the municipal study[142], only 10 percent of Georgia's population uses a central heating system with 90 percent heating a segment of their houses. It is projected that energy consumption for heating will increase with further economic growth and the resulting rise in household incomes as more households will be able to afford central heating systems and the ability to heat an entire house.

Another critical factor to be included in analyzing the sensitivity of the energy sector towards climate change is the thermal insulation of houses, as insulated houses require less energy for heating and cooling. For instance, roof insulation significantly reduces cooling and heating expenses. Consequently, thermal insulation of residential houses is a constructive method for reducing both the sensitivity and potential impacts of climate change. According to the same study, 85 percent of Georgian residential buildings do not have roof insulation while wall insulation is not available for 97 percent of housing. In addition, only 50 percent of those without insulation plan to use it in the future. Moreover, thermal insulation is not widely used due to the high investment costs and a general lack of public awareness regarding energy efficiency. Overcoming these barriers and providing thermal insulation for housing will reduce the sensitivity of energy consumption due to the potential impacts of climate change.

As a result of prioritizing energy efficiency and renewable energy technologies within the frame of the project on Climate Change Mitigation and Technologies Needs Assessment[143], three types of technologies were proposed to mitigate climate change, including wood stoves and energy-efficient construction. In addition, the study demonstrated that promoting the use of energy-efficient wood stoves will reduce wood consumption, which is crucial for municipalities with little accessibility to fuel wood. Finally, implementation of energy-efficient construction will reduce energy consumption for cooling and heating, thus reducing the potential climate change impacts on energy consumption.

According to the US Climate Change Science Program, climate change also has an indirect impact on the energy sector[144]. According to studies carried out through this program, climate change can impact the risk management and investment policies of energy companies, and will likely influence research and development (R&D) as well as future technologies.

According to the same study and to the "Regional Climate Change and Variability"[145] survey, the industrial sector's energy consumption is less sensitive towards climate change. Consequently, the sensitivity of the residential and commercial sectors to climate change and the resulting potential climate change impacts were studied.

At present, there are no comprehensive studies, at either the national or regional level, on Georgia's future ability to access renewable energy sources and the vulnerability of these sources towards climate change. For example, there are no comprehensive analyses and/or forecasts of solar radiation in the regions and no thorough forecasts are available for all main rivers. In addition, there are no available quantitative surveys on the effects of climate change on energy consumption, such as how much energy consumption will be changed in the event of a one-degree increase in external temperatures.

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140 Penetration rate of a given technology is the number of active users within a specific population.

141 Development of Strategies/EC-LEDS Clean Energy Program "Knowledge, Attitude and Behavior Baseline Survey",Winrock International. 2014, pg. 37.

142 Ibid.

143 The Ministry of Environment Protection of Georgia. "Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation", Georgia's official TNA report, 2012. http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNR_CRE/e9067c6e3b97459989b2196f12155ad5/e8e037dbb07b4a348c1f21ca63443cb7.pdf (accessed March 19, 2016)

144 "Effects of Climate Change on Energy Production and Use in the United States", U.S. Climate Change Science Program. Synthesis and Assessment Product 4.5. 2006, p. 2 http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1005&context=usdoepub (accessed March 22, 2016).

145 R. Matthias, K. Donaghy, P. Kirshen, "Regional Climate Change and Variability. Impacts and Responses", Cheltenham, UK, 2006.

SENSITIVITY INDICATORS

To assess the potential impacts of climate change on the residential and commercial sectors' energy consumption, the following sensitivity indicators towards climate change were used:

- Sensitivity of the demand for heating;
- Sensitivity of the demand for cooling;
- Sensitivity of the heating load and cooling load.

In order to create a baseline, the average climate data of 1961-1990 was used to establish climate change parameters. The following parameters were used to calculate the sensitivity of energy consumption towards climate change:

- Estimated heating period; Assessed as the average number of cold days when average daily temperatures were lower than 8°C. This temperature is taken from the technical regulations for construction projects in Georgia[146] as it is assumed that heating is necessary when the outside temperature is less than 8°C.
- Estimated cooling period; As there is no standard for cooling in Georgia, the expected cooling period was assumed to be the average number of hot days when the daily average temperature was more than 25°C.
- Average annual maximum and minimum extreme temperatures, reflecting the average temperatures from the hottest 15 and the coldest 15 days.

The above-mentioned climate parameters allow researchers to assess the demand for energy. However, both the heating and cooling loads are also affected by extreme temperature values. The projected increase in extreme temperatures may require residents and businesses to install heating or cooling devices with higher capacities, also impacting the electricity system's load curve, thus increasing the daily peak volume and/or duration.

In addition to the climate parameters, researchers also used the following relative parameters to create the sensitivity index: (a) population size by municipality and; (b) number of employees in the commercial sector in each municipality.[147] Both parameters were normalized in order to calculate a relative parameter. These relative parameters are important in performing a comparative analysis of the municipalities.

Therefore, sensitivity indicators of energy consumption to climate change is an aggregate value of the following four indicators from both the residential and commercial sectors:

- Sensitivity of the demand for heating to climate change;
- Sensitivity of the demand for cooling to climate change;
- Sensitivity of both the heating and cooling loads to climate change.

In assessing each indicator, researchers combined one relative parameter and one absolute value. In assessing the indicator for the residential sector, population size was used as the relative indicator, while for the commercial sector the number of employees per municipality was used as the relative indicator. By calculating the relative indicators, researchers may rank the climate sensitivity of municipalities in a proper way. For example, even if the municipality demonstrates a high sensitivity of energy consumption only on the basis of climate data, the use of a relative indicator, such as population size or the number of employees, in the calculation of indexes can impact the sensitivity index and make it lower if the relative indicator for the municipality is small. In contrast, a municipality with a large population may have a higher sensitivity index, even if the energy sector of the mentioned municipality demonstrates a lower sensitivity calculated only on the basis of climate data.

[146] Decree N 71 of the Government of Georgia, "On approval of technical regulations for construction of territory of Georgia", January 15, 2014.
[147] National Statistics Office of Georgia, www.geostat.ge, (accessed in December 2015).

The following climate parameters were used to assess the existing demand for energy for both heating and cooling purposes:

- Estimated heating period during the baseline period, 1961-1990, is the average number of cold days on which the average daily temperature was below 8°C;
- Estimated cooling period for the baseline period, 1961-1990, is the average number of hot days on which the average daily temperature was above 25°C;

- Average extreme temperatures of the baseline period were used to calculate both the heating and cooling loads[148].

Energy consumption sensitivity to climate change was calculated by the following formula:

$$S=\sum_{i}^{8}=1\ (RA)$$

Where S is the energy consumption sensitivity aggregated index, R is the normalized value of relative indicator (population for residential sector and number of employees for commercial sector) and A is the normalized value of the sensitivity indicator for the base year normalized from 0 to 1 with i representing the energy consumption sensitivity indexes that were separately calculated for the residential and commercial sectors, a total of eight indexes.

The final aggregate energy consumption sensitivity index of the combined value of the above-mentioned eight indicators, were normalized. This methodology was used to calculate the climate sensitivity indexes of the energy sector, per municipality (see Maps 48, 49 and 50).

SENSITIVITY OF ENERGY INFRASTRUCTURE

Due to the high construction standards of oil and gas pipelines, it is most likely that natural disasters, such as floods and avalanches, will not impact their operability. However, in certain cases, some natural disasters may affect these critical infrastructure sites (see Section 3.5 on natural disasters).

This study reviews the sensitivity only of the electricity infrastructure towards natural disasters, in particular flooding and avalanches for which the affected area can be estimated[149]. To calculate the number of customers, researchers used statistical data provided upon request by JSC Energo-Pro Georgia from September 2015, while the substation's load data was derived from the factual consumption of electricity as reported in 2014[150] by the following formula:

$$L = E / 8,760$$

Where E is 2014 energy consumption data and 8,760 is the number of hours in a year.

This study focuses on the energy consumption demands within municipal administrative centers as a concentration (value) of energy consumption in which the potential effects of disasters are much higher than in other municipal settlements. Since it is difficult to precisely forecast consumption of each municipality in a medium- and long-term perspective, in order to estimate the scale of the potential damage it is assumed that energy consumption will remain at the existing level.

Figure 17 shows the critical infrastructure in the energy sector if it falls into zones with the risk of potential natural disasters such as floods and avalanches[151]. This analysis included a quantitative assessment of the potential immediate damage due to natural disasters by regions.

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148 For example, the increase of extreme summer temperatures will increase the cooling load, necessitating that end users install more powerful cooling technologies.

149 For other natural disasters, the affected territory/area cannot be calculated therefore they are not covered by geo-spatial analysis under the energy section of the Road Map. Each infrastructure site should be studied individually to evaluate how landslides, mudflows or debris flows will affect it.

150 Information provided by JSC Energo-Pro Georgia in September 2015 upon request of ICCAMGR.

151 Information about floods and avalanches from the last decades are collected from different official and non-official sources, including external media sources.

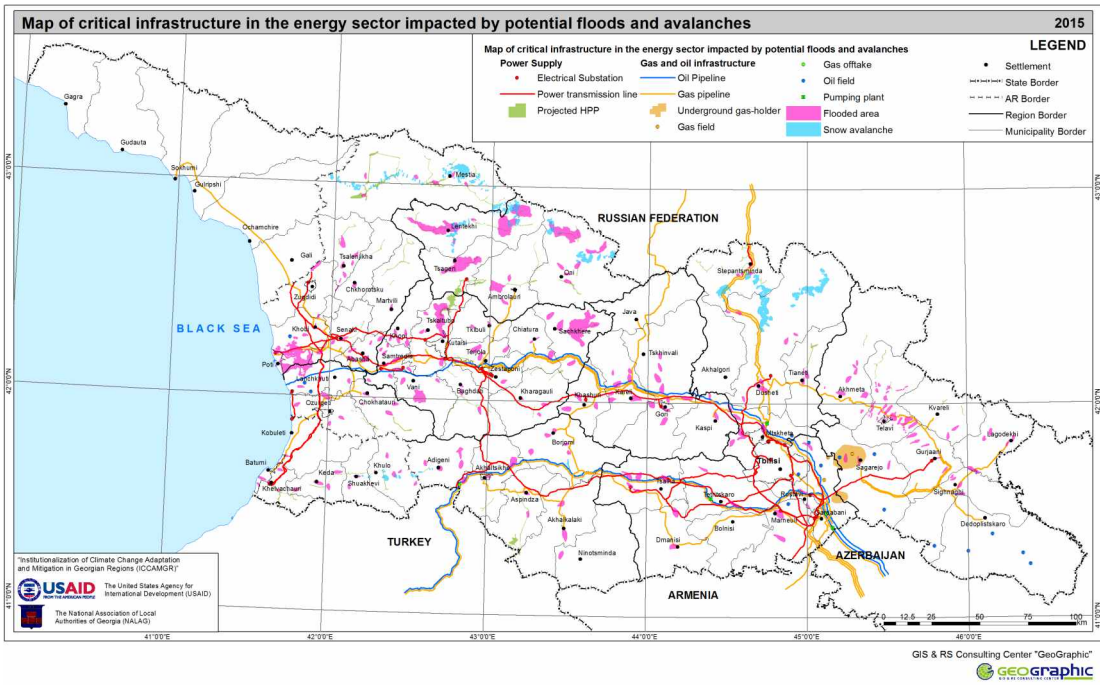

Fig 17. Map of critical infrastructure in the energy sector impacted by potential floods and avalanches

ADJARA

Part of the Keda Settlement is located in a potential flood zone. This means that unless preventive measures are taken, such as the construction of new protective structures and/or rehabilitation of old ones, 2,000 customers might be left without electricity with an average total load of 370 kW. This load will depend on the season, time of day and other external factors. The amount of time needed to recover the energy supply and the amount of lost electricity will depend on the duration of the disaster, its severity, the amount of infrastructural damage and other concerns.

Part of the Shuakhevi Settlement is also located in a flood zone. If a flood damaged the electrical distribution infrastructure, the electricity supply might be cut to 2,379 customers, with an average total load of 313 kW.

Khelvachauri is also partially located in a flood zone and in the event that the electrical distribution infrastructure were to be damaged by a flood, 2,000 customers might not receive electricity with an average total load of 840 kW.

GURIA

A part of the City of Chokhatauri is located in a potential flood zone and in the event the electrical distribution network was damaged electricity might not be supplied to 3,000 customers with an average total load of 4,100 kW that is generated from the Chokhatauri 110 Kv Substation.

SAMEGRELO – ZEMO SVANETI

The City of Martvili is located partially in a flood zone. This means that 2,300 customers with an average total load of 370 kW that are connected to the Martvili 110 kV Substation would be without electricity in the event of a natural disaster.

A part of the Mestia Municipality is also located in a flood zone. In the event of a natural disaster impacts the 35/10 kV Mestia Substation, an average total load of 600 kW will be suspended to up to 400 customers.

In addition, the Senaki City is partially located in a flood zone, and, in the event of a flood, a potential 1,530 kW average total load could be suspended for up to 3,000 customers.

Poti has, within its administrative boundaries, nine high voltage substations. Some of them are located in a potential flood zone, which, combined with damage of other electricity distribution infrastructure, could potentially suspend power distribution of 1,620 kW average total load impacting up to 8,000 customers.

The Chkhorotsku City is located in a potential flood zone and, in case the Chkhorotsku Substation is damaged, the electrical supply of 360 kW average total load will be suspended to up to 2,000 customers.

The Tsalenjikha City is also in located in a partial flood zone and, in the event the Tsalenkikha Substation is damaged the electrical supply of 470 kW average total load will be suspended to up to 2,700 customers.

IMERETI
The City of Bagdati is located in a potential flood zone. If the 110/35/10 Bagdati Substation, which distributes on average total load of 1,295 kW, is impacted by a flood, 8,716 customers would potentially be left without electricity.

A segment of Tkibuli is also in a potential flood zone and if the locally based electrical infrastructure, such as substations "Tkubuli 1" and "Tkibuli 3" and distribution network, which distributes average 1,746 kW average total load, were impacted by a flood, electricity would be shut off for up to 4,000 customers.

A part of Tskaltubo City is also in a potential flood zone and electricity is supplied from the 110/35/6 Tskaktubo Substation with an average total load of 1,837 kW. In the event of a natural disaster, electricity might be cut for up to 5,000 customers.

A part of Chiatura City is also located in a potential flood zone. Some out of five sub stations located in the town could be under the threat of flooding, which might cause electricity to be cut off for up to 8,000 customers, with an average total load of 1,200 kW.

In addition, Kharagauli City is in a flood zone and in the event of a natural disaster impacting locally based critical infrastructure, which distributes an average total load of 4,685 kW, about 3,400 customers would be left without electricity.

RACHA LECHKHUMI KVEMO SVANETI
Lentekhi, which receives electricity from the 35/10 kV Lentekhi Substation, which distributes an average total of 237 kW, is located in a potential flood zone. In the event of a serious disaster, 1,236 customers may remain without electricity. Lentekhi HPP is at the stage of pre-feasibility study and in case the plant is built with a reservoir, the risks of flooding will be reduced. In addition, Tsageri is fully included in the potential flood zone, which means that 3,684 customers might not receive electricity from the 35/10 kV Tsageri Substation, which distributes an average total load of 643 kW.

SAMTSKHE JAVAKHETI
Adigeni is located in a potential flood zone. There is a danger that 5,926 customers will remain without electricity if the Adigeni 110kvV Substation is damaged as it has an average total load of 805 kW

Aspindza, which receives electricity from 110/35/10 kV Aspindza Substation, that distributes an average total load of 278 kW, is in a potential flood zone. A natural disaster might leave 1,535 customers without electricity.

A segment of Akhalkalaki City is in a potential flood zone, and in the event a natural disaster impacted local critical electrical infrastructure, electricity cut might affect up to 3,000 customers, which receive an average total load of 700 kW.

A part of Akhaltsikhe city is also in a potential flood zone. In the event local critical electrical infrastructure was impacted, electricity might be cut off to 5,000 customers that receive an average total load of 1,450 kW from the Akhaltsikhe 110 kV Substation.

The City of Borjomi is partially located in a potential flood zone. In the event local critical electrical infrastructure was impacted, electricity might be cut off to 5,700 customers, with total average load 2,500 kW that are fed from the Borjomi- 1,110 kV and Borjomi- 2,110 kV Substations.

SHIDA KARTLI

A part of Gori is located in a potential flood zone and up to 10,700 customers might not receive electricity if local critical energy infrastructure that distributes an average total load of 3,200 kW were impacted.

Kareli City is also partially located in a potential flood zone and receives electricity from the 110/35/10 kV Kareli Substation and the 110/10 kV Kareli Tseva Substation. In the event of a natural disaster, up to 8, 000 customers, who receive estimated average total load of 640 kW, might remain without electricity.

MTSKHETA MTIANETI

The City of Dusheti is in a potential flood zone and in the event of a natural disaster impacting the 110/35/10 kV Dusheti Substation, with an average total,load of 937 kW, 4,509 customers might be left without electricity.

The City of Tianeti is partially located in a potential flood zone. In the event of a natural disaster, 1,500 customers, that are fed from Tianeti 110 kV Substation with an average total 190 kW load, may be left without..

KVEMO KARTLI

Part of Dmanisi is in potential flooding zone. Here electricity supply might be suspended for up to 3,000 customers with 372 kW average total load.

City Marneuli is partially in potential flooding zone. The City is supplied with electricity by two high power sub stations. In the event one of the sub stations is damaged about 6,000 customers with 5,250 kW average total load might remain without electricity.

City Tsalka is not located in a potential flooding zone, but the Khramhesi Substation – 2 (110/10 kV), providing electricity for 120 customers (60 kW average total load) residing in the Tsalka municipality, is included in a flood zone; which may result in the suspension of electricity supply for these customers.

KAKHETI

City Lagodekhi is located partially in a potential flood zone. In case of disaster, up to 5,000 customers with total average load of 800 kW might not receive electricity.

Part of Sagarejo City is located in a potential flood area, due to which an electricity cut might affect about 2,000 customers with total average load of 320 kW.

During the last decades, natural hazards and their effects have become one of the most significant socio-economic and environmental problems for the majority of countries of the world. When they occur, the protection of populations and the safe operation of infrastructure have to be managed. In the beginning of the 21st century, difficulties became even more acute for mountainous countries when, against the backdrop of climate change and wide-scale anthropogenic pressure, the negative impacts of natural disasters became irreversible. Georgia is one of the more complex mountainous regions living through the development of natural disasters, in which multi-spectral natural hazards are distinguished by their high recurrence rates and negative consequences for the population and infrastructure, as well as high rates of land resource losses and economic damage. Among the different types of natural disasters that periodically cause significant damage to the country's economy and often cause human casualties, the most important are: landslides, floods, mudflows and associated flashfloods, avalanches, and coastal erosion. Almost all morphological-climatic zones, starting with the sea coastline up to the high altitude mountain alpine-nival zone, have experienced damage to different extents. Over 50,000 landslides of different sizes and over 3,000 mudflow-transforming watercourses (rivers, canyons) have been identified in the country, as well as hundreds of kilometers of eroded riverbanks and coastline. Up to 70% of the territory and around 63% of the population are permanently at risk of natural disasters of different intensities. Since the 1970s, over 60,000 families have been assigned a status of eco-migrants and moved from their living places to safer areas. Over 400,000 residential houses and infrastructure units have been registered as damaged to different extents and as being situated in hazardous areas. A total of 1.5 million ha of agricultural lands were damaged and are no longer available for agricultural use. Geological disasters caused over 1,000 casualties, including 140 casualties in 1995-2015. Total damage was estimated at over $15 billion.

Within the framework of this study, the sensitivity of different municipalities of Georgia towards different natural hazards was investigated, as well as the increased risks of these hazards with the consequences of climate change for the two projected periods: Future 1 (2021–2050) and Future 2 (2071-2100). An attempt has been made to assess the impact of certain natural hazards on infrastructure using a standardized methodology and the available information for different municipalities.

3.5.1 Sensitivity of municipalities to natural hazards[152]

RELEVANCE

The anthropogenic impact on the geological environment causes particular vulnerability in rural settlements as well as in the highly urbanized areas of Georgia. The main reason lies in the overestimation of stability and potential longevity of the geological environment of the given areas on the one hand and insufficiency of agricultural lands on the other.

Agricultural lands are scarce in municipalities where population density is over 99 to 240/km^2 on average (Chiatura, Kharagauli, Ozurgeti, Zugdidi, Khelvachauri, Kobuleti, etc.), accounting for about 0.14 ha per person, which is insufficient to meet needs. House construction and the assimilation of scarce agricultural lands are carried out in these most sensitive and unacceptable areas of the geological environment. Each such construction and assimilation (treatment) of such lands provokes the rapid disturbance of the fragile equilibrium and homeostasis of the environment. In addition, unsystematic (unplanned and unmanaged) forest cuts in mountainous settlements, including the use of "log-skidding ravines" due to the absence of roads, cause the development and triggering of erosive and landslide processes. The important problem of desertification and degradation of agricultural lands throughout the territory of Georgia is related to the inappropriate and even reckless interventions of human activities in the geological environment, rather than the direct impact of climate change.

[152] Em. Tsereteli, G. Gaprindashvili, Ts. Donadze, T. Nanobashvili, and O. Kurtsikidze, "Some Aspects of the Methodology of Disaster Geological Process Hazard and Risk Mapping on The Example of Georgia", Proceedings of International Conference "Applied Ecology: Problems, Innovations" (ICAE-2015) May 7-10, 2015, Tbilisi, Batumi. pp. 30-36.

It has been shown that over 50% of the registered landslides in Georgian villages took place due to improperly conducted human activities, and 80-90% of erosive processes observed on arable lands are also related to inappropriate human activities. Taking into account all of the above, it is necessary to define relevant geological tolerability criteria prior to beginning development actions in a given mountainous area. This means that prior assessment of possible negative geological consequences is to be conducted. In particular, the type, location and scale of possible geological phenomena, as well as the type of potential threats to the population and their infrastructure should be assessed in such a way as to allow to take into consideration all relevant and necessary measures in case of emergency.

EXISTING STUDIES

Since the second half of the 20th century, natural geological phenomena have become a significant threat to the population of Georgia. Along with considerable economic damage, these natural hazards have also caused human casualties. Tens of thousands of families have had to leave their historical homes and move to other regions. In this regard, in the 1970s, the Government of Georgia passed the Special Decision on Measures for Protection of Population and Lands against Landslides, Mudflows, Erosion and other Geological Processes. The State Department of Geology (SakGeologia) was commissioned to conduct a special large-scale (1:10,000–1:25,000) engineering-geological reclamation research project at the request of the Ministry of Agriculture in agricultural areas that had been damaged by natural geological processes and/or were in high-risk areas in order to develop relevant preventive technologies for reducing these adverse phenomena.

For these purposes, the above-mentioned research was carried out in 35 administrative districts of Georgia that covered over 45 % of the territory of the country. Those districts were: Khashuri, Kareli, Kaspi, Gori, Tskhinvali, Akhalgori, Kazbegi, Dusheti, Aspindza, Akhaltsikhe, Adigeni, Borjomi, Akhalkalaki, Ninotsminda, Telavi, Akhmeta, Oni, Amrolauri, Tsageri, Vani, Bagdadi, Zestaphoni, Kharagauli, Terjola, Chakhatauri, Chkhorotsku, Sokhumi, Gudauta, Gali, Gulripshi, Kobuleti, Khelvachauri, Keda, Shuakhevi, and Khulo. Total area of the studied territory comprised 787,100 ha of which 13.1% was still a zone of high-risk to natural hazards, while 14.2%[153] was seriously damaged by geological processes and needed complex measures for recovery. The level of damage for each municipality as well as for population and for infrastructure was defined separately. All landslide areas and mudflow-prone watercourses were registered in the cadaster and preventive measures were developed. Specialized maps at the relevant scale were created for each administrative district (municipality) including engineering-geological maps that show:

1. Damage levels of the territory caused by elemental processes and their consistency with development factors; and
2. Reclamation zoning, where the studied areas were ranged by damage level, hazard risk intensity, level of development of the target area and level of their applicability before and after carrying out of preventive measures.

[153] Em. Tsereteli, R. Gobejishvili, and M. Gaprindashvili (2010), Risk of natural hazardous phenomena in mountainous Georgia and the relevant mitigation measures. Monography "Problems in socio-economic developments in Georgian mountainous regions and ways to solve them". National Academy of Sciences of Georgia, pp. 63-64.

SENSITIVITY INDICATORS

The above-mentioned specialized engineering-geological reclamation maps for each separate administrative district (municipality) have been developed based on sensitivity analysis and generalization of all elements of qualitative characteristics of the given geological environment and process-provoking factors where the geological environmental conditions, terrain class, level of damage caused by elemental processes, threat risk and level of development of the area is ranked according to the taxonomic order: district, sub-district and site (neighborhood). Each area, in turn, is divided into three groups according to its sustainability level:

1. Stable: there are no elemental geological processes identified; damage caused by erosion is insignificant;
2. Limit stable: a stabilized landslide is identified; gully erosion processes are rare; soil erosion is of medium intensity; However, in the case of development of the area with a higher load than at present, there is a real danger of activation of these processes if preventive measures are not conducted;
3. Unstable: area significantly damaged by hazardous geological processes; high level of soil erosion; high risk of activation of landslide, erosive and mudflow processes.

Lands suitable for agricultural purposes are divided into four groups:

1. Suitable: hazardous geological processes are absent; no erosion taking place;
2. Limit suitable: soil and the soil forming parent material extends intermittently in places; the soil is thoroughly washed out in a number of areas and bare parent material substrate is observable, though there are not any other types of hazardous geological processes; there is a threat of activation of hazardous geological processes in case of increased land exploitation;
3. Suitable after modification: Preventive measures need to be carried out against further hazardous geological processes in an area that has already been damaged; and
4. Hazard-prone area: Exploitation is not allowed in this area if preemptive preventive measures are not conducted.

For the purposes of effective use of agricultural lands and protection of lands against hazardous processes, the maps show the location and type of work that should be conducted, be it organizational, agro-technical, bioengineering, or any other type of preventive work.

At the same time, in accordance with the ordinance of the Government of Georgia, the Geological Service developed a summarized edition "Master Plan of Georgia on Anti-erosion Measures for 1981-2000"[154], based on research data from studies conducted since the 1970s. Research data were represented on different scales (1:50,000; 1:200,000) and were obtained through different specialized engineering-geological studies conducted for agricultural purposes. The plan addresses all types of geological hazardous processes that took place in Georgia, and all natural and anthropogenic factors that cause them. Zones are defined according to risk of each separate type of geological process and according to land use. The plan contains all types of measures preventing erosion together with relevant technologies and economic calculations. It was the first scientific work that served as a basis for a new direction in agriculture and agro-engineering-geological reclamation.

[154] General scheme of erosion preventive measures of Georgian SSR for period of 1981-2000 (monography), Tbilisi, "Sabchota Sakartvelo, 1988, p. 726"

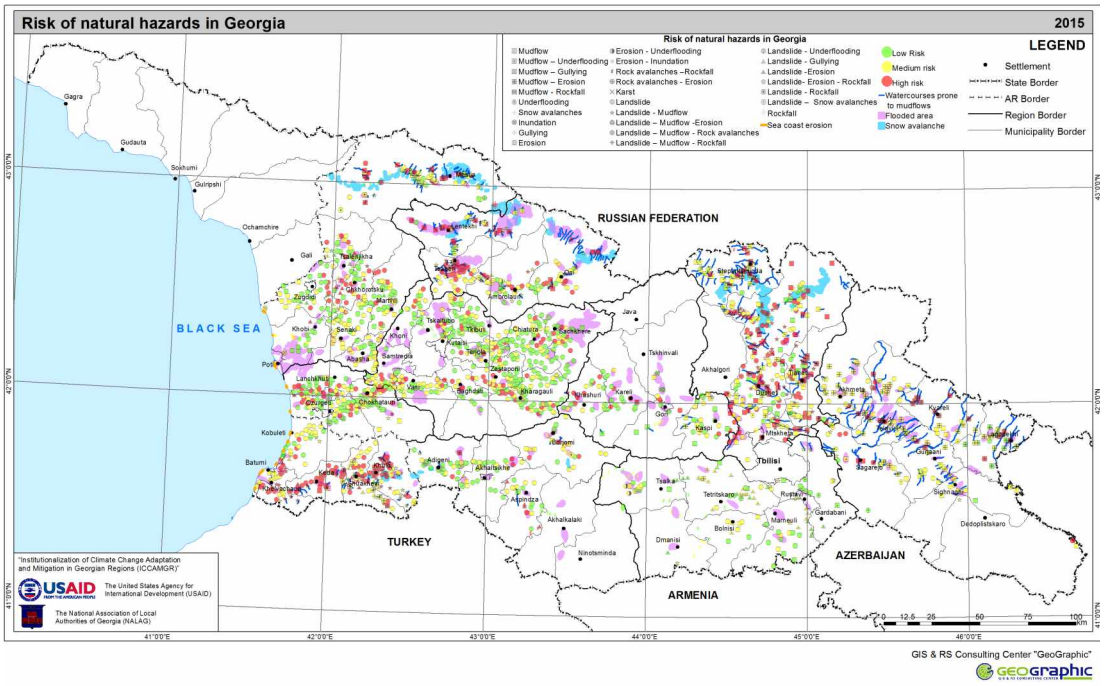

Fig. 18. Risk of natural hazards in Georgia

Major natural hazards, such as floods[155], erosion, landslides, flash floods and avalanches (see Fig. 18) directly depend on the deviation of values of atmospheric precipitation from multiannual averages within the intra-annual intervals, in the combined syncretic space of the relevant process-defining geological environment. The occurrence and/or extreme activation regime of these processes at the background level is directly correlated with the quantitative indices showing a positive balance of atmospheric precipitation, while the attenuation or temporary stabilization of the processes is correlated with the deficit from the multiannual average. According to multiannual observation at the country scale, limiting parameters for the landslide and mudflow processes were defined, above which abrupt transitions of dynamic regime take place.

Proceeding from the above and taking into account the aim of the study to assess sensitivity of the municipalities to different natural hazards and for the purpose of visualization of the hazards in question, the following indicators and indexes were used:

Sensitivity of municipalities to landslides:
The existing settlements in the municipality located within landslide-prone areas, are graded into three categories: high, medium and low risk. Each category has its own coefficient: high – 3; medium – 2; low – 1. The scores defined for each category summarize in accordance with the existing landslide-gravitational phenomenon. The types of landslide-related processes are summarized and a total sum is given in the category.

Sensitivity of municipalities to mudflows:
Ratio of total length of mudflow-transforming watercourses to the total length of the river network of the whole basin.

[155] Identification of flood and freshet zones for a multi-annual database was based for 80% of the area on different historical sources: newspaper "Komunisti", "Iveria", "Archive of the Department of Hydrometeorology", etc. Taking into account that the flooded areas have been identified from the text of newspapers, the exact locations and geographical coordinates were unknown. The flooded areas given on maps, consequently, may be inexact.

Sensitivity of municipalities to coastal erosion:
Ratio of the total length of the eroded seacoast to the total length of the coastal line of the municipality.

Sensitivity of municipalities to avalanches: ratio of the territory within the area of potential threat of avalanches in the municipality to total area of the municipality. Data on avalanches was calculated in accordance with the maximum possibility of extension of the process.

Sensitivity of municipalities to floods: ratio of the flooded areas to the total area of the municipality. It should be noted that the flooded area was calculated based on 100 years of data on recurrences.

All of the above provides support for the statement that the maps composed on the basis of indicators are valid regarding climate sensitivity (baseline) and climate impact (forecast).

Maps 51-56 were produced based on these indicators and indices.

3.5.2 Sensitivity of infrastructure to natural hazards

Human engineering and economic activities, alongside other determining factors in a baseline regime, are known as decisive factors in generating or reactivating natural hazards. Their potential impact can be expressed through measuring the tolerance of the geological environment to these different types of infrastructure loads.

The tolerance of the geological environment to engineering and economic activities can be divided into two general categories:

1. Natural processes influenced by anthropogenic processes. These occur first without intervention of human activity, though later their dynamic regime and the threat risk is fully conditioned by anthropogenic factors.
2. Anthropogenic processes fully conditioned by human activities. Negative natural hazards would never occur in the given geological environment if improper human activities, such as the settlement and unsystematic exploitation of lands without any prior assessment, construction and re-construction of new line structures, irregular forest cuts, quarrying of mining resources, etc., had not triggered the destruction of the established homeostatic balance.

Other than in higher mountain areas in Georgia, the generation and activation of hazardous processes are directly connected to the impact of anthropogenic factors. Anthropogenic pressure is important, especially relating to mining operations in quarries, the number of which in Georgia exceeds 5,000.

Few geo-ecological areas have been as effected as the Chiatura Manganeese mining area, which has been transformed by mining projects. For the last 125 years of exploitation, the area of 150 km^2 endured anthropogenic alteration of the relief. Agricultural lands were thoroughly destroyed, over 2,000 houses were razed, and up to twenty villages were abandoned. Taking into account the above, it is necessary to provide a complete study on load tolerance of the geological environment in the given territory to assess it properly prior to exploitation. Special attention should be given to conditions that spontaneously interact with climate change as the synthesizer to the conversion of its integrated features[156].

[156] Z. Tatashidze, and Em. Tsereteli, Anthropogenic relief, Geography of Georgia (Part 1), "Mecniereba", pp. 66-68, Tbilisi, 2000.

RELEVANCE

Geo-ecological complications of the geological environment on infrastructure are especially important for large-scale linear structures such as highways, railroads, and oil and gas pipelines. Member of the Academy of Sciences, E. Sergeev noted at the International Geological Congress (1989) that during construction of 1 km of a main pipeline, around 4 ha of soil and plant cover are damaged, and during constructing of 1 km of highway around 2 ha are damaged. Taking into account that most such infrastructure construction in Georgia takes place in high mountainous relief in complex geological environments and that their total length is over 30,000 km, the scale of changes in the geological environment, as well as the types of potential natural hazards, become evident. According to incomplete data gathered by the geological service in the Natural Hazards Bulletin (2000), 562 km of highways in total were under risk of development of hazardous geological processes. The most threatened areas were identified in Adjara, Svaneti and Mtskheta-Mtianeti regions, while the less threatened regions were Kvemo Kartli, Shida Kartli and Kakheti, except Tsiv-Gombori ridge and Tusheti. In general, 30-35% of highways in Georgia are located in the areas under high risk of natural hazards. It should be noted also, that Tbilisi, Sokhumi and Tskhinvali by-pass highways had problems a very short time after being put into service because of the development of landslides and it became necessary to find new alternative solutions.

A total of 2,688 landslide-prone areas, 990 mudflow-transforming watercourses, 974 km of total length of eroded riverbanks and over 400 locations that regularly develop avalanches are registered as recognized areas at high risk of hazardous geological processes. In particular, these areas are located along 3,000 km of total length of highways of primary importance, as well as along international oil and gas pipelines and railways (Dzirula, Chiatura and Marabda-Kartsakhi areas). Correspondingly, it is necessary to conduct permanent monitoring of such significant constructions by relevant organizations[157].

The status of marine ports located on the southern Georgian coast, such as at Poti, Kulevi and Batumi varies, taking into account different geo-morphological and geological conditions, litho-dynamics and global climate change conditions. Deposits of solid sediments in the underwater canyon of River Rioni ceased 70 years ago, when the estuary of the Rioni moved north by 4 km, and the large volumes of inert material started accumulating in the Poti port, permanently creating problems for the port infrastructure. A similar situation has been created in the freight port. Due to the construction of the port infrastructure, the Khobistskali River stopped delivering solid sediment to the south. On one hand, this caused intensive erosion of the coastal zone, and on the other hand, accumulation of solid sediment in the port. It should be noted that the Batumi port does not have similar problems.

Eustatic changeability of sea level also influences stability of the coast and ports. On the one hand, this is directly connected to global climate change, and on the other hand, to differential tectonic movements. It has been proven that the coastal land adjacent to the Rioni River estuary is sinking by 6.5 mm/year, while the coastal area of Supsa-Kobuleti-Tsikhisdziri segment goes up by 1-2 mm/year. Kakhaberi lowland, which covers Batumi port, is sinking by 0.8 mm/year.

EXISTING STUDIES

Taking into account that most linear infrastructure pass through mountainous relief amidst a sensitive geological environment, landslide-gravitational, mudflow processes and avalanches significantly complicate their operation. Climatic and meteorological conditions as well as the critical tension level of slopes caused by engineering and economic activities periodically activate the above-mentioned processes. At the same time, erosion and floods can be frequently observed along the riverbanks of the Kura, and the Rioni and Tskhenistskali rivers in the Kolkheti lowland, which pass in close vicinity to highways and railways, and along oil and gas pipelines. For instance, during the floods in 1977, 1982, 1987, 1999, 2004, 2009 and 2010, over 100 km of highways and over 16 km of the railway were washed out. In this regard, the Roads Department in the 1970s and 1980s ordered a special survey from specialists of geological services.

[157] Em. Tsereteli, R. Gobejishvili, N. Bolashvili, G. Gaprindashvili and T. Nanobashvili, "State of natural exo-dynamic natural disasters and threat risk from anthropogenic pressure in Georgia: Management optimization measures." V. Bagrationi Institute of Geography, Collected papers #4 (83), Tbilisi, 2012, pp. 50-63. Information bulletin "About ground hydrosphere state and study and prognoses on the hazardous geological processes", Tbilisi, 2000.

The survey was conducted on first class highways, such as Mtskheta-Stepantsminda, Tsiteli Khidi-Sokhumi-Gagra, Zugdidi-Mestia, Kutaisi-Tsageri-Lentekhi, Kutaisi-Ambrolauri-Shovi, and some other roads. Total length of the surveyed roads was about 3,000 km. The geo-dynamic conditions were assessed and the relevant geological reports were developed with special maps that have been passed to the Roads Department. In 2010-2011, the Railway Department ordered a survey from the National Environmental Agency on the assessment of geological threats for the Tbilisi-Samtredia-Batumi railway. The relevant engineering-geological report of the survey was passed to the Railway Department for further development of rehabilitation projects. In 2003-2012, special geological surveys on geo-dynamic conditions and environmental impact assessment were conducted for the highways connecting the following cities: Tbilisi-Senaki-Leselidze-Svaneti-Ruisi, Zestaponi-Samtredia, Samtredia-Grigoleti, Abasha-Martvili, Zugdidi-Mestia, and Tbilisi-Gombori-Telavi. The survey served as a basis for further development of relevant rehabilitation projects. Besides the above-listed surveys, since 2004, the National Environmental Agency has been conducting permanent regional geological monitoring surveys throughout the overall territory of Georgia. Geological complications connected to highways and other types of line constructions revealed in the mentioned surveys are published in the annual bulletin of the National Environmental Agency, which regularly submits this information to the Ministry of Regional Development and Infrastructure[158].

Note: A total length of 562 km of highways damaged by periodically activated landslides and riverbank erosion was described in the information bulletins of 1981-2000.

SENSITIVITY INDICATORS

Determination of sensitivity indicators for highways, railways, oil and gas pipelines, and marine ports in Georgia depends on multi-component natural morphological and climatic elements, as well as on anthropogenic factors. Taking into consideration that the line and port engineering constructions represent the most complex engineering facilities, the reliability of their sensitivity parameters and the duration of their stability should be defined on the basis of surveys with continuous monitoring and supervision, including assessment of changes over time and their compensation.

Proceeding from the above and the goals of the survey, the following indicators and indexes were used to assess different natural hazards and to visualize these processes[159]:

Sensitivity of highways to floods is calculated using the following methodology:
Ratio of the area of asphalt roads affected by floods to the total area of asphalt roads within the municipality territory.

Sensitivity of highways to avalanches is calculated using the following methodology:
Ratio of the area of asphalt roads affected by avalanches to the total area of asphalt roads within the municipality territory.

Maps 57 and 58 were produced based on these indicators and indices.

[158] Annual information bulletin on geological threats for 2004-2015, edited by the National Environmental Agency.
[159] Except avalanches and flooded areas, a precise calculation of areas impacted by natural hazards is not feasible. Visualization of these processes concerning the highway network is impossible. It should be noted also that data on spatial distribution of other infrastructure (mining enterprises, reclamation network, industrial units, and railway) were not available within the frame of the current study. To assess vulnerability of infrastructure towards climate change and visualize their spatial distribution, an additional, larger scale study must be conducted.

Among multi-spectral natural processes which take place in Georgia and which are hazardous to populations, infrastructure, the economy and the ecological balance of the environment, the dominant processes are landslides, mudflows and the associated flash floods, floods, avalanches and riverbank erosion. These natural hazards can turn into a large-scale catastrophe and this is connected to receptor features of extremely special and sensitive geological environment.

RELEVANCE

As previously mentioned, up to 70% of the territory of Georgia is at risk of different types and scales of natural hazards. Taking into account that the geological environment of the country is highly polymorphous and the climatic and meteorological factors can cause different consequences for the environment, there is a major difference in risk levels not only between different regions, but even within one municipality of the same region. This is clearly reflected in the tables provided below: Risk of natural hazards in the municipalities of Georgia (landslide, mudflow, flood, avalanche, and coastal erosion (Table 4), and, Characteristics of the municipalities under risk of natural hazards in different periods (Table 5). Consequently, it is necessary to conduct regular monitoring on regional and municipal levels taking into account the level and intensity of the damage caused by natural hazards and the intervals between monitoring activities should not exceed 2-3 years. Based on the statistical data obtained and the relevant analysis of the information on process-defining and provoking factors, the relevant adaptation, technological and management measures should be developed. The results should be submitted in a timely manner to the Ministry of Environment and Natural Resources Protection and the Ministry of Regional Development and Infrastructure, as well as to the relevant regional and municipal authorities.

EXISTING STUDIES

Natural hazards have been actively developing in Georgia since the second half of the 20th century and have affected large areas of agricultural lands and human settlements. The authorities of the country issued a number of legal documents on minimization and mitigation of the potential threats of geological hazards and the optimization of relevant management measures. First of all, the State Geological Service was tasked in the early 1960s to study the situation related to geological hazards in Georgia and to develop appropriate management measures. Since that time, over several decades, the geological services carried out mapping of hazardous geological processes throughout the country, provided their identification, defined spatial limits, reasons for and regularity of the generation or activation of the processes, provided risk assessment to population and infrastructure units, developed the relevant cadasters and composed specialized engineering-geological maps of different content and on different scales.

For the time being, the following information is available:

- Specialized engineering-geological research conducted at the country level at the scales 1:500,000–1:200,000 and the specialized engineering-geological and geo-dynamic maps of the same scales; with relevant geological reports developed;

- Large-scale (1:10,000–1:25,000) specialized engineering-geological reclamation survey conducted for separate administrative districts (37 municipalities), that comprise 45% of the total area of the country; the relevant specialized maps on risks and threats to population, damage levels to agricultural lands are developed and risks of threat categorized;
- In accordance with the Order of the Government, a monographic work 'Master Plan on Erosion Prevention in the Territory of Georgia for 1981-2000' was developed and published; the plan provides descriptions of all types of geological processes taking place in Georgia as well as the relevant measures and technologies to be taken together with the relevant economic justifications;
- Engineering-geological map (1:200,000) of hazardous geological conditions for the whole territory of Georgia developed and published; maps describing threat risk and potential damage by landslides and mudflows for the whole territory of Georgia (by districts) developed and published (1:500,000);
- Long-term prognosis for 1981-2000 on landslides, mudflows and coastal erosion in Georgia developed; the prognoses have been verified with high reliability coefficient during the geological monitoring conducted.
- The relevant Institutes of the National Academy of Sciences of Georgia, such as Institutes of Geography, Geophysics, Hydro-technics and Reclamation, Engineering-Geology and Hydro-geology, also conduct significant studies regarding threat management of geological processes.

Consequently, there is a significant volume of information on the management of natural hazards available for Georgia. The analysis and summary of this information could make an invaluable contribution to carrying out effective geological monitoring research and to developing long-term prognoses.

SENSITIVITY INDICATORS

The scale of development and re-activation of hazardous processes and spatial and time activation trends depend first on special characteristics of the geological environment and sensitivity to processes conditioning, permanently existing factors that determine the basis of the geological processes. Second, the trends depend on hardly predictable stochastic process-provoking factors, such as, for instance, intra-annual alterations of meteorological elements of multi-annual norms, or frequency of earthquakes of different intensity as well as tolerance of the geological environment to anthropogenic pressure. It is obvious that the above-mentioned process-provoking stochastic factors could vary in different regions of the country and often in different municipalities of the same region. To provide answers to concrete questions, studies and analyses should be conducted and summarized, in particular:

1. Comprehensive studies on integrated elements of the geological environment (general conditions and features, tectonic tension, energy potential of the relief, type of groundwater and lithologic composition of rocks); grouping of the mentioned factors according to their sensitivity to geological processes and composition of engineering-geological maps according to development conditions of the hazardous geological processes at national, regional and municipal levels;
2. Geological monitoring research to define the dependence of the development and regularity of the hazardous geological processes, in particular on the conditioning and triggering of stochastic factors (especially climatic-meteorological). This research should be based on the maps defined above.

3. Since the main provoking factor launching the majority of exo-geological processes is the alteration of intra-annual meteorological elements (atmospheric precipitations, humidity, etc.) from multi-annual mean value, it is necessary to treat historical statistical data and the increased intra-annual alterations obtained from meteorological stations for each region (and if available, for each separate municipality). It is also necessary to analyze this information and to detect existing correlations with the dynamic regime data of the hazardous geological processes; the obtained information should be inserted into an integrated database.

Climatic-meteorological factors provoking natural hazardous processes, such as landslides, mudflows, floods, riverbank erosion, and avalanches, are dominant factors in the dynamic processes of generating or reactivating these kinds of phenomena. At the same time, the climate is the combination of meteorological conditions in a given place, formed within a geographical environment in conditions of a general regime of atmospheric circulation and within which certain kinds of natural geological processes develop. Climate should be considered as a static function while assessing the background state. However, the intra-annual positive or deficit deviation values of atmospheric precipitation from the multi-annual mean are in direct relation with remediation receptors (i.e. integrated or combined activity of the sensitive receptors of geological environment) of the relevant process-conditioning syncretic geological environment. Hence, the intra-annual alteration values of process-provoking precipitation cannot be one-dimensional for geological environments of all regions on the planet. Correlation of statistical data on dynamic regimes of generation-reactivation of natural geological processes and multi-annual statistical data on process-provoking atmospheric precipitations was defined for Georgia. Correspondingly, the limiting values for landslides and mudflows were adjusted, and under these limits, in conditions of a multi-annual deficit of precipitation, the dynamic regime of the processes enters the temporary stabilization phase – the process starts attenuating, or even temporarily stops. While in the case of a positive balance, the processes are activated from the background level to extreme expression. The dynamic sensitivity criteria of the landslide and mudflow processes are defined based on the above-mentioned information. For instance, consider the background data for landslides, when their dynamics regime is within the multi-annual mean of atmospheric precipitations. If precipitation values are below the limiting multiannual mean, a stable state of landslides for the given period will be observed. When the sum of annual precipitation exceeds the background multi-annual mean value of precipitation, activation of the dynamics regime of the landslides will be observed, starting from a stressed state towards an extreme state. Based on these parameters, we can find a dynamic regime coefficient for landslide and mudflow processes and develop a long-term prognosis for changing their dynamic regime[160].

[160] E. Tsereteli, M. Gaprindashvili, G. Gaprindashvili, T. Chelidze, O. Varazanashvili, and N. Tsereteli, "Problems of Natural-Antropogenic disasters in Georgia", Journal of the Georgian Geophysical Society, Issue A. Physics of Solid Earth, volume 15A, pp. 14-23, 2012; N. Bolashvili, Em. Tsereteli, O. Qutsnashvili, G. Gaprindashvili, and O. Kurtsikidze, "Climate as an Integral

Table 4. Risk of natural hazards in the municipalities of Georgia (landslides, mudflows, floods and riverbank erosion, avalanches, and coastal erosion

N	Municipality	Region	Landslides	Mudflows	Floods, riverbank erosion	Avalanche	Coastal erosion
1	Shuakhevi	Adjara	0.50	0.25	0.15	0.10	0.00
2	Keda	Adjara	0.60	0.30	0.10	0.00	0.00
3	Khulo	Adjara	0.45	0.20	0.15	0.20	0.00
4	City of Batumi	Adjara	0.00	0.00	0.60	0.00	0.40
5	Khelvachauri	Adjara	0.47	0.18	0.15	0.00	0.20
6	Kobuleti	Adjara	0.65	0.00	0.15	0.00	0.20
7	Ozurgeti	Guria	0.45	0.05	0.40	0.00	0.10
8	Chokhatauri	Guria	0.65	0.12	0.18	0.05	0.00
9	City of Ozurgeti	Guria	0.00	0.00	1.00	0.00	0.00
10	Lanchkhuti	Guria	0.35	0.05	0.45	0.00	0.15
11	Bagdadi	Imereti	0.60	0.05	0.28	0.07	0.00
12	Vani	Imereti	0.70	0.08	0.16	0.06	0.00
13	Kharagauli	Imereti	0.70	0.15	0.09	0.06	0.00
14	Zestafoni	Imereti	0.60	0.10	0.30	0.00	0.00
15	Samtredia	Imereti	0.60	0.00	0.40	0.00	0.00
16	Sachkhere	Imereti	0.65	0.06	0.29	0.00	0.00
17	Chiatura	Imereti	0.75	0.08	0.12	0.05	0.00
18	Terjola	Imereti	0.70	0.00	0.30	0.00	0.00
19	Tkibuli	Imereti	0.54	0.18	0.18	0.10	0.00
20	Khoni	Imereti	0.25	0.07	0.68	0.00	0.00
21	City of Kutaisi	Imereti	0.65	0.00	0.35	0.00	0.00
22	Tskaltubo	Imereti	0.30	0.10	0.60	0.00	0.00
23	Dedoplistskaro	Kakheti	0.08	0.10	0.82	0.00	0.00
24	Signagi	Kakheti	0.63	0.08	0.29	0.00	0.00
25	Akhmeta	Kakheti	0.45	0.30	0.15	0.10	0.00
26	Sagarejo	Kakheti	0.32	0.50	0.18	0.00	0.00
27	Gurjaani	Kakheti	0.35	0.60	0.05	0.00	0.00
28	Lagodekhi	Kakheti	0.25	0.30	0.45	0.00	0.00
29	Kvareli	Kakheti	0.15	0.65	0.20	0.00	0.00
30	Telavi	Kakheti	0.55	0.30	0.15	0.00	0.00
31	City of Telavi	Kakheti	0.00	0.90	0.10	0.00	0.00
32	Dusheti	Mtskheta-Mtianeti	0.30	0.50	0.10	0.10	0.00
33	Tianeti	Mtskheta-Mtianeti	0.47	0.35	0.18	0.00	0.00
34	Kazbegi	Mtskheta-Mtianeti	0.18	0.49	0.08	0.25	0.00
35	Mtskheta	Mtskheta-Mtianeti	0.81	0.12	0.07	0.00	0.00
36	City of Mtskheta	Mtskheta-Mtianeti	0.58	0.12	0.30	0.00	0.00

Synthesizer in Development-Reactivation Processes of Landslide and Diagnostic Criterion of its Evaluation", Engineering Geology for Society and Territory, Vol. 2, Springer International Publishing Switzerland, 2014, pp. 1781-1787.

N	Municipality	Region	Landslides	Mudflows	Floods, riverbank erosion	Avalanche	Coastal erosion
37	Dmanisi	Kvemo Kartli	0.45	0.25	0.20	0.10	0.00
38	Marneuli	Kvemo Kartli	0.30	0.40	0.30	0.00	0.00
39	Bolnisi	Kvemo Kartli	0.60	0.15	0.25	0.00	0.00
40	Tetritskaro	Kvemo Kartli	0.55	0.18	0.27	0.00	0.00
41	Tsalka	Kvemo Kartli	0.60	0.00	0.40	0.00	0.00
42	City of Rustavi	Kvemo Kartli	0.10	0.15	0.75	0.00	0.00
43	Gardabani	Kvemo Kartli	0.15	0.20	0.65	0.00	0.00
44	Ambrolauri	Racha-Lechkhumi-Kvemo Svaneti	0.60	0.15	0.25	0.00	0.00
45	Oni	Racha-Lechkhumi-Kvemo Svaneti	0.52	0.18	0.20	0.10	0.00
46	Tsageri	Racha-Lechkhumi-Kvemo Svaneti	0.60	0.15	0.17	0.08	0.00
47	Lentexi	Racha-Lechkhumi-Kvemo Svaneti	0.29	0.29	0.12	0.30	0.00
48	City of Ambrolauri	Racha-Lechkhumi-Kvemo Svaneti	0.80	0.00	0.20	0.00	0.00
49	Ninotsminda	Samtskhe-Javakheti	0.50	0.00	0.40	0.10	0.00
50	Akhalkalaki	Samtskhe-Javakheti	0.55	0.10	0.35	0.00	0.00
51	Aspindza	Samtskhe-Javakheti	0.60	0.15	0.15	0.10	0.00
52	Akhaltsikhe	Samtskhe-Javakheti	0.78	0.12	0.10	0.00	0.00
53	Adigeni	Samtskhe-Javakheti	0.63	0.15	0.12	0.10	0.00
54	Borjomi	Samtskhe-Javakheti	0.55	0.18	0.15	0.12	0.00
55	City of Akhaltsikhe	Samtskhe-Javakheti	0.60	0.10	0.30	0.00	0.00
56	Abasha	Samegrelo-Zemo Svaneti	0.25	0.00	0.75	0.00	0.00
57	Khobi	Samegrelo-Zemo Svaneti	0.25	0.00	0.70	0.00	0.05
58	Senaki	Samegrelo-Zemo Svaneti	0.75	0.10	0.15	0.00	0.00
59	Martvili	Samegrelo-Zemo Svaneti	0.83	0.05	0.12	0.00	0.00
60	Zugdidi	Samegrelo-Zemo Svaneti	0.55	0.00	0.25	0.00	0.20
61	Chkhorotsku	Samegrelo-Zemo Svaneti	0.70	0.15	0.15	0.00	0.00
62	Tsalenjikha	Samegrelo-Zemo Svaneti	0.57	0.18	0.25	0.00	0.00
63	Mestia	Samegrelo-Zemo Svaneti	0.30	0.40	0.12	0.18	0.00
64	City of Zugdidi	Samegrelo-Zemo Svaneti	0.20	0.00	0.80	0.00	0.00
65	City of Poti	Samegrelo-zemo Svaneti	0.00	0.00	0.40	0.00	0.60
66	Kaspi	Samegrelo-zemo Svaneti	0.55	0.25	0.20	0.00	0.00
67	Gori	Shida Kartli	0.48	0.12	0.40	0.00	0.00
68	Kareli	Shida Kartli	0.45	0.25	0.30	0.00	0.00
69	Kashuri	Shida Kartli	0.40	0.30	0.25	0.05	0.00
70	City of Gori	Shida Kartli	0.20	0.00	0.80	0.00	0.00

Table 5. Number of settlements affected by natural hazards, by municipality (2014)

N	Municipality	Region	Settlements under threat	Total number of settlements
1	Shuakhevi	Adjara	64	69
2	Keda	Adjara	63	64
3	Khulo	Adjara	78	79
4	City of Batumi	Adjara	0	1
5	Khelvachauri	Adjara	58	78
6	Kobuleti	Adjara	32	51
7	Ozurgeti	Guria	67	74
8	Chokhatauri	Guria	60	62
9	City of Ozurgeti	Guria	0	1
10	Lanchkhuti	Guria	51	56
11	Bagdadi	Imereti	17	23
12	Vani	Imereti	35	43
13	Kharagauli	Imereti	69	78
14	Zestafoni	Imereti	49	59
15	Samtredia	Imereti	16	56
16	Sachkhere	Imereti	39	53
17	Chiatura	Imereti	43	62
18	Terjola	Imereti	36	46
19	Tkibuli	Imereti	33	47
20	Khoni	Imereti	16	40
21	City if Kutaisi	Imereti	0	1
22	Tskaltubo	Imereti	12	50
23	Dedoplistskaro	Kakheti	0	16
24	Signangi	Kakheti	14	21
25	Akhmeta	Kakheti	41	61
26	Sagarejo	Kakheti	21	44
27	Gurjaani	Kakheti	20	31
28	Lagodekhi	Kakheti	24	64
29	Kvareli	Kakheti	13	22
30	Telavi	Kakheti	22	29
31	City of Telavi	Kakheti	0	1
32	Dusheti	Mtskheta-Mtianeti	198	291
33	Tianeti	Mtskheta-Mtianeti	63	83
34	Kazbegi	Mtskheta-Mtianeti	24	46
35	Mtskheta	Mtskheta-Mtianeti	49	71
36	City of Mtskheta	Mtskheta-Mtianeti	0	1
37	Dmanisi	Kvemo Kartli	7	60
38	Marneuli	Kvemo Kartli	21	74

N	Municipality	Region	Settlements under threat	Total number of settlements
39	Bolnisi	Kvemo Kartli	10	48
40	Tetritskaro	Kvemo Kartli	23	84
41	Tsalka	Kvemo Kartli	14	46
42	City of Rustavi	Kvemo Kartli	0	1
43	Gardabani	Kvemo Kartli	11	50
44	Ambrolauri	Racha-Lechkhumi-Kvemo Svaneti	48	69
45	Oni	Racha-Lechkhumi-Kvemo Svaneti	46	65
46	Tsageri	Racha-Lechkhumi-Kvemo Svaneti	50	59
47	Lentexi	Racha-Lechkhumi-Kvemo Svaneti	48	60
48	City of Ambrolauri	Racha-Lechkhumi-Kvemo Svaneti	0	1
49	Ninotsminda	Samtskhe-Javakheti	0	32
50	Akhalkalaki	Samtskhe-Javakheti	0	65
51	Aspindza	Samtskhe-Javakheti	21	24
52	Akhaltsikhe	Samtskhe-Javakheti	32	48
53	Adigeni	Samtskhe-Javakheti	26	57
54	Borjomi	Samtskhe-Javakheti	24	43
55	City of Akhaltsikhe	Samtskhe-Javakheti	0	1
56	Abasha	Samegrelo-Zemo Svaneti	24	41
57	Khobi	Samegrelo-Zemo Svaneti	19	57
58	Senaki	Samegrelo-Zemo Svaneti	25	64
59	Martvili	Samegrelo-Zemo Svaneti	41	75
60	Zugdidi	Samegrelo-Zemo Svaneti	35	58
61	Chkhorotsku	Samegrelo-Zemo Svaneti	21	30
62	Tsalenjikha	Samegrelo-Zemo Svaneti	34	36
63	Mestia	Samegrelo-Zemo Svaneti	84	135
64	City of Zugdidi	Samegrelo-Zemo Svaneti	0	1
65	City of Poti	Samegrelo-Zemo Svaneti	0	1
66	Kaspi	Shida Kartli	12	72
67	Gori	Shida Kartli	12	162
68	Kareli	Shida Kartli	15	83
69	Khshuri	Shida Kartli	20	79
70	City of Gori	Shida Kartli	0	1
	Total		2050	3656

Climate change exerts a direct influence on human health, health care and social security systems. Therefore, decision-makers need to react to the challenges posed and take action after appropriate study and analysis.

The current report describes the impact of climate change on the social sector by each municipality. The report took into account both international and local studies, selected indicators on the basis of which the sensitivity of the sector towards climate change was identified, and assessed the impact of climate change.

On the basis of the obtained results, recommendations were developed both at the national level and in accordance with each municipality. In general, it was revealed that the impact of climate change on social sector is complex, requiring coordinated work in different sectors (health care, social security, disaster risk management, environmental protection) to ensure effective adaptation to climate change challenges.

RELEVANCE

Despite the reforms carried out in recent years, the system of health and social security in Georgia faces a number of challenges. The increase of life expectancy has also created an ageing population: over the last 20 years, the percentage of the population over 60 increased from 15 percent to 19 percent. According to the United Nations Population Fund (UNFPA) forecast, which relies on 2005 data, the percentage of this age group will increase even more up to 2050, when it will most probably reach 26 percent[161]. An ageing population, coupled with a decrease in the percentage of the able-bodied population, creates significant problems for Georgia's economic development as well as its health care and social protection systems.

According to 2009 data from the World Health Organization (WHO), illness, death and disability has inflicted significant damage on Georgia's economy, leading to significant expenditure on health care and reducing the ability of the active population to work – either temporarily or permanently[162]. This problem requires a solution if the country is to enjoy stable economic development.

Health challenges in the different age groups of the population differ: in the able-bodied population (aged between 15 and 60), 69 percent of the diseases are mental, cardiovascular, or related to cancer and traumas. In the population over 60, 79 percent of diseases are cardiovascular, or hearing-, eyesight- and tumor- related illnesses[163].

Total national expenses on health care have grown significantly from year to year, and at present constitute approximately 10 percent of the GDP. A third of the population's non-food expenses is spent on health care. This indicates that the country's potential for economic growth is low. The state program of general insurance, which was introduced in 2013, is considered to be a partial step forward, and has considerably eased the financial situation of the population. However, the efficiency of the program expenses has not yet been assessed, given that it was only introduced relatively recently.

One of the main indexes of the health care system is the state of medical infrastructure and the training of personnel. The medical infrastructure in Georgia is currently undergoing a step-by-step renovation. Despite the level of privatization, the majority of the population still manages (through private or state insurance) to access medical services. In Georgia, the index of health care provision is rather high. However, this does not mean that patients are guaranteed to receive high-quality medical services. In some cases, the poor training of medical staff, as well as their low salaries, results in their low productivity[164].

These challenges should be taken into account when adapting the health care and social security system to potential climate changes. For example, socially deprived and elderly people are particularly sensitive to the impacts of climate change. (Please see the sub-sections on sensitivity indicators of Section 3.6) If not sufficiently addressed at the state level, (through increased targeted social assistance and the growth of pensions among other actions), the vulnerability of this group of the population to climate change will increase further.

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[161] R. Hakkert, G. Kadyrkulova and. E. Jongstra, "Population Situation Analysis: Georgia 2014, Final Report", UNFPA, Tbilisi, 2015, http://eeca.unfpa.org/sites/default/files/pub-pdf/PSA%20_Final%20Print%20version.pdf (accessed March 22, 2016)

[162] The Ministry of Labor, Health and Social Affairs of Georgia, 2011, Georgia, National Health State Strategy 2011-2015, Access to Quality Health care", http://www.opml.co.uk/projects/georgia-health-sector-strategy-2011-2015 (accessed March 22, 2016)

[163] "National Report on the Health of Georgian Population"; Department of Health Protection, Ministry of Labor, Health and Social Affairs, 2009, Georgian version available here: http://www.greenadvocacy.net/photos/3296-National%20Report%202009.pdf (accessed March 22, 2016).

[164] The Ministry of Labor, Health and Social Affairs of Georgia, 2011, op, cit.

The poor conditions of medical personnel mean that locally based populations, where the effects of climate change are strongest, are at risk for not receiving medical attention to manage climate-related illnesses. The pathologies that are exacerbated by climate change conditions include cardiovascular, respiratory illnesses and infectious diseases. In addition, climate change significantly increases the risk of natural disasters, such as extreme rains among others. Regions such as Zemo Svaneti (Mestia municipality) where the risk of natural disasters is quite high should therefore have medical infrastructure and personnel to provide primary medical assistance, such as traumatology and general surgery.

According to the WHO, specific population groups are particularly vulnerable to climate change: old people, the chronically ill, infants, socially vulnerable groups and others[165]. The WHO further indicates that climate change has three particular impacts on health: change of infectious disease patterns, an increase in the frequency of natural disasters and increased heat waves[166]. Thus, climate change has various impacts on human health:

- Natural disasters increase the frequency of traumas, as well as diarrheal diseases. During natural disasters, the water supply and sewage systems may break down, which results in the spread of gastro-intestinal infections;
- Under the conditions of increased atmospheric temperature and humidity growth, insect carriers of different diseases easily multiply, which ultimately creates a danger of vector-borne infections such as malaria; and
- Extremely high temperatures over long periods increase the likelihood of severe cardiovascular and respiratory illnesses[167].

In light of the above, it is very important to study the impact of climate change on human health at the national level, as well as the impact on the health care and social protection system. In particular, it is necessary to answer the following questions:

- What types of diseases will most probably emerge or become more frequent in Georgia as a result of climate change?
- How vulnerable is the country to different climate developments, including natural disasters and other potential risks?
- How ready is the health care sector to cope with climate change?

The issues to be studied include the following: the ability of the current medical infrastructure to cope with existing risks such as assessing the facilities for primary medical assistance in the regions at greatest risk of natural disasters; the level of preventive measures being carried out, such as sharing information about the rules of behavior during natural disasters, including among vulnerable groups; and the level of preparedness of the medical personnel, including the extent to which they have information and experience in the management of climate-related diseases.

As a rule, the study of the impact of climate change on public health involves an assessment of the frequency of climate-related diseases, the demographic and social structure of the country, and the capabilities of the health care system to cope with climate change. In addition, it is very important to know the extent to which climate-related diseases and management are currently widespread.

A reliable study will facilitate the development of preventive and/or risk-reduction mechanisms, including an evidence-based insurance system, which would increase the stability of the social protection sector.

[165] WHO, Fact sheet N266, September, 2005, http://www.who.int/mediacentre/factsheets/fs266/en/ (accessed March 22, 2016).
[166] Ibid.
[167] ibid.

EXISTING STUDIES

Many international and national studies describe the impact of climate change on the social sector, such as on human health and on the health care and social protection systems.

International studies: The most remarkable international study is Social Vulnerability and Climate Change[168] by the US Department of Agriculture, which describes how far the challenges of climate change affect vulnerable groups in society: the poor, the uneducated, children, elderly people and persons with chronic diseases. The document also describes the vulnerability of the populations living in areas at risk of natural disasters and the importance of adaptation.

A second important document is the Climate Change Report[169] of the ESPON, which highlights the vulnerability of urban populations towards high temperatures because of the "urban heat island effect". Heat waves negatively affect population groups over 65, who are inclined to cardiovascular, chronic respiratory diseases, arterial hypertension and coronary disease. These are, in general, poor population groups who cannot adapt to high temperatures by, for example, purchasing air conditioners.

As for national studies, the Second National Communication of Georgia to the UNFCCC[170] assessed the trends of heat waves in several Georgian cities such as Tbilisi, Lentekhi and Dedoplistskaro. The study specifically revealed that the population of Tbilisi is most sensitive towards heat waves, due to the role played by the urban heat island effect.

The effect of heat waves in Georgia was studied more closely during the preparation of the Third National Communication, which identified the problem in the densely populated cities of Tbilisi, Batumi and Kobuleti. The same document assessed the impact of extremely high temperatures on human health[171], and highlighted the danger that climate-related diseases, such as cardiovascular and respiratory diseases, may increase in frequency.

Another study that assessed the past and future impact of heat waves on the population in Tbilisi is described in the "Climate Vulnerability Assessment Report"[172], which concludes that heat waves are expected to become more frequent in Tbilisi, which will negatively influence the health of vulnerable groups in society, such as elderly people, children and people with chronic diseases. The assessment was carried out using the heat index[173] methodology.

These studies underline the importance of the problem at both international and national levels. In particular, studying the socially vulnerable population, including their numbers and density by region, is important for any assessment of the ability of a country's population to adapt to climate change.

SENSITIVITY INDICATORS

As the studies and reports mentioned above demonstrate, any assessment of the vulnerability of the social sector to climate change requires sensitivity indicators towards climate change and its challenges. It is known that certain population groups, such as elderly people, children, population below the poverty line, and persons with chronic diseases, are particularly sensitive to extremely high temperatures. By studying the number and distribution areas of such groups, it is possible to assess the sensitivity of the country, region or even municipality to climate change. Since this study focuses on the relative sensitivity of municipalities and their visualization, unified indicators were selected for all municipalities in order to provide a basis for comparison.

Given the numeric data that currently exists in Georgia, two types of indicators of social sensitivity towards climate change were taken, as follows:

- Socio-demographic: the population over 65 years of age;
- Socio-economic: population below the poverty line.

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168 K. Lynn, , K. MacKendrick; and E. M. Donoghue, "Social Vulnerability and Climate Change: Synthesis of Literature", USDA, 2011.

169 ESPON Climate report, 2011, op. cit.

170 The Second National Communication of Georgia to the UNFCCC, op. cit., p. 145.

171 The Third National Communication of Georgia to the UNFCCC, op. cit., pp. 174-188.

172 The "Climate Vulnerability Assessment" report and study were prepared within the European Union-financed project "Climate Change in the East", http://climateforumeast.org/uploads/other/0/771.pdf (accessed March 20, 2016).

173 The Heat index is calculated by the combination of air temperature and relative humidity and shows the temperature that is actually felt by a person at a given humidity value.

Socio-demographic indicator: The number of people in a municipality over 65 years of age[174] was selected, because of their sensitivity to heat waves[175]. Elderly people have difficulty bearing extreme high temperatures because of a decreasing ability to adapt to changes in the environment. People over 65 also suffer from different chronic pathologies, including cardiovascular diseases such as ischemic strokes and arterial hypertension. This is the primary cause of mortality in Georgia, and makes the elderly even more sensitive to climate change in general, and to prolonged episodes of extremely high temperatures, or "heat waves", in particular. Some studies show that, during heat waves, ischemic strokes are particularly frequent and a number of cardiovascular diseases are aggravated[176].

Therefore, the higher the number of people over 65 in a municipality, in both relative and absolute terms, the more sensitive the municipality is from a social viewpoint. As a result, decision-makers should make greater efforts to assist the population in adapting to climate change.

Socio-economic indicator: the number of people in the municipality below the poverty line. Some reports, such as the ESPON Climate Change Report[177], take the unemployment index as an indicator. In 2014, the unemployment rate in Georgia was officially 12.4 percent while actual unemployment levels may differ from the official index as part of the population is "unofficially" employed. Instead, this report focuses on poverty, and uses the number of those who are receiving targeted social assistance (TSA) as an indicator, which is a more accurately representation[178].

The higher the number of people living below the poverty line in a municipality, the more sensitive it is towards climate change, since people below the poverty line do not have the financial resources to cope with the challenges it presents (see Maps 59 and 63). For example, during heat waves a poor family is unable to use air conditioners for cooling. They also do not have the ability to repair damage caused by a natural disaster etc.

According to the WHO, women are more sensitive towards climate change than men[179], due both to their physiology and to economic and social barriers. For example, many women cannot afford medical services as their income[180] and employment level[181] is lower than their male counterparts. If the majority of elderly people and those below the poverty line are women, the government will need to make greater efforts to ensure adaptation to climate change of this vulnerable group of population at all levels. Because of this, one of the indicators of the sensitivity towards climate change is the number of women in the municipality over 65 and below the poverty line, which allows us to assess the problem from a gender perspective. As demonstrated by Maps 61, 62, 65 and 66, the number of women in both social groups is much higher than the number of men.

As reviewed in the sub-section "Existing Studies", urban populations are particularly vulnerable to extreme high temperatures because of the heat-island effect. On one level, hot air negatively impacts human health and increases the risk of climate-related diseases and mortality. These health conditions include: syncope caused by the heat, such as being unconscious for a short time, edema caused by the heat, such as tumefaction, and increased hemo-concentration, or increased blood viscosity, number of red cells and thrombocytes. In addition, it increases the risk of coronary artery thrombosis, brain ischemia and renal failure. These risks increase even more in socially unprotected groups of the population, and raise the overall cost of health care.

In order to take this into account, the study considers all social indicators for urban settlements. To do so, sensitivity indicators were divided by municipality area, as a result of which the researchers calculated the density index of vulnerable population groups over 65 years old and below the poverty line, which coincided with intensely urbanized territories (See Figures 19 and 20). This process identified municipalities where, due to the emergence of urban heat islands, the population is more sensitive towards extreme temperatures and heat waves.

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174 June 2015 data are taken from the Georgian Ministry of Health, www.moh.gov.ge (accessed March 20, 2016).
175 ESPON Climate report, 2011, op. cit.
176 I. Vachiberidze, "Boomerang principle" Manual of Climate-dependent Disease Management for Medical Care Personnel, Tbilisi, Georgia, 2008.
177 ESPON Climate report, 2011, op. cit.
178 June 2015 data are taken from the Georgian Ministry of Health, www.moh.gov.ge (accessed March 20, 2016).
179 S. Garimella, et al. Gender, climate change and health, WHO, 2005. http://www.who.int/globalchange/publications/reports/final_who_gender.pdf (accessed March 18, 2016).
180 GeoStat, Average monthly nominal salary of employees by economic activity and sex (by 2007-2015 quarters) http://www.geostat.ge/index.php?action=page&p_id=149&lang=eng (accessed March 18, 2016).
181 GeoStat, Unemployment level according to gender (2007-2015): http://www.geostat.ge/index.php?action=page&p_id=146&lang=eng (accessed March 23, 2016).

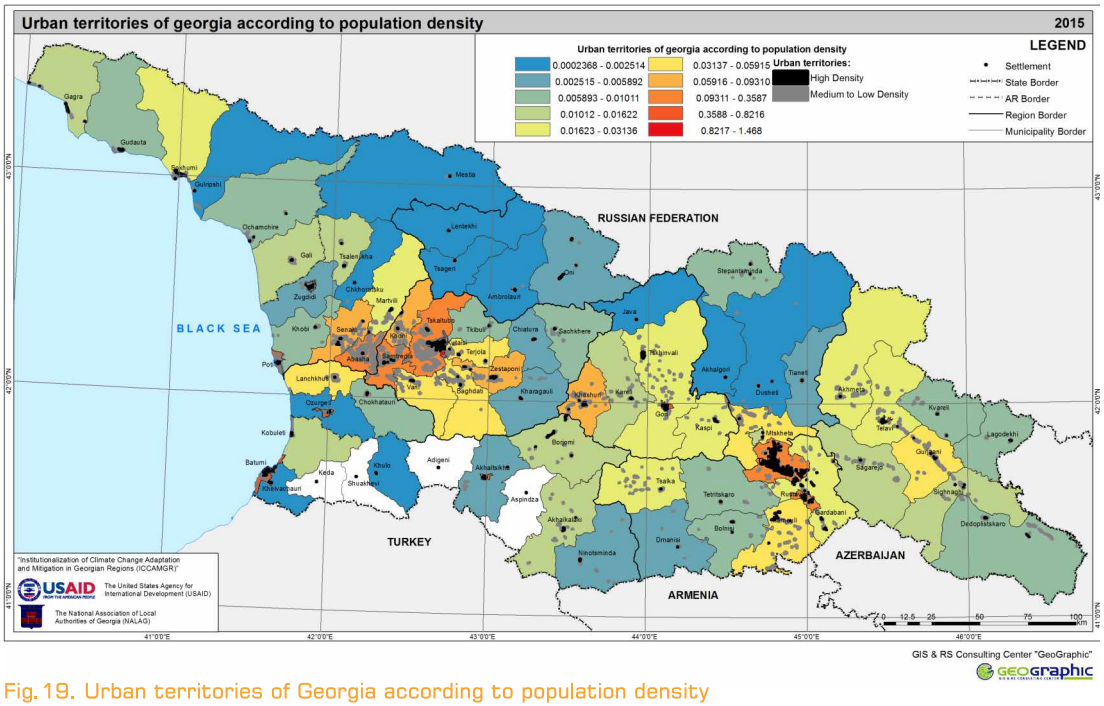


Fig. 19. Urban territories of Georgia according to population density

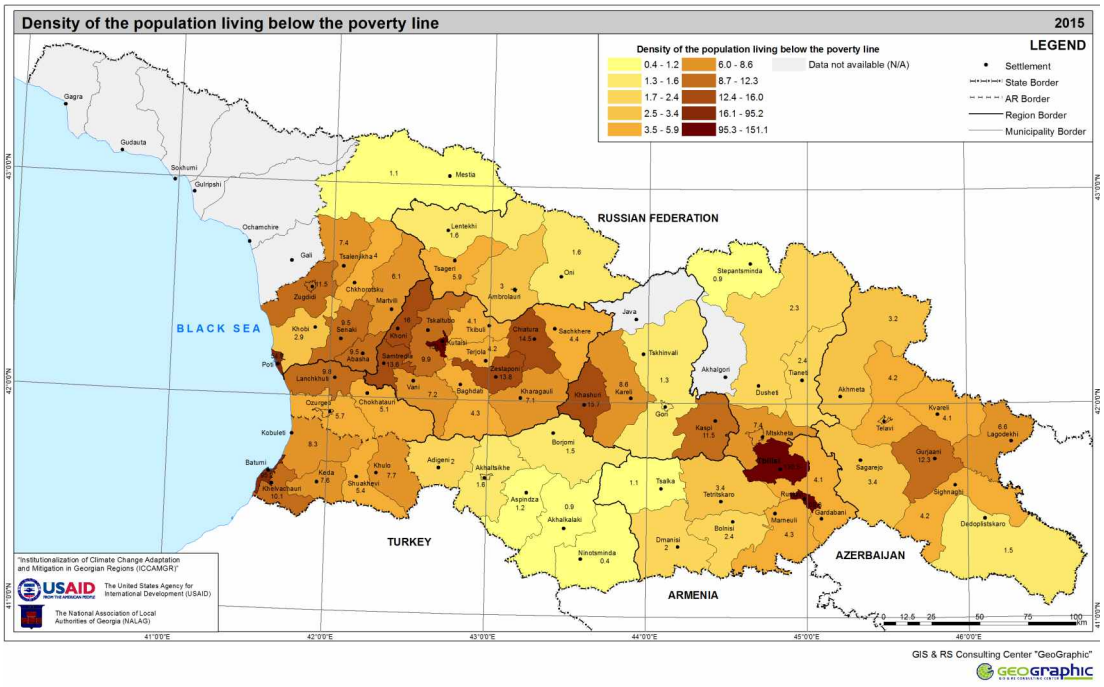


Fig. 20. Density of the population living below the poverty line

Thus, the final indicators of sensitivity towards extreme temperature and heat waves are:

1. Density of population over 65 years of age, also considered from a gender perspective, and;
2. Density of population below the poverty line, also considered from a gender perspective.

It should be noted that non-urban populations might not experience the effects of heat waves and be less sensitive towards extreme temperature and heat waves, but nevertheless they may face other types of challenges. For example, in many regions of Georgia, particularly in the mountainous regions, natural disasters increase the risks of trauma. If the number of people below the poverty line and over 65 is high in these municipalities, they are more sensitive towards climate change (see Maps 59, 61-63, 65 and 66 describing the absolute number of elderly population and population living below the poverty line, including gender perspective).

The most sensitive group of municipalities towards natural disasters such as landslides, mudslides, floods and avalanches, among others, are the following: Dusheti, Khulo, Tsageri, Mestia, Tianeti, Mtskheta, Kazbegi, Kharagauli, Lentekhi, Ambrolauri, Chokhatauri, Chiatura and Oni among others.

To better visualize those municipalities where natural disasters pose particular risks to socially and economically vulnerable groups, aggregated maps of social vulnerability and natural disasters were created. This involved summarizing normalized data of the absolute numbers of socially and demographically vulnerable populations in the municipalities alongside normalized data for natural disasters. This was done for both baseline and projected periods.

Those municipalities where the number of people below the poverty line and over 65 years of age is higher and the risk of natural disaster is also high are more economically and socially vulnerable to these natural phenomena. It is quite clear that the ability of the socially vulnerable population to repair the damage caused by natural disasters is lower than that of the rest of the population, while the ability of the population over 65 to survive or protect themselves during natural disasters is also lower. Figure 21 shows the baseline social and economic vulnerability of the municipalities towards natural disasters for the year 2015.

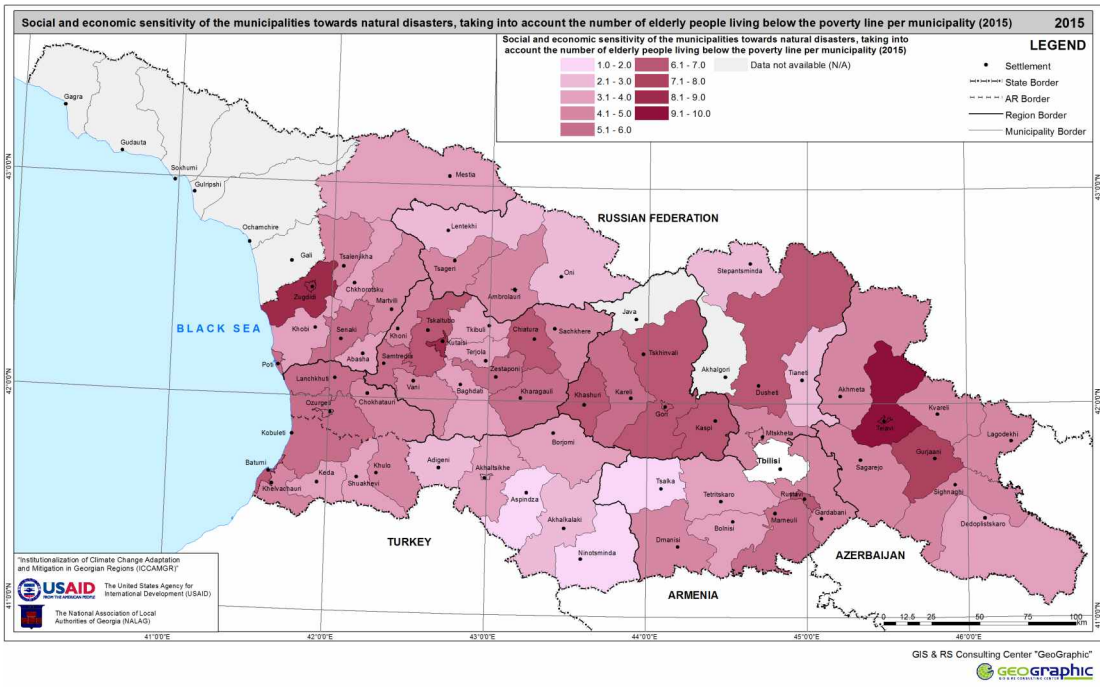
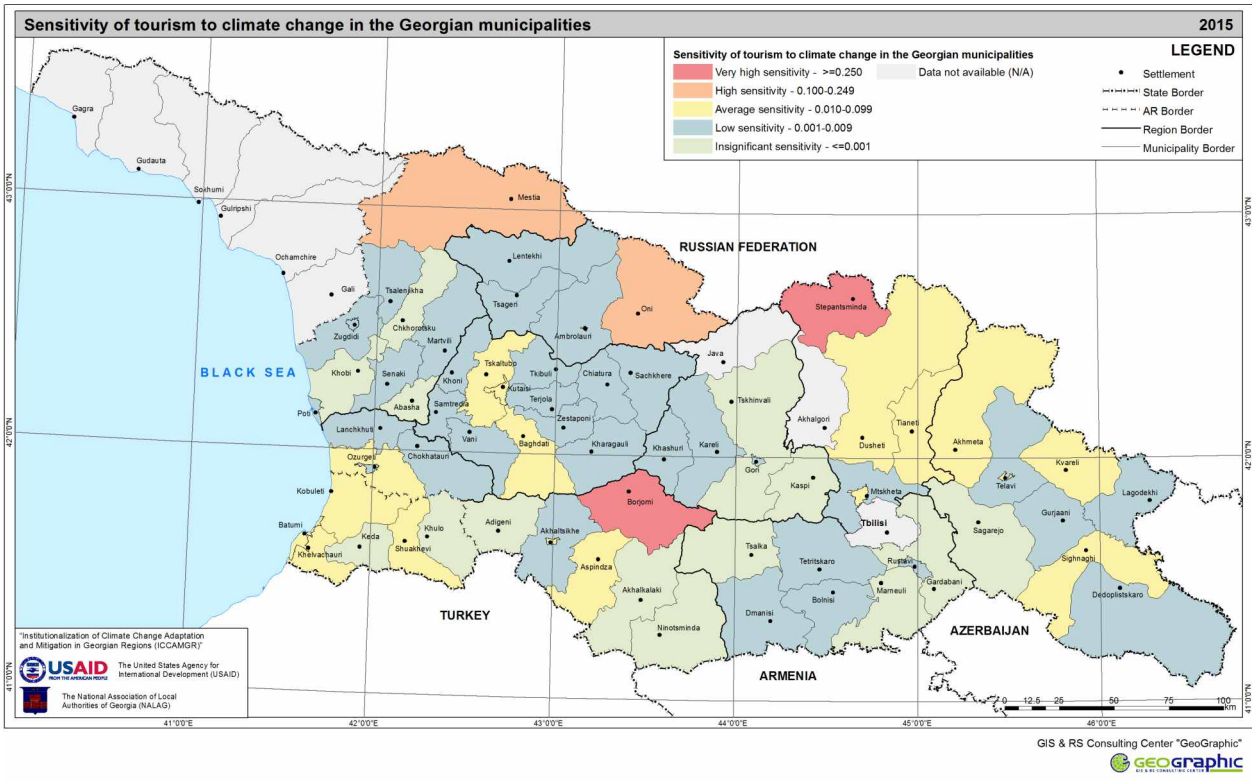


Fig. 21. Social and economic sensitivity of the municipalities towards natural disasters, taking into account the number of elderly people living below the poverty line per municipality (2015).

Climate change sensitivity maps for the Baseline Period: 2015



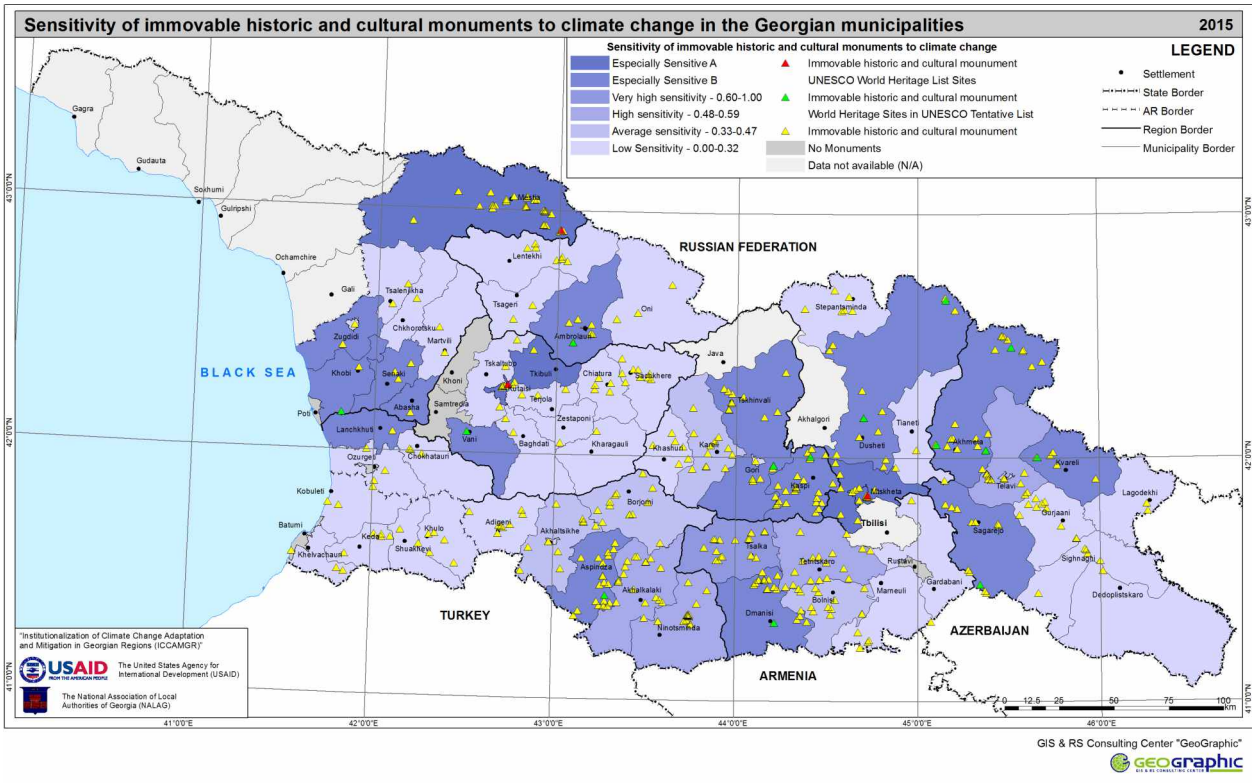
Map 41: Sensitivity of tourism to climate change in the Georgian municipalities

The map reflects the different levels of sensitivity of tourism to climate change in the municipalities of Georgia[182]. Tourism sensitivity is calculated through the ratio of the total number of beds in accommodation/lodging facilities to the total population size. Such an indicator reflects not only the economic importance of tourism in the region, but also the possibility of employment in the tourism sector, which is particularly important for the municipalities of Georgia.

As demonstrated by the map, two municipalities – Kazbegi and Borjomi, where tourism is traditionally concentrated – fall into the "very high sensitivity" category. Mestia municipality, where tourism has been developing rapidly over the last decades, is in the next category ("high sensitivity"). All three municipalities belong to highland regions: Kazbegi and Mestia are within the Greater Caucasus, while Borjomi is in the southern highlands of Georgia. Their high sensitivity can be explained by the fact that both summer and winter tourism are well developed in these municipalities. A comparatively lower level of sensitivity was revealed in the Black Sea resort zone: in Khelvachauri, Kobuleti, Ozurgeti municipalities and Batumi self-governing city ("Average sensitivity"). "Low sensitivity" is characteristic of Lanchkhuti and Zugdidi municipalities, where two developing seaside resorts, Grigoleti and Anaklia, are located. Tourism, particularly in terms of seaside resorts, is a significant share of the economy of municipalities and self-governing cities. The comparatively low sensitivity score is a result of both the high population density and insufficient use of hotels and other lodging facilities by tourists.

In most other municipalities, insignificant sensitivity (either category "low" or "insignificant") was noted, which can be explained by the low level of development of tourism in these areas.

[182] According to the Organic Law of Georgia "Self-governance Code", municipalities are divided into the two groups: Self-governing cities and self-governing communities



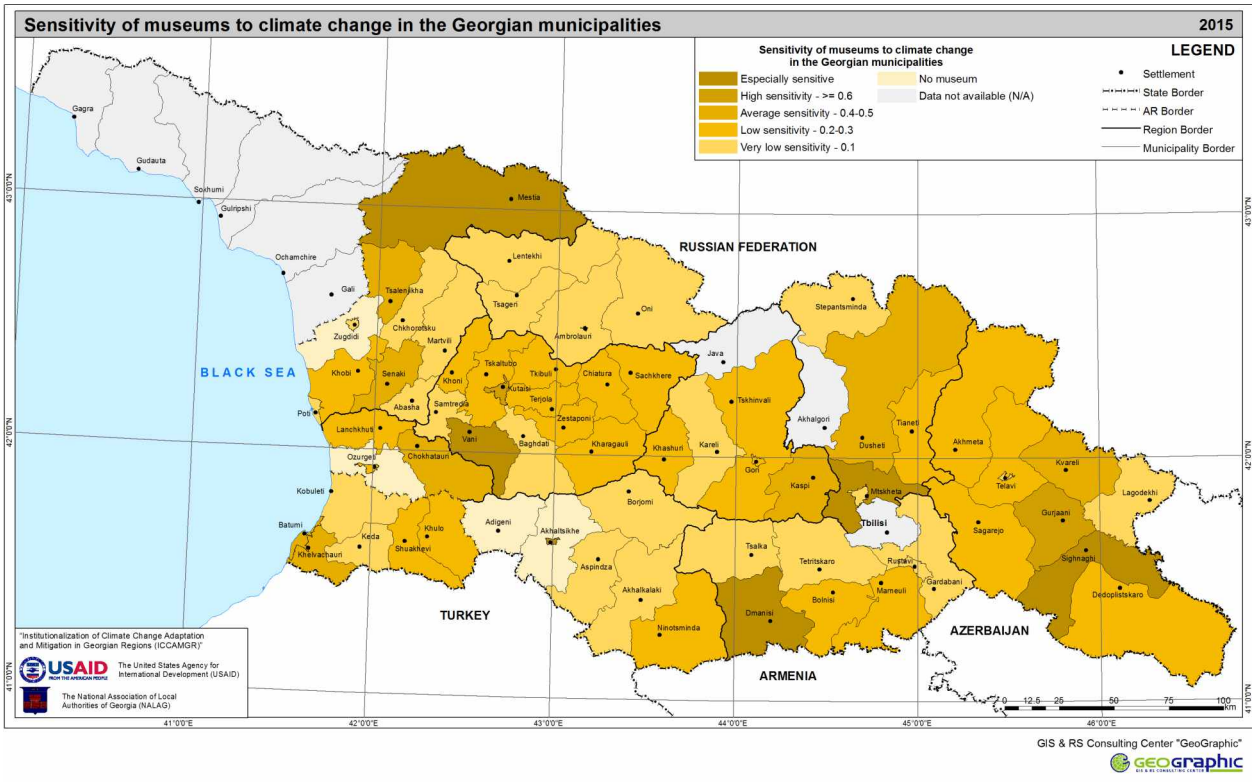
Map 42: Sensitivity of immovable historic and cultural monuments to climate change in the Georgian municipalities

This map reflects the sensitivity of immovable historic and cultural monuments to climate change in municipalities of Georgia[183]. Sensitivity is calculated using a combination of quantitative and qualitative indicators.

Immovable monuments of history and culture are found in almost all the municipalities of Georgia. They are especially numerous in Mestia (33), Gori (31), Kaspi (26), Akhmeta (23) and Tsalka (20). Their sensitivity to climate change was assessed by a quantitative indicator. Five categories in total have been singled out by quantitative indicators: "very high sensitivity", "high sensitivity", "average sensitivity", "low sensitivity" and zero ("no monument"). Those municipalities of Georgia that have no information about the number of immovable monuments of cultural heritage have been assigned to a separate category "not available (N/A)".

However, some immovable historic and cultural monuments are of particular importance, such as UNESCO World Heritage List Sites. Any damage or destruction to those kinds of monuments would result in greater loss of material and spiritual values. There are three such sites in Georgia: the Chazhashi village, in Mestia self-governing community, (Upper Svaneti); Gelati Monastery and Bagrati Cathedral (Tkibuli self-governing community and Kutaisi self-governing city); and the Historic Monuments of Mtskheta (Mtskheta self-governing city and Mtskheta self-governing community). The municipalities where the World Heritage Sites are located are in the "Especially Sensitive A" category. Another 15 municipalities have World Heritage Sites in UNESCO Tentative List, which were included in the "Especially Sensitive B" category. These are: Kaspi, Akhmeta, Aspindza, Gori, Dmanisi, Dusheti, Sagarejo, Ambrolauri, Kvareli, Senaki, Zugdidi, Abasha, Lanchkhuti, Khobi, and Vani municipalities. The sensitivity to climate change of immovable historic and cultural monuments in the rest of the municipalities ranges between "very high" and "very low".

[183] According to the Organic Law of Georgia "Self-governance Code", municipalities are divided into the two groups: Self-governing cities and self-governing communities



Map 43: Sensitivity of museums to climate change in the Georgian municipalities

This map shows the sensitivity of museums to climate change in the municipalities of Georgia[184]. Museums store movable historic and cultural artifacts that serve as material and spiritual witnesses to the past of the municipalities and of the country as a whole. Therefore, local authorities have a significant interest in preserving them from damage or destruction as a result of climate change.

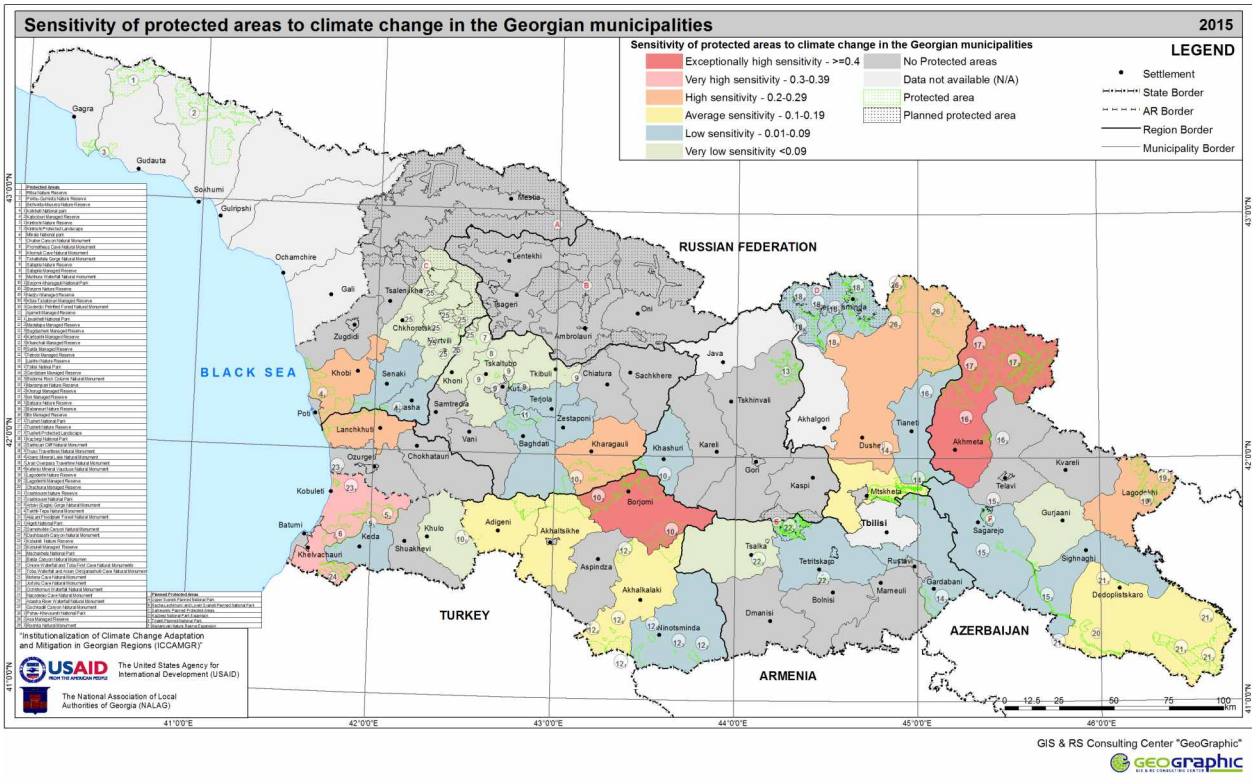
The sensitivity assessment of these cultural heritage artifacts in municipalities was made by a combination of quantitative and qualitative indicators. Their total number in the municipalities was taken as a quantitative indicator, which is divided into five categories: "very high sensitivity", "high sensitivity", "average sensitivity", "low sensitivity" and "no museum"). Those municipalities of Georgia for which no information about the number of museums could be obtained have been assigned to a separate category, "not available (N/A)".

In addition, any municipality that hosts a regional branch of the National Museum would be categorized as "Especially Sensitive". Naturally, the damage caused by climate change to national museums that keep and display artifacts of particular importance would outweigh the damage caused to local museums.

In terms of museums, the municipalities that are especially sensitive to climate change include: Dmanisi, Vani, Mtskheta, Sighnaghi self-governing communities and the self-governing city of Akhaltsikhe, since they have regional branches/museums of the Georgian National Museum. The self-governing city of Kutaisi and Gurjaani self-governing community fell into the "High Sensitivity" category, while Dusheti, Kaspi, Senaki, Kvareli, Chokhatauri, Tsalenjikha and Khelvachauri municipalities (self-governing communities) and the Batumi self-governing city fell into the "average sensitivity" category. Another 50 territorial units are characterized as being of low and very low sensitivity. Four municipalities have no museum: Adigeni, Akhaltsikhe, Ozurgeti and Zugdidi municipalities (self-governing communities)[185].

[184] According to the Organic Law of Georgia "Self-governance Code", municipalities are divided into the two groups: Self-governing cities and self-governing communities

[185] The self-governing cities Ozurgeti, Akhaltsikhe and Zugdidi have museums.

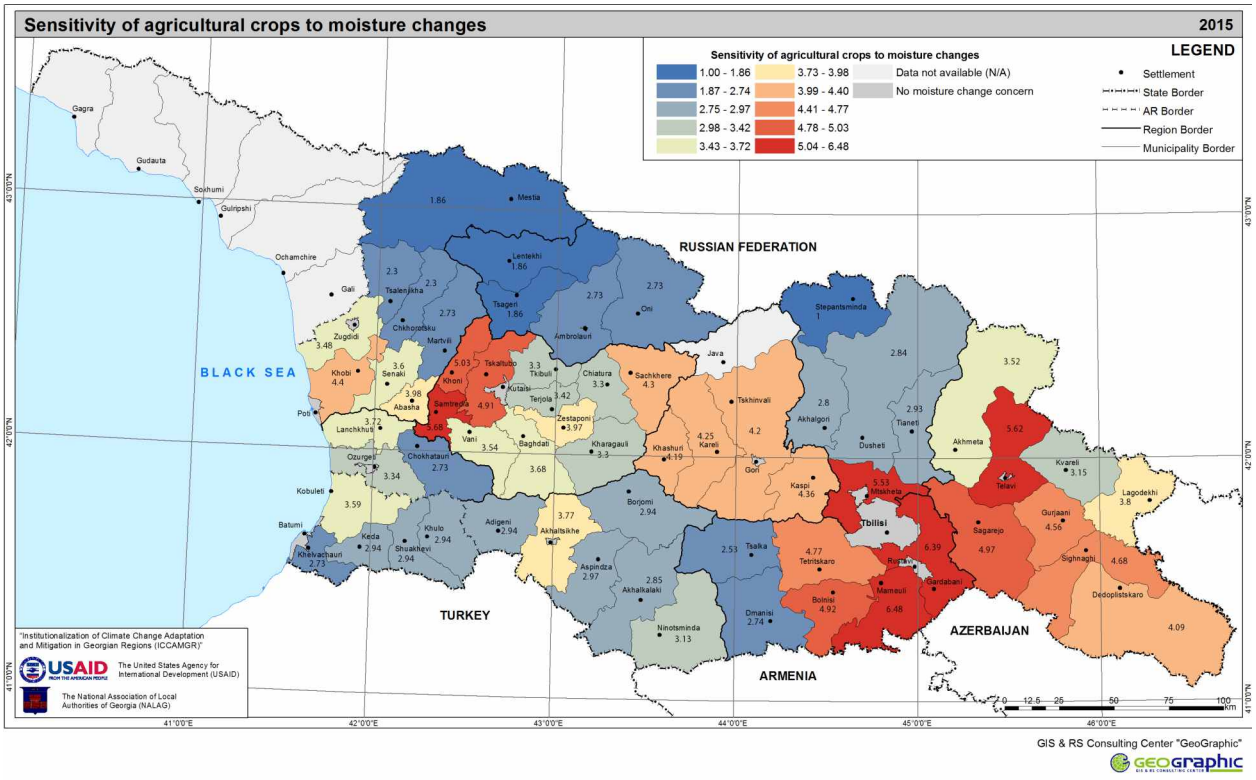


Map 44: Sensitivity of protected areas to climate change in the Georgian municipalities

This map demonstrates the sensitivity of protected areas to climate change in the municipalities of Georgia. Protected areas are the most valuable part of the regions' natural wealth and potential. However, their significance to the different municipalities varies.

The most general indicator of sensitivity of protected areas to climate change in the municipalities of Georgia is the size of the area under protection. Naturally, those municipalities that have more area under protection may potentially suffer greater damage from climate change than those with less. Therefore, the proportion of protected areas to the total area of the municipality was taken as a sensitivity indicator.

A total of 34 municipalities of Georgia have no protected areas. The share of protected areas in the total area of other municipalities varies and, accordingly, their sensitivity indicator also varies. Two municipalities where the protected areas occupy over 40% of the total area fall into the "exceptionally high sensitivity" category: Akhmeta (Tusheti Strict Nature Reserve, Batsara Strict Nature Reserve, Babaneuri Strict Nature Reserve, Tusheti National Park, Ilto Managed Reserve, Tusheti Protected Landscape, 1244.8 km^2 in total) and Borjomi (Borjomi Strict Nature Reserve, Borjomi-Kharagauli National Park (part of Borjomi), Nedzvi Managed Reserve, Ktsia-Tabatskuri Managed Reserve (part of Tori), 684,01 km^2 in total). Two more fall into the "very high sensitivity" category: Kobuleti and Khlevachauri. The protected areas in these municipalities, which are mainly national parks, occupy over 30% of the total area. The sensitivity is "high" in Lagodekhi, Kharagauli, Lanchkhuti and Khobi municipalities. Adigeni, Akhalkalaki, Akhaltsikhe, Dedoplistskaro and Mtskheta municipalities are of "average" sensitivity. There are also smaller protected areas in 21 other municipalities that include natural monuments and managed reserves: these municipalities are designated as "low sensitivity" or "very low sensitivity".



Map 45. Sensitivity of agricultural crops to moisture changes

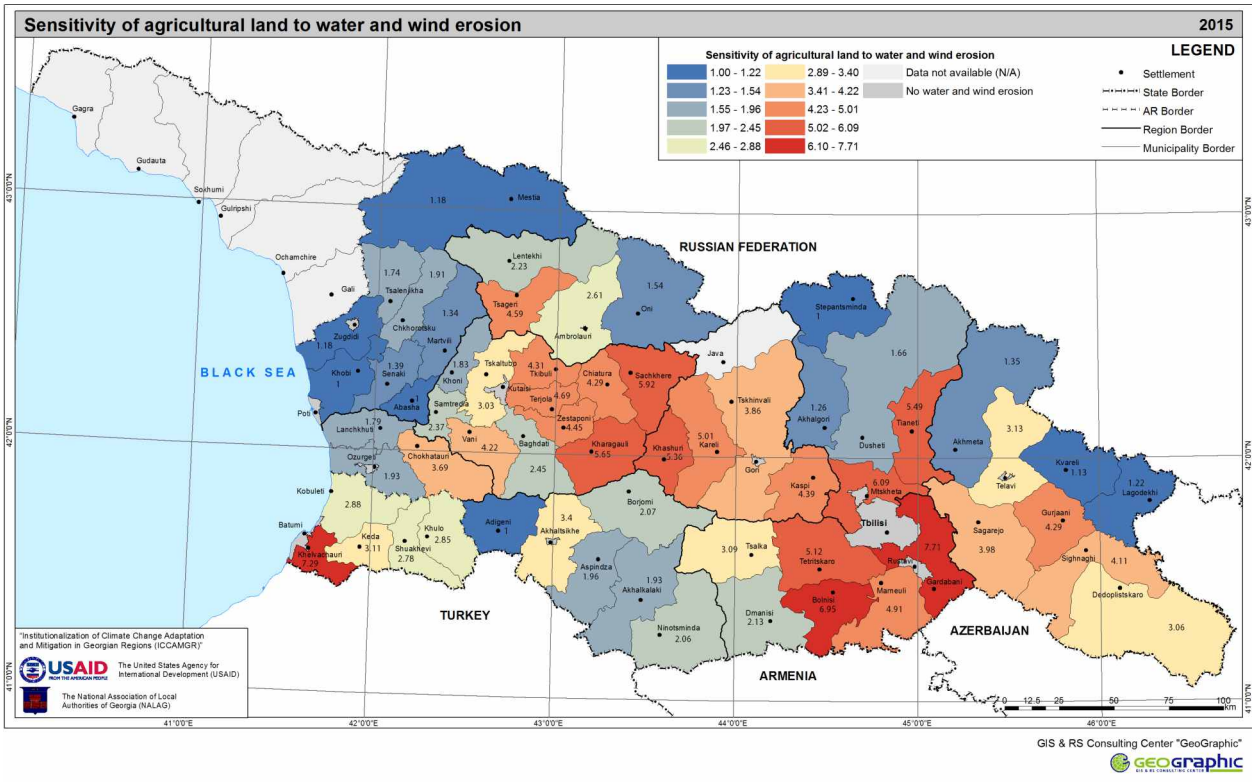
Map 45 shows the sensitivity of agricultural crops to moisture changes for each municipality of Georgia. To establish the reclamation sensitivity of the agricultural sector to climate change, the data of Georgian Reclamation Ltd., under the Ministry of Agriculture of Georgia, have been used. It should be mentioned that state/public irrigation systems are in place in 40 municipalities of Georgia. In the other 19 municipalities, irrigation has an irregular character and is carried out when necessary by the farmers themselves. Due to the damp climate (or high humidity), drainage systems are generally present in western Georgia; and because of its comparatively dry climate, only a few, currently non-operating, drainage systems are found in eastern Georgia.

The sensitivity of agricultural crops is measured by indicators such as the amount of water supplied to different agricultural plants during the year, the reclamation potentiality and the operating irrigation and drainage networks of a municipality. In the municipalities lacking state irrigation systems, the irrigation standards are determined by those of previous years or those of municipalities with similar climatic conditions.

On average, the sensitivity index for Georgia equals 3.5. By region, the indices are as follows: Kakheti is 4.3 (highest in Sagarejo, 4.97, lowest in Kvareli, 3.15); Mtskheta-Mtianeti is 3.02 (highest in Mtskheta, 5.53, lowest in Kazbegi, 1.0); Kvemo Kartli is at 4.6 (highest in Marneuli , 6.48, lowest in Tsalka, 2.53); Shida Kartli is 4.28 (highest in Kaspi, 4.36, lowest in Khashuri, 4.19); Samtskhe-Javakheti is 3.1 (highest in Akhaltsikhe, 3.77, lowest in Akhalkalaki, 2.85); Imereti is 4.04 (highest in Samtredia, 5.68, lowest in Chiatura and Kharagauli, 3.3); Samegrelo-Zemo Svaneti is 3.02 (highest in Khobi, 4.40, lowest in Mestia, 1.86); Racha is 2.3 (highest in Oni, 2.73, lowest in Tsageri, 1.86); Guria is 3.26 (highest in Lanchkhuti, 3.72, lowest in Chokhatauri, 1.73); and Ajara is 3.03 (highest in Kobuleti, 3.59, lowest in Khelvachauri, 2.73).

The municipalities in which sensitivity indicators are high are characterized by their agriculture being dependent on reclamation activities – irrigation in eastern Georgia and drainage in western Georgia. In locations where reclamation systems are lacking, sensitivity indices are minimal.

In the municipalities where the sensitivity index exceeds 3, reclamation systems must be rehabilitated and water-saving measures should also be applied. Where there is a lower sensitivity index, the application of special measures is not necessary.



Map 46. Sensitivity of agricultural land to water and wind erosion

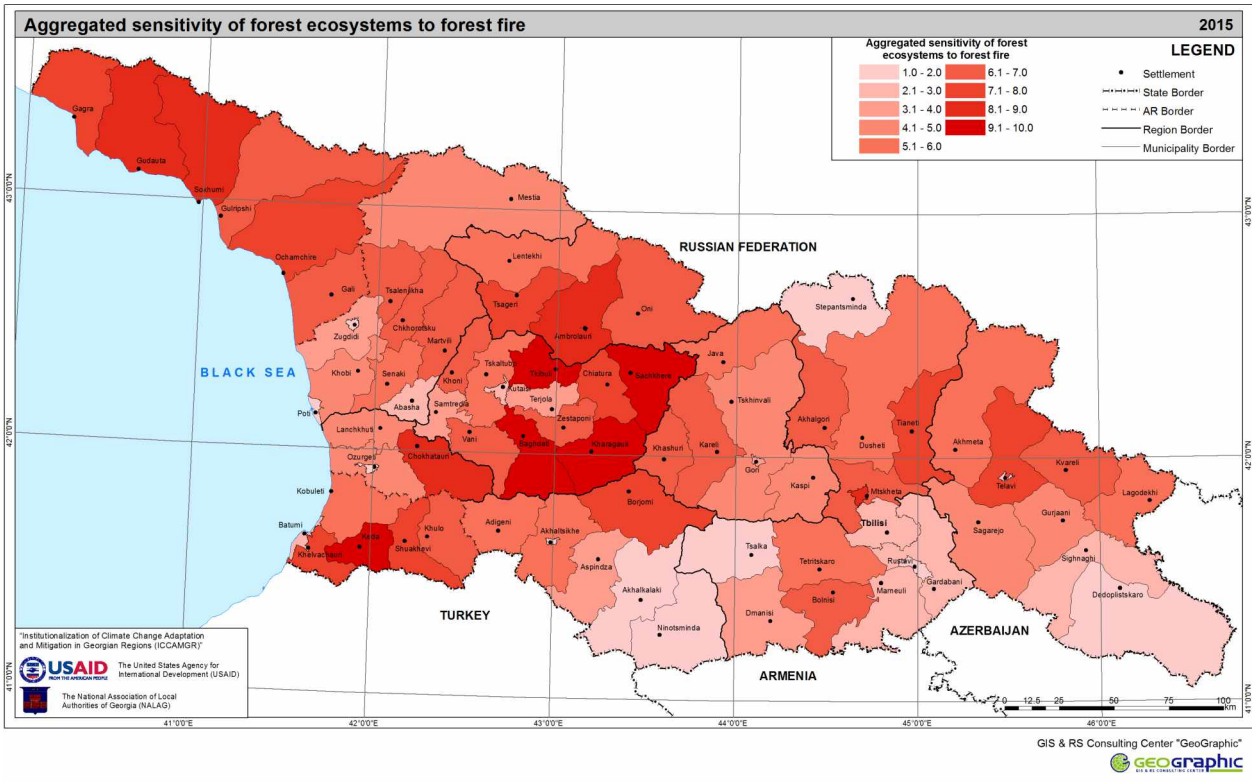
Map 46 reflects the aggregate state of existing water and wind erosion in Georgia. Almost all municipalities of Georgia except Abasha, Adigeni, Akhalgori, Kazbegi and Khobi municipalities are affected by water erosion. Since irrigation erosion represents one of several types of water erosion and the identification of the irrigation exposure is not possible, all water-eroded agricultural land is taken into consideration.

Wind erosion has been recorded in Akhalgori, Akhalkalaki, Akhaltsikhe, Bolnisi, Gardabani, Gori, Gurjaani, Dedoplistskaro, Dmanisi, Tetritskaro, Kaspi, Marneuli, Mtskheta, Sagarejo, Kareli and Khashuri municipalities. The aggregated index of total erosion is derived by normalizing the ratio of water and wind-eroded areas against the total municipality agricultural land area.

On average, the erosion sensitivity for Georgia equals 3.19. By region, the indices are as follows. For Kakheti average (2.78, highest in Gurjaani (4.29), the lowest in Kvareli (1.13); Mtskheta-Mtianeti the average is 3.1, the highest in Mtskheta (6.09) and the lowest in Kazbegi (1.0); in Kvemo Kartli the average is 4.99 highest in Gardabani (7.71) and lowest in Dmanisi (2.13); for Shida Kartli the average is 4.66 with the highest in Kareli (5.01) and lowest in Gori (3.86); for Samtskhe-Javakheti the average is 2.07 with the highest in Akhaltsikhe (3.04) and lowest in Adigeni (1.0); for Imereti the average is 3.93 the highest in Sachkhere, (5.68) lowest in Khoni (1.83); for Samegrelo-Zemo Svaneti the average is 1.34, with the highest in Chkhorotsku (1.91) and the lowest in Abasha and Khobi (1.0); for Racha-Lechkhumi and Kvemo (Lower) Svaneti the average is 2.74 with the highest in Oni (1.54) and the lowest in Tsageri (4.59); for Guria the average is 2.47 with the highest in Lanchkhuti (1.79) and the lowest in Chokhatauri (3.69); for Ajara the average is 3.79 with the highest in Khelvachauri (7.29) and the lowest in Khulo (2.85).

In municipalities where the sensitivity index is high, the losses of agricultural lands from erosion are correspondingly high. The lowest erosion index has been recorded in the municipalities that are free from erosion.

To mitigate water erosion (primarily in Khelvachauri, Sachkhere and Bolnisi municipalities), it is recommended to take erosion-preventive measures. In the regions where wind erosion has been recorded (primarily in Gardabani, Dedoplistskaro and Khashuri municipalities), windbreaks should be restored. In general, it is desirable for vegetation cover on the land surface to be preserved where possible.



Map 47. Aggregated sensitivity of forest ecosystems to forest fire

Map 47 demonstrates forest sensitivity to fires based on 2005-2015 satellite data and a quantitative assessment of forests conducted in 2011, for which an aggregate index has been derived and a geometrical mean of forest numbers, and two forest areas (equilibrium indicators) calculated.

In particular, to determine the quantitative indicator of wildfires for each municipality, NASA's Fire Information for Resource Management System (FIRMS) was used[186]. The system encompasses the satellite observation data (5th version) of hotspots/thermal anomalies detected by the MODIS satellite to within 1 km during 2000-2015. The data naturally contains the fires observed both within forest and cropland areas.

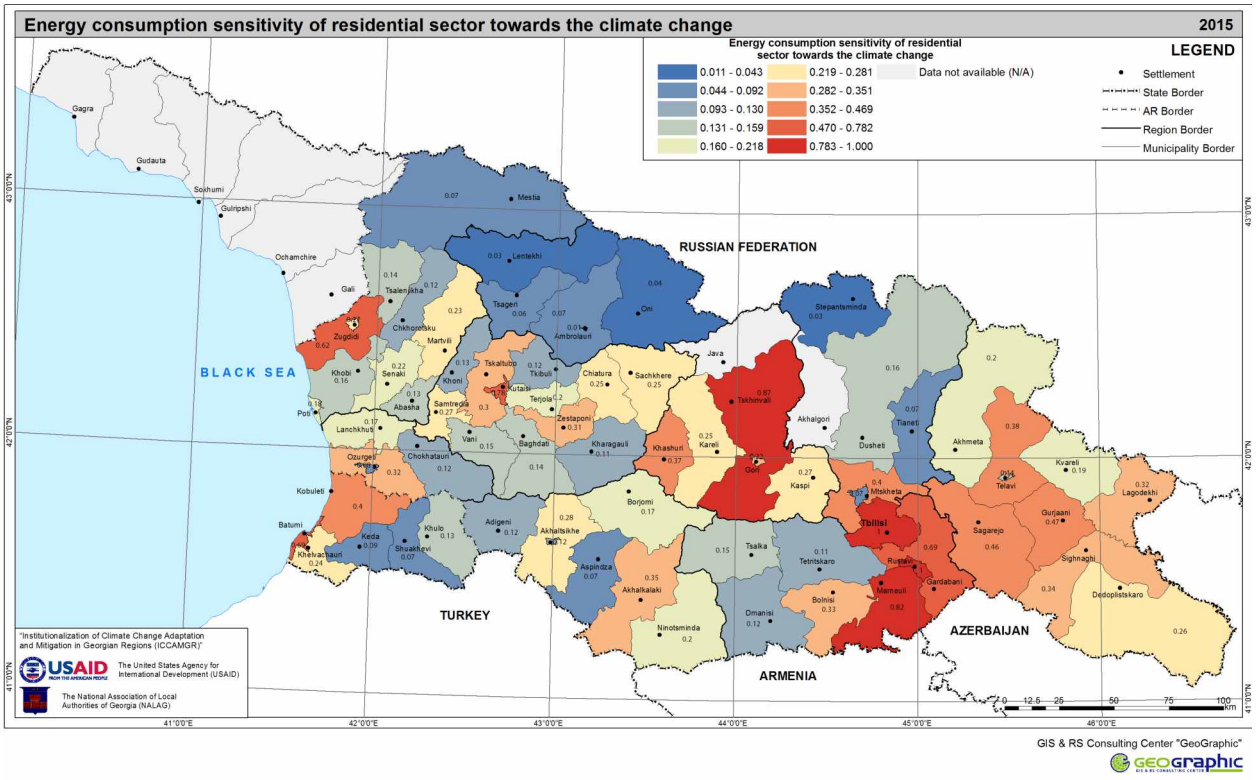
From 2000 to 2015, a total of 6,000 fires were recorded in Georgia. To separate forest fires from the common database, the following sources of forest cover were used: a 350 m resolution map (with 2009 data from GlobCover of the European Space Agency[187]), a 30 m resolution map (with 2010 data (from Globeland 30)[188], and a forest cover map developed for Georgia within the framework of the GIZ project entitled "Sustainable Biodiversity Management in the South Caucasus" (2011, a 5 m resolution map). With the help of these three sources and the GIS vector analysis, respectively, 1,019 fires (on 350 m resolution map), 789 fires (on the 30 m resolution map) and 644 fires (on the 5 m resolution map) were identified.

[186] See http://earthdata.nasa.gov/firms (accessed March 18, 2016).
[187] See http://due.esrin.esa.int/page_globcover.php (accessed March 18, 2016).
[188] See http://www.globallandcover.com/GLC30Download/index.aspx (accessed March 18, 2016).

As accuracy of the observation of total fires was only within 1 km (NASA FIRMS), it was not possible to identify forest fires on low-resolution maps of forest cover. Therefore, the lowest number of fires (644) has been used to produce the map, as it complies with the best resolution forest cover maps (GIZ, 5 m resolution map) and gives a clearer picture of forest fires within the territories of each municipality.

The same forest cover layer was used for calculating another non-dimensional indicator (i.e. ratio of forest-covered area in a municipality against the municipality's total area, also standardized from 1 to 10). By aggregating these two indicators, a single indicator for assessing the impact of climate change on the frequency of forest fires has been derived.

In addition to the comparison of the registered under-field conditions and satellite-derived data as well as the integrated program on measures to manage forest and agricultural fires, the dissemination of fire management standards among the population and forest monitoring should be initiated urgently.



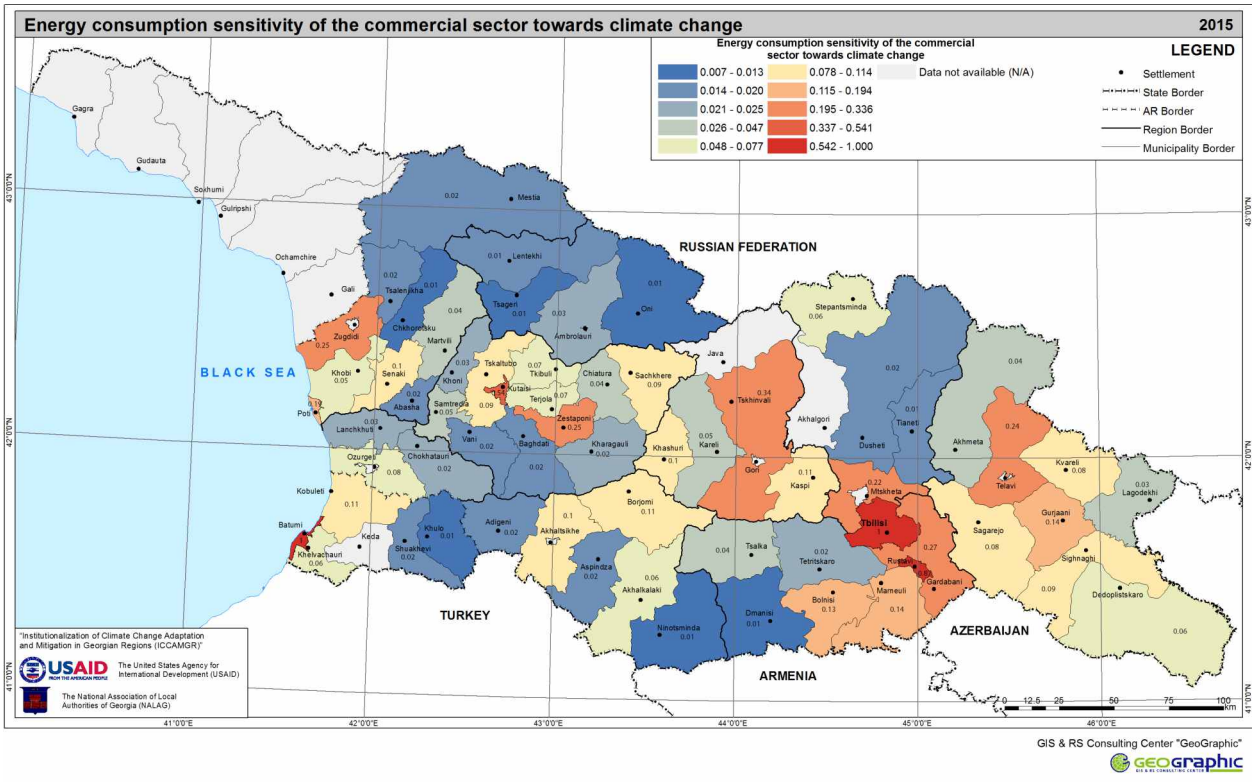
Map 48. Energy consumption sensitivity of the residential sector towards climate change

Map 48 shows the energy consumption sensitivity of the residential sector towards climate change. Compared to other municipalities, the self-governing cities of Tbilisi, Kutaisi and Rustavi and Gori, Marneuli self-governing communities[189] have the highest index with Gardabani municipality and the self-governing city of Batumi also demonstrating high indexes. Batumi has a high cooling load sensitivity index for the residential sector. The self-governing city of Kutaisi has one of the highest cooling load sensitivity index for the residential sector. Gori municipality has one of the highest heating load sensitivity indexes for the residential sector.

Relative to other municipalities, in the given municipalities cooling technologies are more widespread with greater ownership of modern air conditioners, which increases the energy consumption sensitivity index: 13.7 percent of Tbilisi population has modern air conditioners, 30.3 percent of Batumi population, 11.1 percent of Rustavi and 22.6 percent Kutaisi population[190].

[189] According to the Organic Law of Georgia "Self-governance Code", municipalities are divided into the two groups: Self-governing cities and self-governing communities

[190] Winrock International "Knowledge, Attitude and Behavior Baseline Survey: Summary Findings by Target Municipalities", 2015, produced within EC-LEDS project.

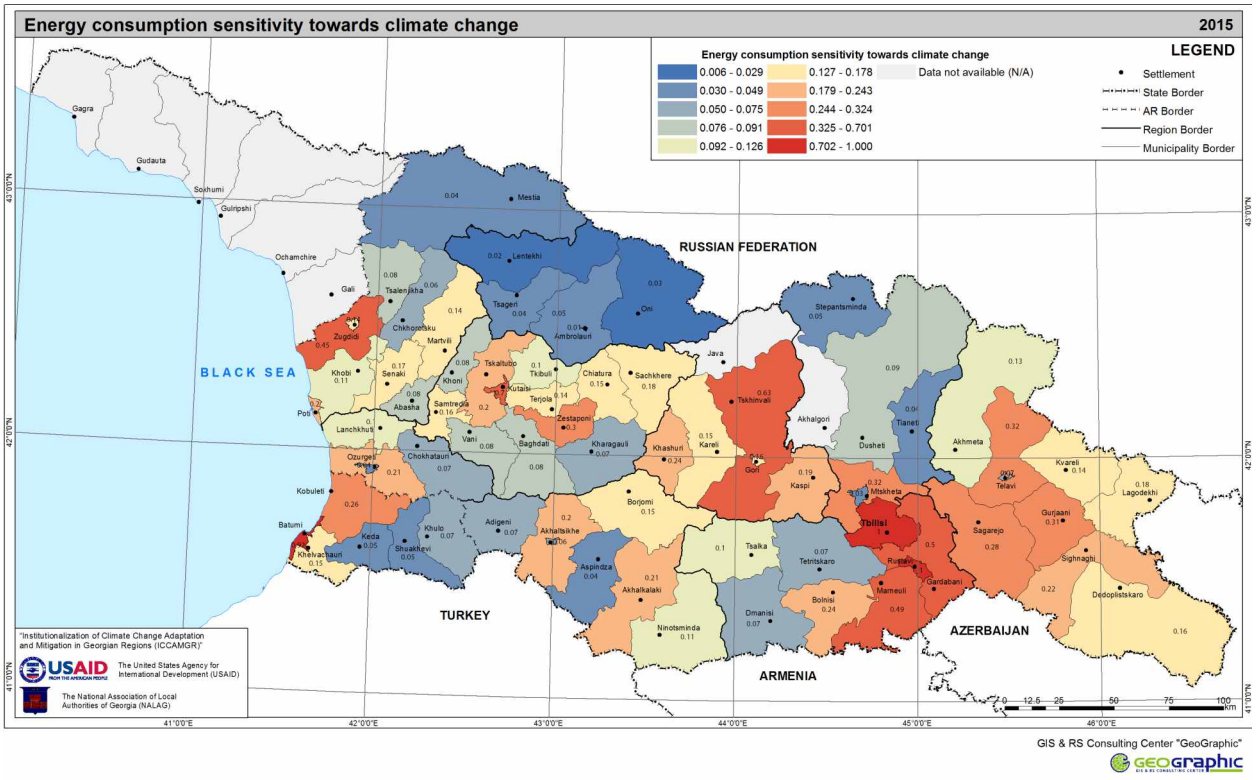


Map 49. Energy consumption sensitivity of the commercial sector towards climate change

Map 49 illustrates the energy consumption sensitivity of the commercial sector towards climate change. In general, the energy consumption of the commercial sector is less sensitive towards climate change than the residential sector. Commercial entities and enterprises are more oriented towards minimization of expenses, including decreased energy consumption, and usually implement modern, relatively energy-efficient technologies and also conduct different energy-efficient measures. Contrary to the residential sector, the commercial sector is less affected by the financial and information barriers of energy-efficiency. Thus, the commercial sector is more prepared and its energy consumption is less sensitive towards climate change. However, by conducting certain measures, commercial enterprises can decrease their energy consumption even more and thereby diminish the potential impacts of climate change.

Compared to other municipalities, the self-governing cities of Tbilisi, Batumi and Rustavi have the highest sensitivity indexes. The reason for that is not only the climate data but also the relative parameter, number of employees in commercial sector, as the given municipality has a high concentration of commercial entities. Tbilisi and Rustavi self-governing cities have high a cooling demand sensitivity index for the commercial sector, which indicates a relatively long cooling period and thus higher demand on electricity for cooling.

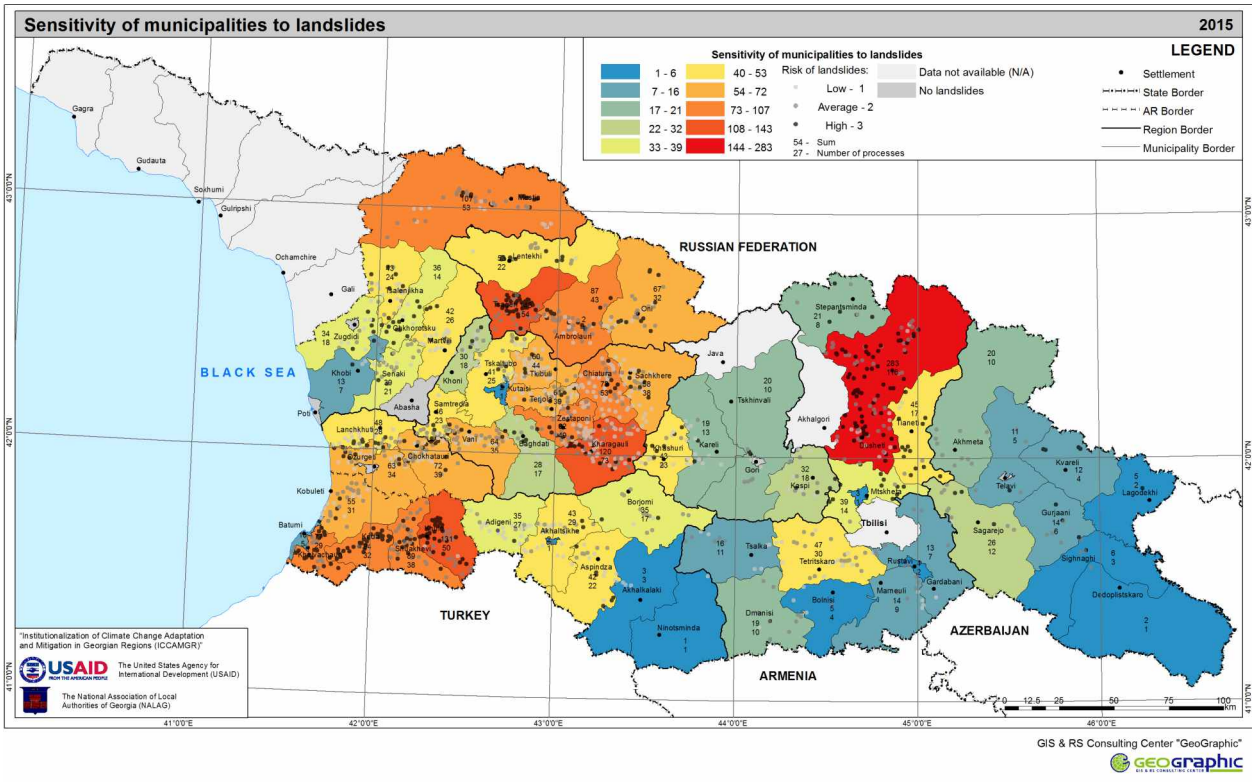
Municipalities where the energy consumption sensitivity index is high, are more vulnerable towards climate change. In short-term perspective, it is necessary for them to conduct the measures listed in the recommendations section, in order to reduce the vulnerability level. These steps will also help municipalities in fulfilling their long-term recommendations and reducing climate change impacts.



Map 50. Energy consumption sensitivity towards climate change

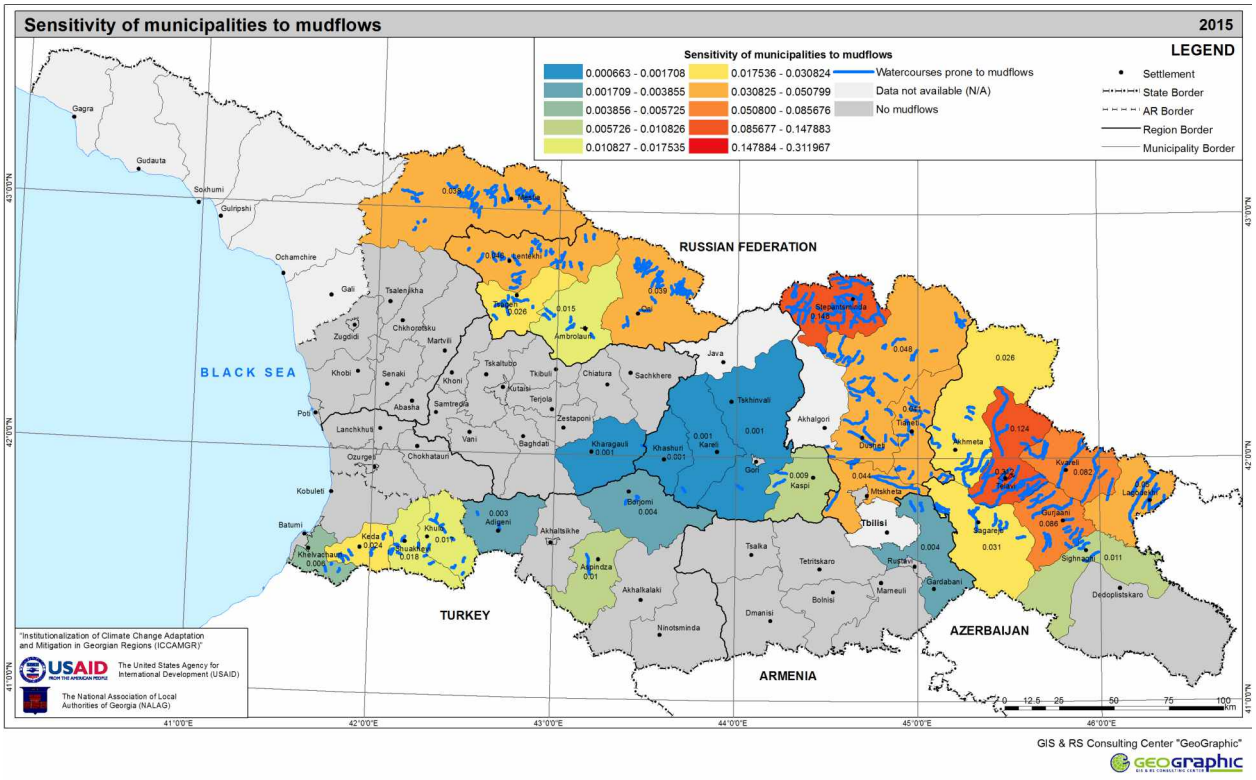
As Map 50 illustrates, the self-governing cities of Tbilisi, Rustavi, Batumi, as well as Gori and Gardabani municipalities have the highest overall sensitivity index of energy consumption.

According to the same map, Ambrolauri, Lentekhi, Oni, Tsageri municipalities and the self-governing city of Mtskheta have the lowest overall sensitivity index of energy consumption. In these municipalities, cooling demand sensitivity of both residential and commercial sectors is minimal, compared to other municipalities. The low sensitivity index in these municipalities is caused not only by climate data, but also relative indicators – the population numbers and the number of employees. The energy consumption of the municipalities with low sensitivity indexes, are less sensitive towards climate change. However, by conducting the measures listed in the recommendations section as listed in Section 5.4, these municipalities can reduce the amount of energy consumed, which will bring economic and environmental benefits, as well as support the improvement of the population's standard of living.



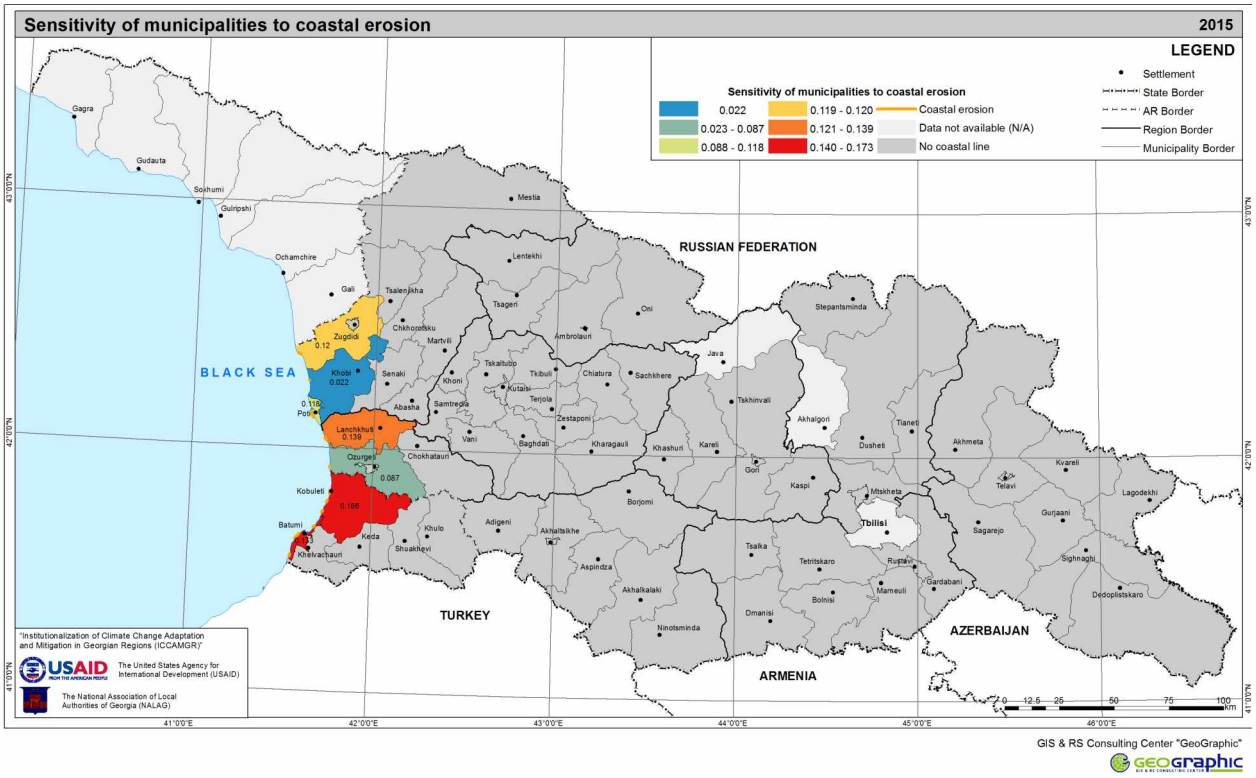
Map 51. Sensitivity of municipalities to landslides

The map shows landslides within separate municipalities. Settlements located in the areas under risk of landslides are categorized as high-, medium-, and low-risk areas and assigned coefficients 3, 2 or 1 accordingly. The processes are summarized and grouped by a ratio of the number of processes in each municipality to the total number of processes. The emphasis was placed on the landslides and gravitational processes that affect settlements and infrastructure. Statistical data available from continuous monitoring in the relevant areas for different years and the geodynamic maps served as the bases of this map. The least impacted municipalities are marked in blue (Akhalkalaki, Ninotsminda, Dedoplistskaro, Rustavi, Khobi, Bolnisi etc.). The most impacted municipalities are marked in red or orange (Dusheti, Khulo, Tsageri, Kharagauli, Ambrolauri, Shuakhevi, Keda, Khelvachauri, Mestia, Chiatura, etc.).



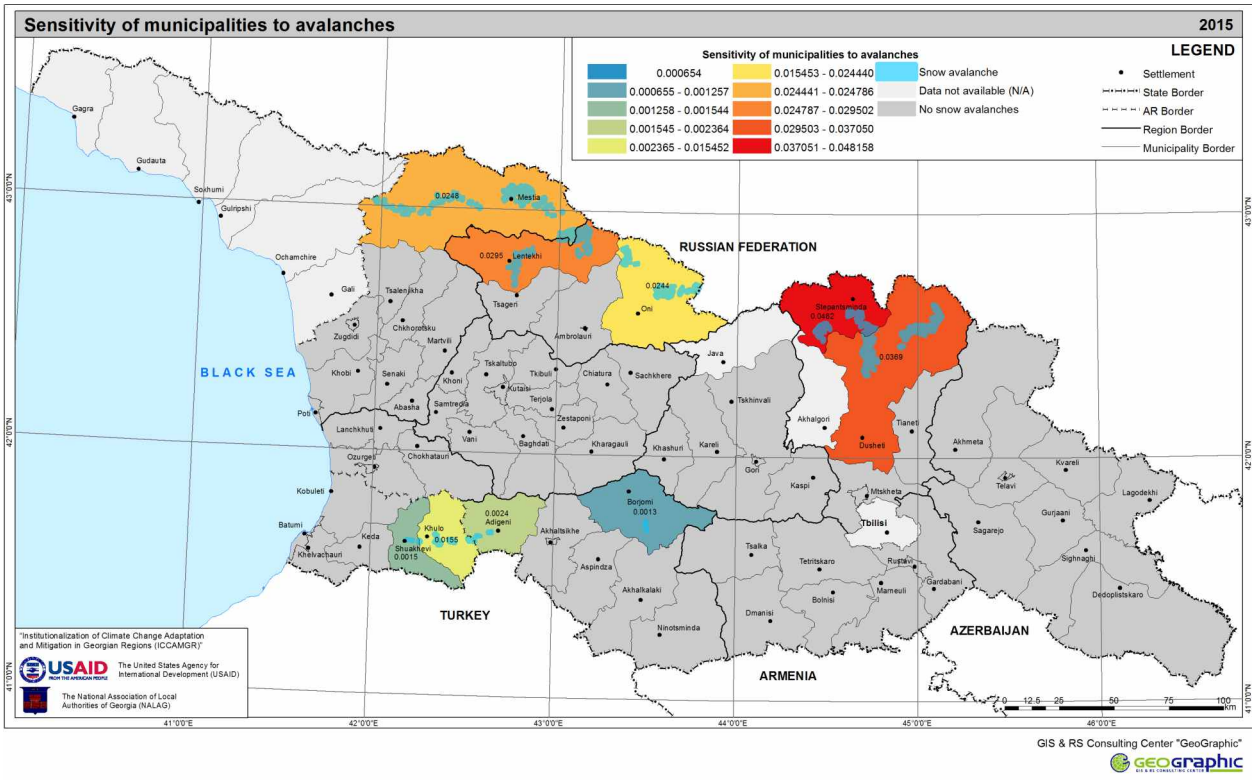
Map 52. Sensitivity of municipalities to mudflows

The map shows risk of mudflows within separate municipalities. Dark blue lines indicate watercourses prone to mudflows. Each municipality is shown with the color of the assigned risk coefficients. The coefficient is the ratio of the total length of mudflow transforming watercourses to total length of all rivers within the whole basin. According to this methodology, the municipalities least impacted by mudflows are shown in grey (Ninotsminda, Akhalkalaki, Dmanisi, Poti city, Batumi city, Kutaisi city), those with a medium risk are blue (Adigeni, Kharagauli, Khashuri, Kareli, etc.), and the municipalities under highest risk of mudflow processes are red or orange (Kazbegi, Dusheti, Telavi, Kvareli, Gurjaani, Oni, Mestia, Lentekhi, Tianeti, etc.)



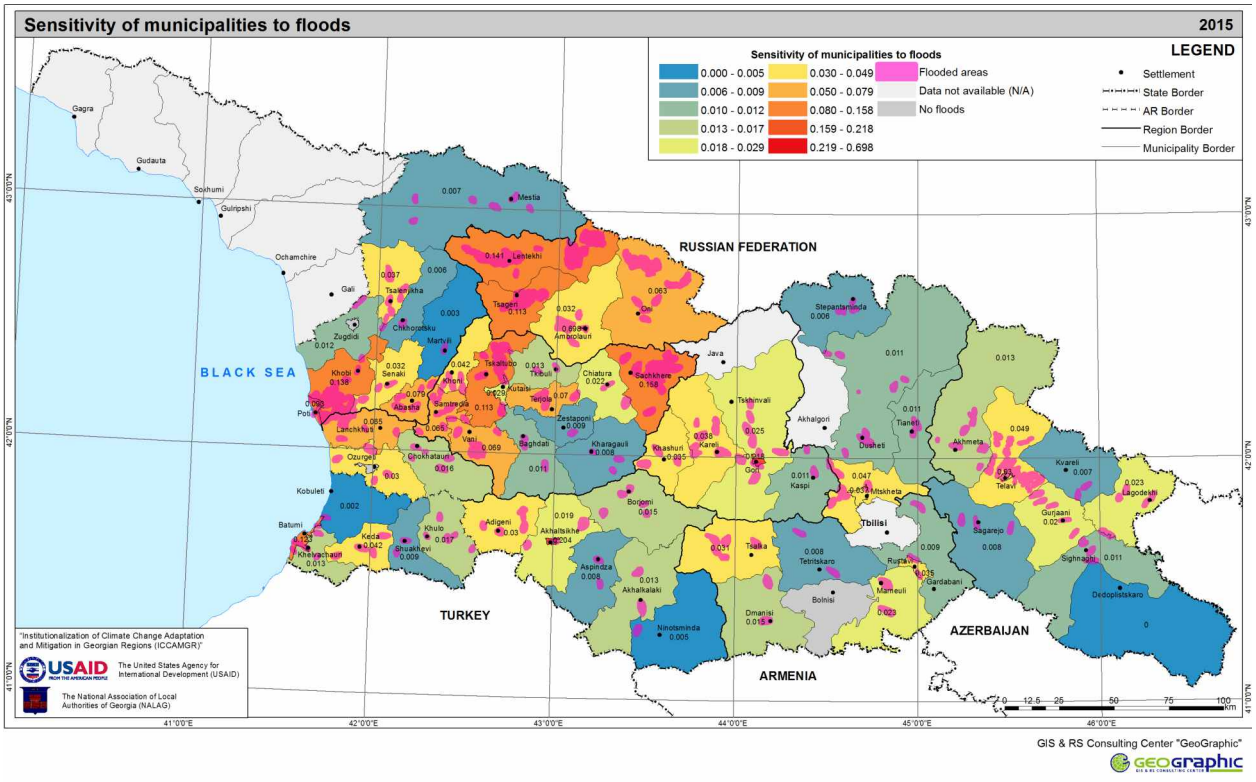
Map 53. Sensitivity of municipalities to coastal erosion

The map shows the risk of coastal erosion within separate municipalities. The colors reflect the erosion coefficient calculated in following way: ratio of total length of the coast subject to erosion to the total length of the coastal line of the municipality. The coastal line of the municipalities that have the least impact from erosion are blue (Poti, Ozurgeti, Khobi), while red indicates the areas with the greatest risk (Kobuleti, Batumi and Lanchkhuti).



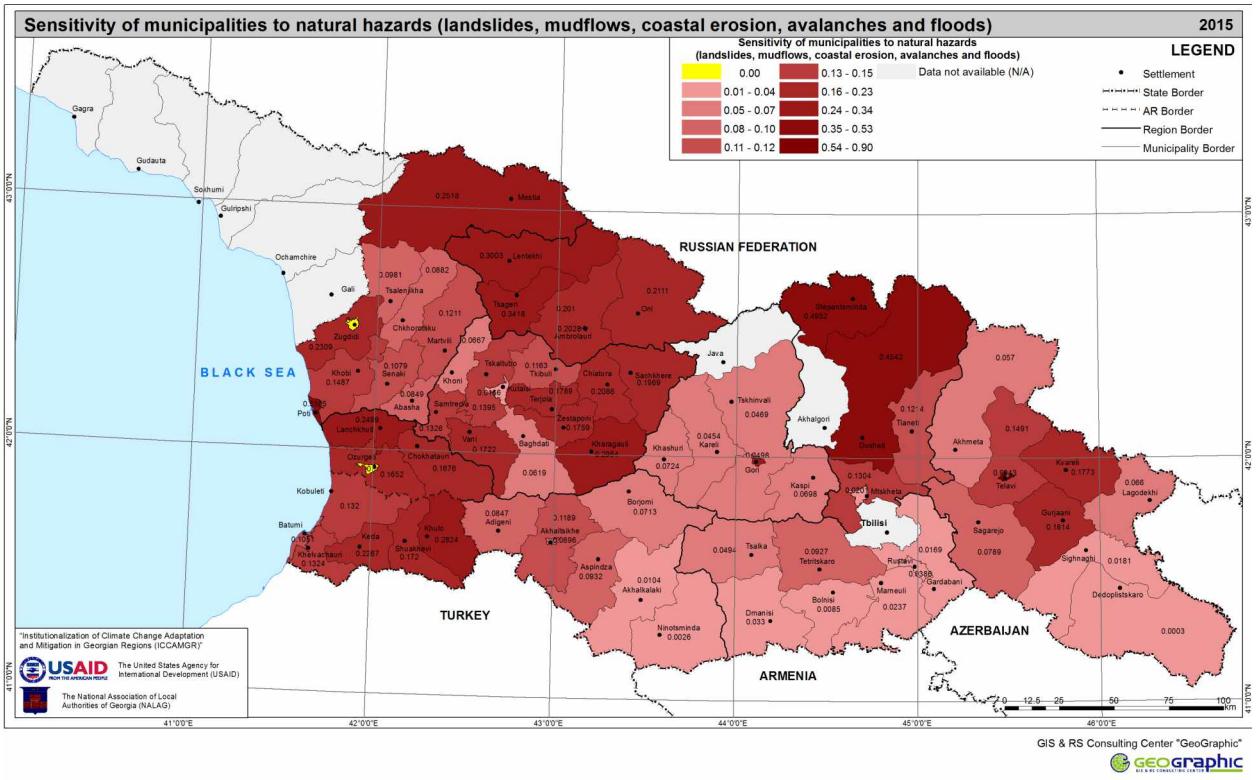
Map 54. Sensitivity of municipalities to avalanches

This map shows the threat of avalanches in the territory of Georgia, with risk levels shown in different colors from low to high risks. The coefficients are calculated by finding the ratio of the at-risk area of a given municipality to the total area of the same municipality. The municipalities that have little risk of avalanches are grey. The municipalities that are periodically damaged by avalanches are blue or green (Borjomi, Shuakhevi, Adigeni, etc.). The municipalities that have a high risk of avalanches are red or orange (Kazbegi, Dusheti, Mastia, Lentekhi, Oni).



Map 55. Sensitivity of municipalities to floods

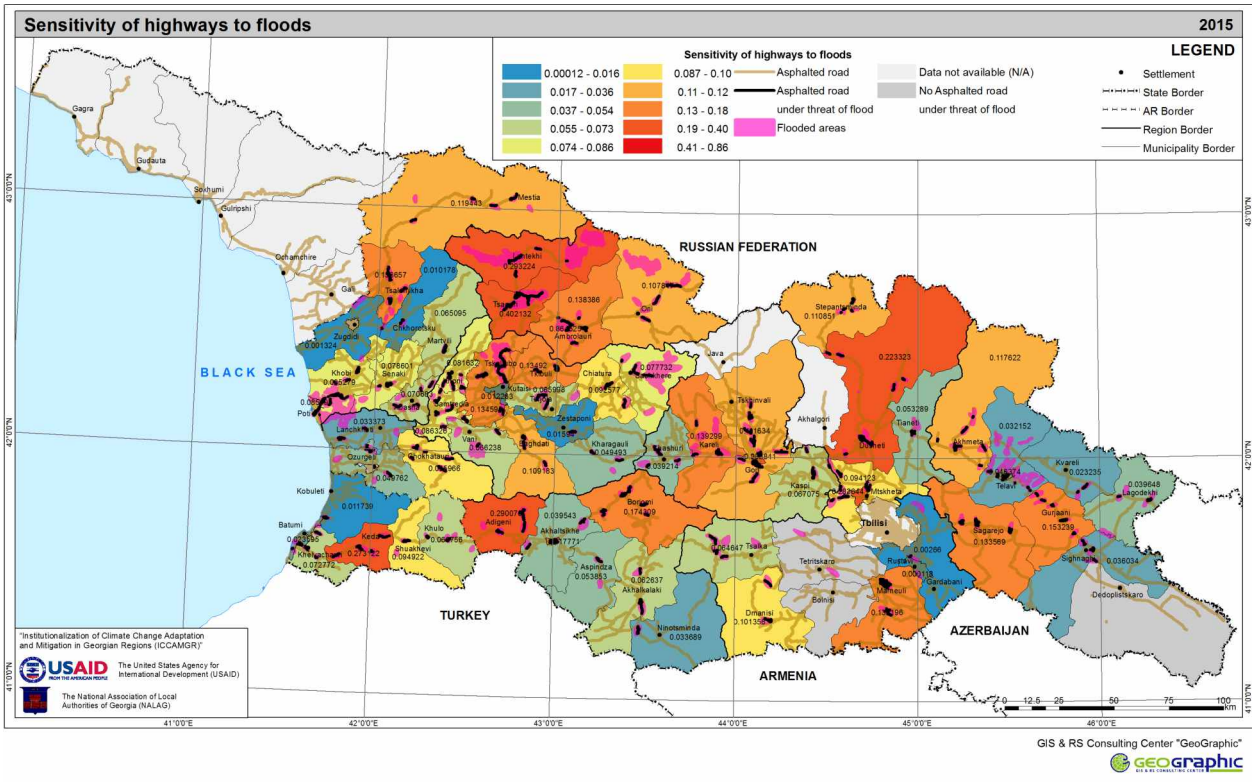
The map shows the risk of floods within separate municipalities. The risk is shown with colors from low risk to high risk. Risk coefficients are calculated by finding the ratio of the flooded areas of a municipality to the total area of the same municipality. Municipalities with a lower risk of floods are blue (Dedoplistskaro, Ninotsminds, Martvili, Kazbegi, Mestia, etc.), while the municipalities under high threat risk of floods are red or orange (Poti city, Khobi, Tskaltubo, Samtredia, Abasha, Batumi city).



Map 56. Sensitivity of municipalities to natural hazards (landslides, mudflows, coastal erosion, avalanches and floods)

This map shows the municipalities affected by all types of natural hazards recorded on the territory of Georgia, with the corresponding risk coefficients.

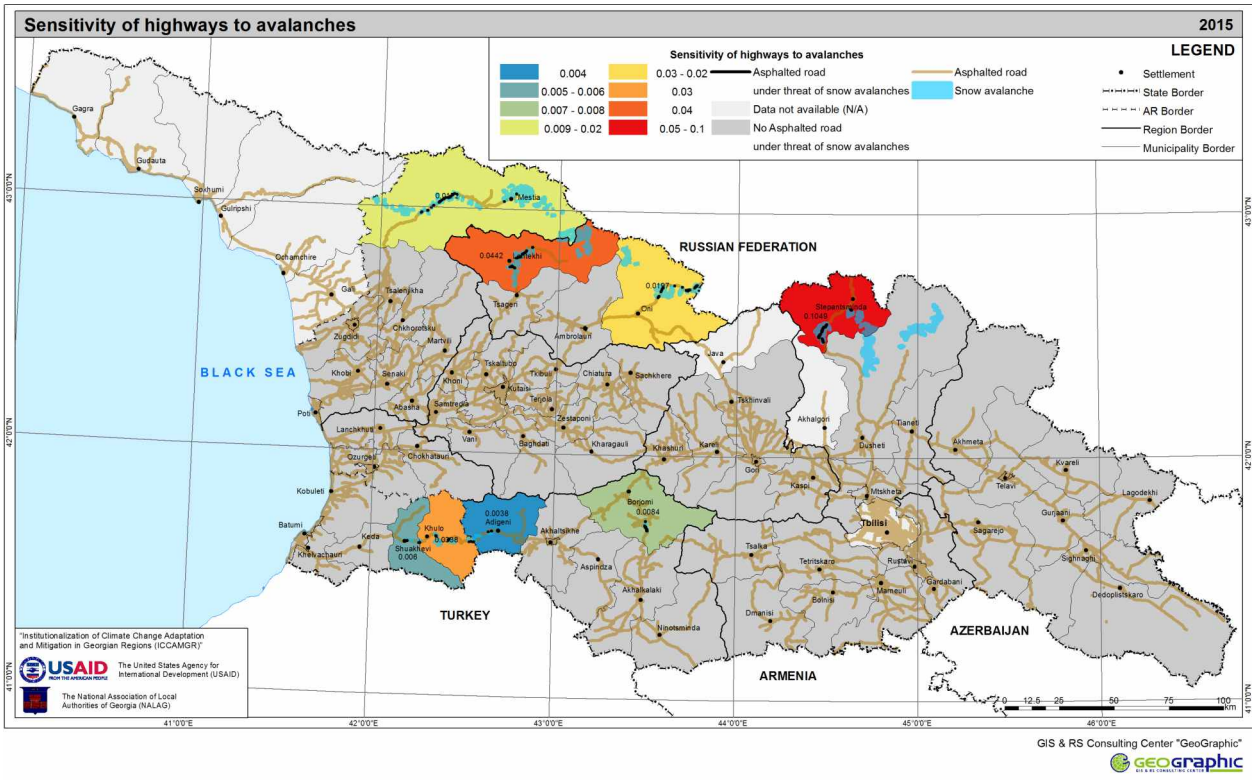
The municipalities that are the least affected by natural hazards are shown in light red (Dedoplistskaro, Ninotsminda, Akhalkalaki, Dmanisi, Marneuli, Gardabani and others) while those most affected by natural hazards are in dark red (Dusheti, Khulo, Tsageri, Kazbegi, Mestia, Ambrolauri, Kharagauli, Lentekhi and others).



Map 57. Sensitivity of highways to floods

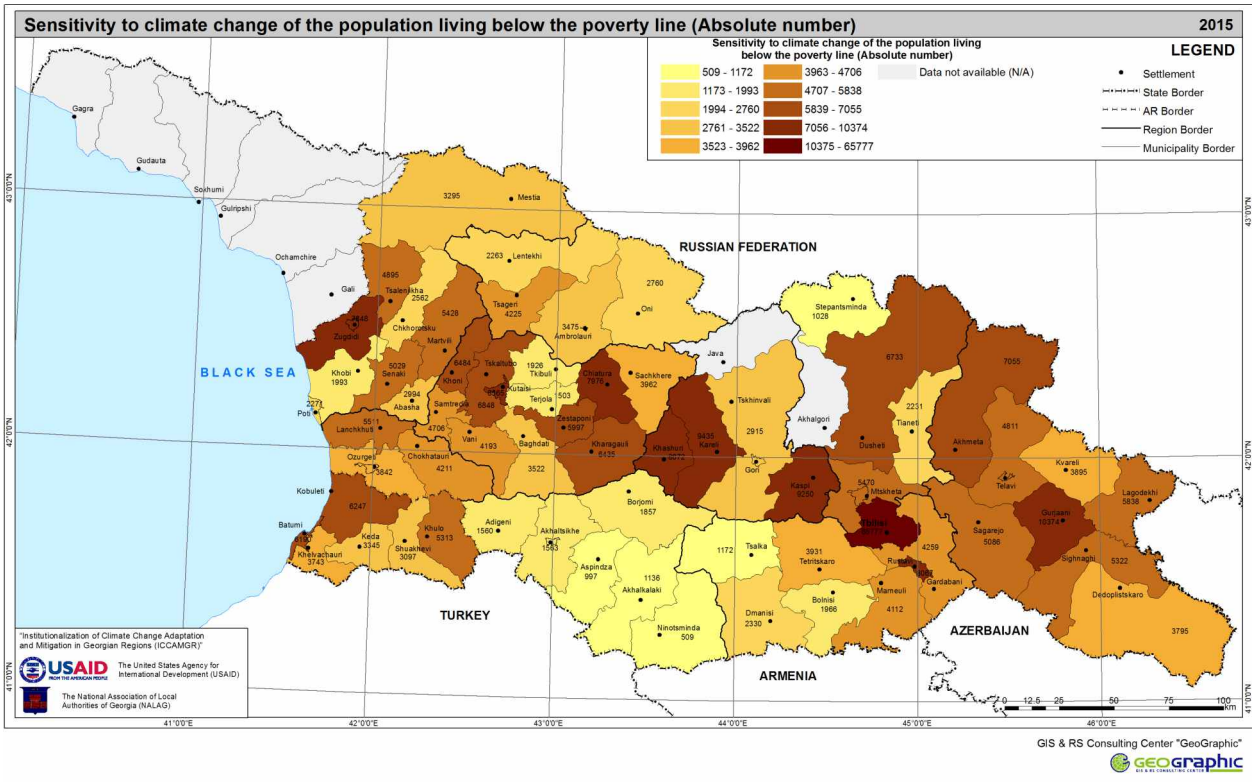
This map shows asphalted roads in flood-prone areas. The municipalities that are the least threatened by floods are shown in light red. The risk is calculated by finding the ratio of the area of asphalted roads under threat of flood within the municipality to the total area of asphalted roads within the same municipality. According to the obtained figures, the asphalted roads of Kobuleti, Zugdidi, Gardabani, Kvareli and Ninotsminda municipalities are under the lowest threat of floods and are shown in blue. The asphalted roads of Dusheti, Marneuli, Gurjaani, Samtredia, Tskaltubo and Kareli municipalities are under the highest risk of floods and are shown in red and orange.

It should be noted that the flooded areas are calculated taking into account a 100-year return period.



Map 58. Sensitivity of highways to avalanches

The map shows asphalted roads under threat of avalanches. The threat is calculated by finding the ratio of area of asphalted roads under threat of snow avalanches within the municipality to the total area of asphalted roads within the same municipality. The asphalted roads of Adigeni municipality (shown in blue) are under the lowest risk of avalanches, while the asphalted roads of Kazbegi, Lentekhi, Khulo, Mestia and Oni municipalities (shown in red, orange and yellow) are under the highest risk.

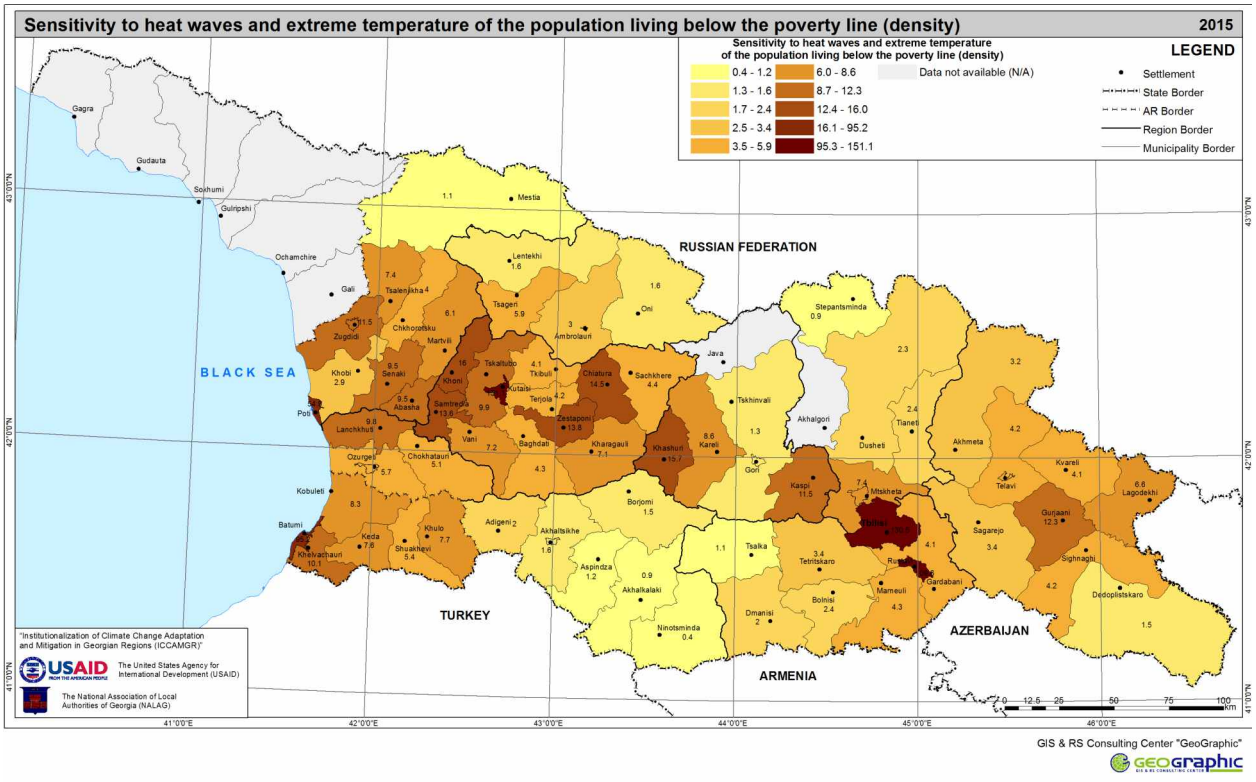


Map 59. Sensitivity to climate change of the population living below the poverty line (absolute number)

As Map 59 shows, the population below the poverty line is unequally distributed between the municipalities. There are large numbers of low-income populations living in the following urban territories: Tbilisi, Rustavi, Kutaisi and Zugdidi. In eastern Georgia, the low-income populations most sensitive to climate change are living in Gurjaani, Kaspi, Kareli and Khashuri, followed by Dusheti and Akhmeta. In western Georgia, the low-income populations most sensitive to climate change live in Chiatura, Samtredia, Khoni, Kobuleti and Batumi. The populations with the lowest levels of sensitivity are in Samtskhe-Javakheti and Kvemo Kartli.

Because of their financial and social situations, the population groups living below the poverty line are vulnerable to different aspects of climate change such as extreme temperatures (high and low), bad weather and more frequent natural disasters. Decision-makers should therefore seek ways to resolve these problems not only with regard to climate change, but also to improve the general social situation of these population groups.

Existing statistics show that the degree of sensitivity is dependent upon the absolute number of people in each municipality: where the population is high, the number of people below the poverty line is also high. On average, the percentage of the population living below the poverty line across municipalities fluctuates between 10 to 30 percent. For municipal leaders, therefore, the numerical presentation of the problem, either in percentage or absolute terms, does not make a difference. However, for central authorities, the absolute population size by municipality better characterizes the challenge on a national scale as social assistance comes mostly from the national budget; therefore the higher the absolute number of people below the poverty line, the greater amount of assistance is to be provided.



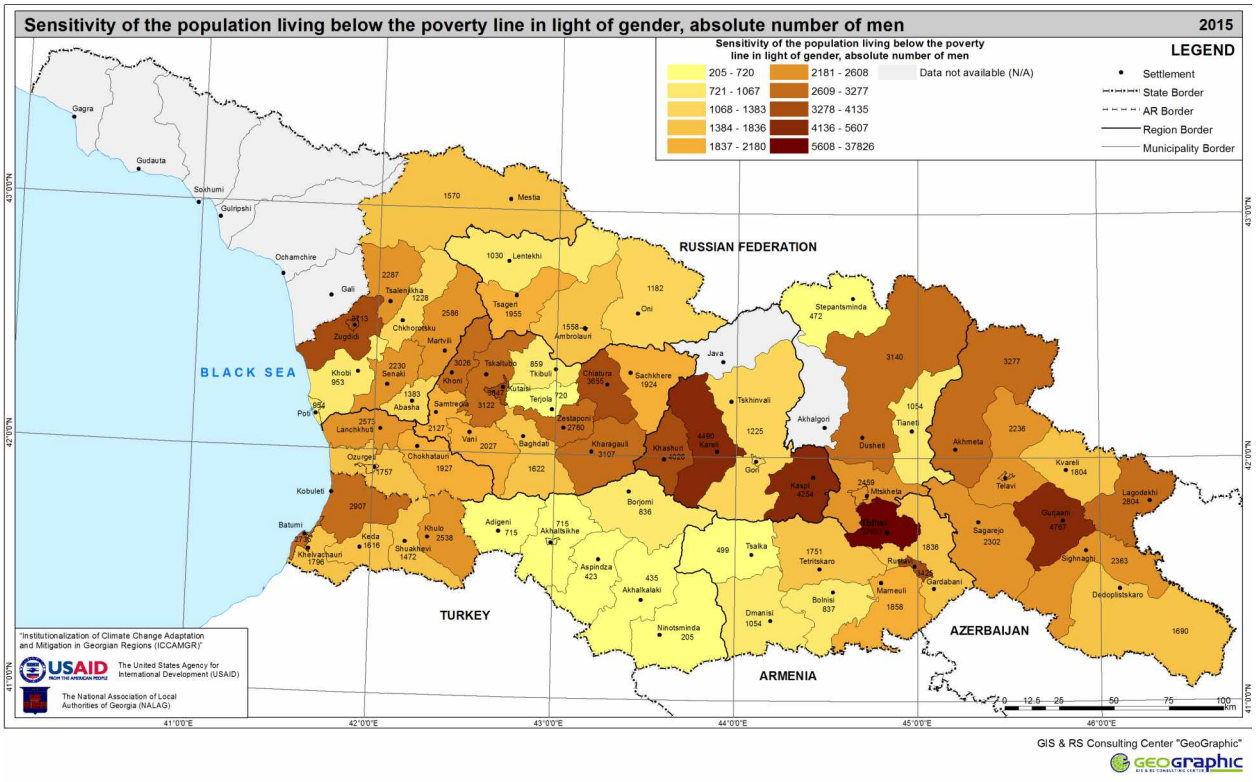
Map 60. Sensitivity to heat waves and extreme temperature of the population living below the poverty line (density)

Urban populations are particularly sensitive towards extreme temperature and heat waves because of the so called "urban heat island effect" in densely populated areas or urban territories, in which white-hot asphalt and buildings heat the air further.

As Map 60 shows, the density of the population below the poverty line (i.e. a sensitivity indicator) is high in urban territories such as Tbilisi, Rustavi, Kutaisi, Batumi and Poti. Other municipalities particularly sensitive to climate change are mostly ones from western Georgia, such as Chiatura, Zestaponi, Khoni, Samtredia, Zugdidi, Senaki, Abasha, Lanchkhuti, Tskaltubo and Khelvachauri. In eastern Georgia, the highest sensitivity rate to heat waves and extreme temperatures, after Tbilisi and Rustavi, is demonstrated in Khashuri, then Kaspi and Gurjaani. The lowest rate in terms of both absolute numbers and density is in Samtskhe-Javakheti and Kvemo Kartli. It should be noted that the "new" self-governance cities[191], such as Gori, Telavi and Mtskheta among others, lack comprehensive information about the populations below the poverty line as of 2015. If this information becomes accessible in eastern Georgia, the picture might change significantly, with the above-mentioned self-governance cities standing out as more sensitive towards extreme temperatures. In this case, adaptation measures for extreme temperatures should be applied in these cities too.

Given that the poor are mainly gathered in densely populated cities, attention should be paid to this vulnerable group during the planning and the implementation of adaptation measures. These initiatives may include the relevant arrangement of infrastructure of settled areas, growth of health care system flexibility and effectiveness and improvement of the social security system in the municipalities in question.

[191] These cities were created in 2014 as a result of the self-governance reform. As a result, this data is not yet present in the database of the Ministry of Health and Social Security.



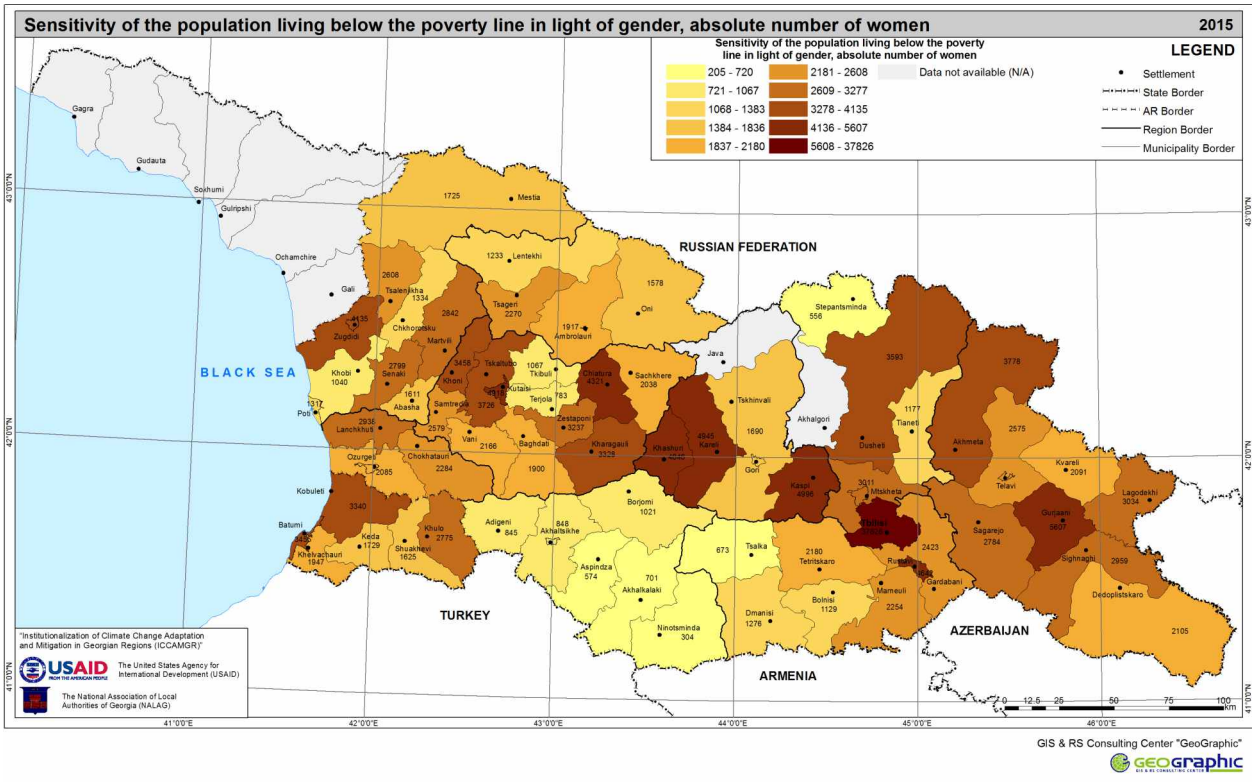
Map 61. Sensitivity of the population living below the poverty line in light of gender (absolute number of men)

As Map 61 shows, the number of men living below the poverty line is unequally distributed in the municipalities. The number is particularly high in urban territories: Tbilisi, Rustavi, Kutaisi, and Batumi. In eastern Georgia, the sensitivity indicator (number of men below the poverty line) is highest in Gurjaani, Kaspi, Kareli and Khashuri, followed by Dusheti and Akhmeta; in western Georgia, it is in Chiatura, Samtredia, Khoni, Zugdidi, Kobuleti and Batumi. The lowest indicators are found in Samtskhe-Javakheti and Kvemo Kartli.

Because of their financial and social situation, men below the poverty line are vulnerable to different aspects of climate change such as extreme temperatures (high and low), bad weather and more frequent natural disasters among others. Therefore, decision-makers should seek ways to resolve the problem both in terms of climate change and poverty alleviation.

Presumably, the degree of sensitivity is dependent on the absolute number of men in each municipality: where the population is high, the number of men below the poverty line is also high. The percentage of men below the poverty line, according to the municipal data, varies from 5 to 15 percent. For municipal authorities, the presentation of the data, either as an absolute number or percentage, is not an issue of relevance. However, for central authorities, the absolute population size by municipality describes the challenge on a national scale as social assistance comes from the national budget. As such, the higher is the absolute number of people living below poverty line, the larger is the budget allocation for social assistance[192].

[192] Men and women are considered separately since women, due to their physiology, social status or for other reasons, are more vulnerable to climate change. See Gender, Climate Change and Health, WHO, op. cit.



Map 62. Sensitivity of the population living below the poverty line in light of gender (absolute number of women)

As Map 62 shows, the number of women living below the poverty line is unequally distributed between municipalities. The number of women, or the climate change sensitivity indicator, is particularly high in urban areas: Tbilisi, Rustavi, Kutaisi and Zugdidi. In eastern Georgia, the highest sensitivity rates are in Gurjaani, Kaspi, Kareli and Khashuri, followed by Dusheti and Akhmeta; in western Georgia, they are in Chiatura, Samtredia, Khoni, Kobuleti and Batumi. The lowest indicators are found in Samtskhe-Javakheti and Kvemo Kartli.

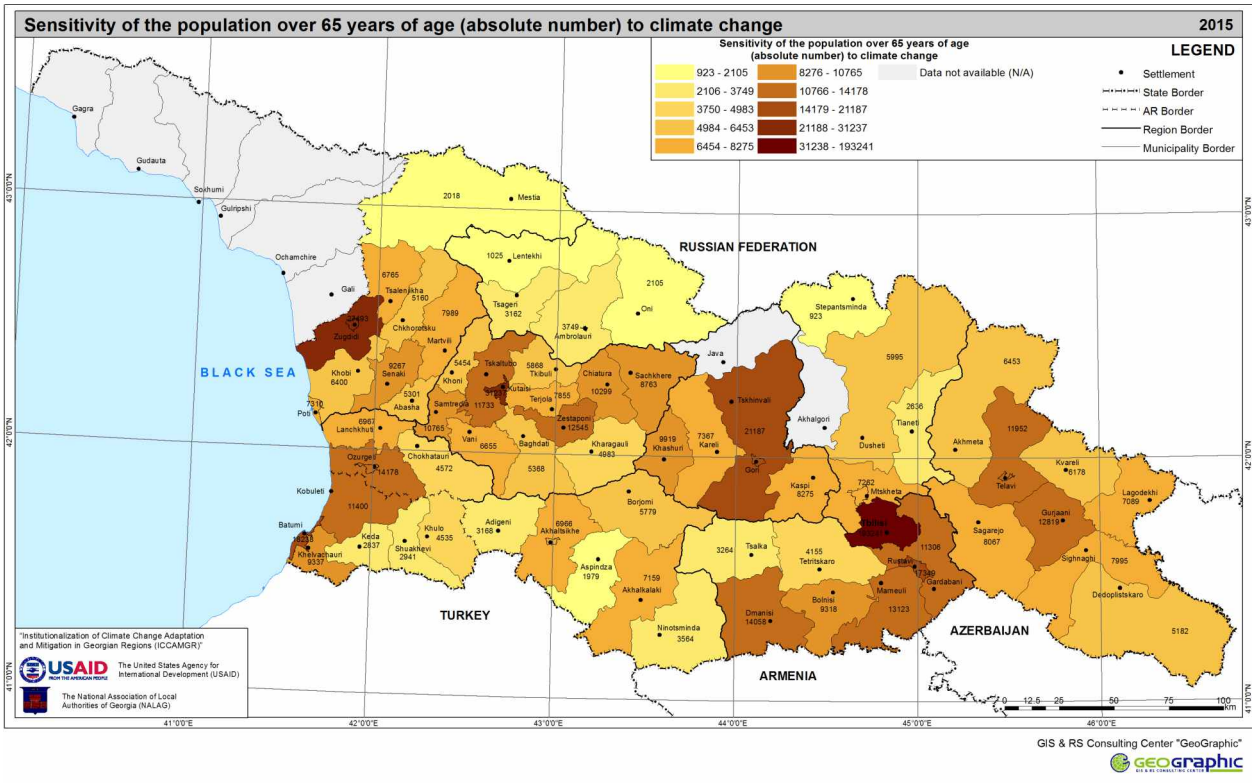
In comparing Maps 61 and 62, more women live below the poverty line at the national level than men. Due to their socio-economic situation and their physiology, women below the poverty line are more vulnerable than men towards different exposures of climate change, such as extreme temperatures (high and low), bad weather and more frequent natural disasters among others[193]. Decision-makers should therefore pay more attention to solving women's problems both in terms of adaptation to climate change and poverty alleviation.

In those municipalities where the number of women below the poverty line is high, the problem of adaptation to climate change is more acute as these municipalities are then more vulnerable towards climate change. On average, the percentage of women below the poverty line, by municipality, varies from 8 to 18 percent. For municipal authorities, the presentation of the data, either as an absolute number or percentage, is not an issue of relevance. However, for central authorities, the absolute population size by municipality describes the challenge on a national scale as social assistance comes from the national budget. As such, the higher the absolute number of people living below the poverty line, the larger the budget allocation for social assistance[194].

To solve this problem, municipal and national government should facilitate the improvement of women's socio-economic circumstances to support better adaptation to climate change.

[193] Gender, Climate Change and Health, WHO, op. cit.

[194] Men and women are considered separately since women, due to their physiology, social status or for other reasons, are more vulnerable to climate change. See Gender, Climate Change and Health, WHO. op. cit.



Map 63. Sensitivity of the population over 65 years of age (absolute number) to climate change

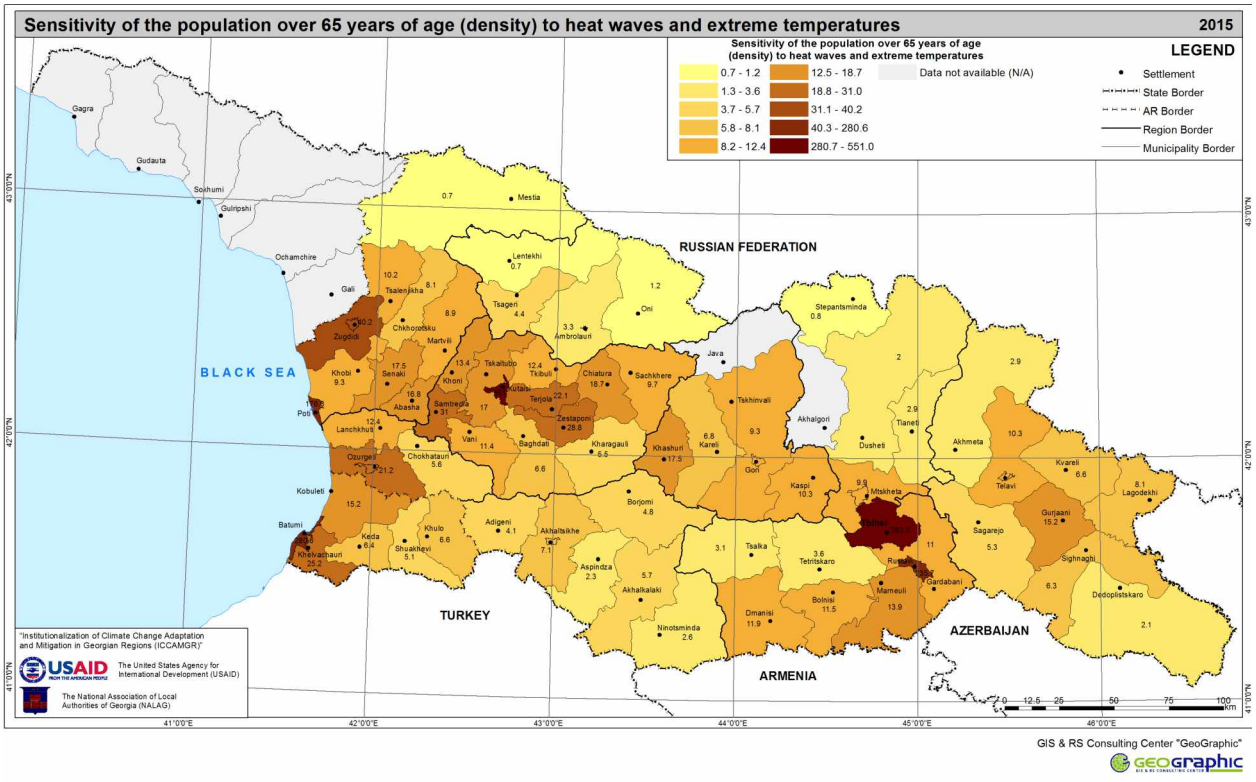
As Map 63 shows, the population over 65 is unequally distributed in the municipalities. The density of this population group, or the sensitivity indicator, is particularly high in urban territories: Tbilisi, Rustavi, Kutaisi, Batumi and, to a lesser extent, Poti. In other municipalities of eastern Georgia, the highest sensitivity levels are in Dmanisi, Marneuli, Gurjaani and Telavi; in western Georgia, they are in Ozurgeti, Zestaponi, Kobuleti and Zugdidi.

The population over 65 is particularly vulnerable to the different impacts of climate change, such as high extreme temperatures and more frequent natural disasters. This is due to their age, decreased adaptation ability to different external factors and, often, deteriorating health.

The degree of sensitivity is dependent on the absolute population number in each municipality: in those municipalities with a high population density, the percentage of the population over 65 is also high. On average, the percentage of the population over 65 varies from 20 to 25 percent, according to the municipalities. For municipal authorities, the presentation of the data, either as an absolute number or percentage, is not an issue of relevance. However, for central authorities, the absolute population size by municipality describes the challenge on a national scale as social assistance comes from the national budget. As such, the higher the absolute number of people living below the poverty line, the larger the budget allocation for social assistance.[195]

To increase the adaptation ability of the population over 65, the health care system needs to become more flexible and effective. It is also necessary to teach adaptive behavior to this demographic group, and manage urban infrastructure in a way to enable them to more comfortably tolerate the climate change exposures. In addition, increasing the amount allocated through the pensions' system would help to alleviate their economic situation.

[195] Men and women are considered separately since women, due to their physiology, social status or for other reasons, are more vulnerable to climate change. See Gender, Climate Change and Health, WHO, op. cit.



Map 64. Sensitivity of the population over 65 years of age (density) to heat waves and extreme temperatures

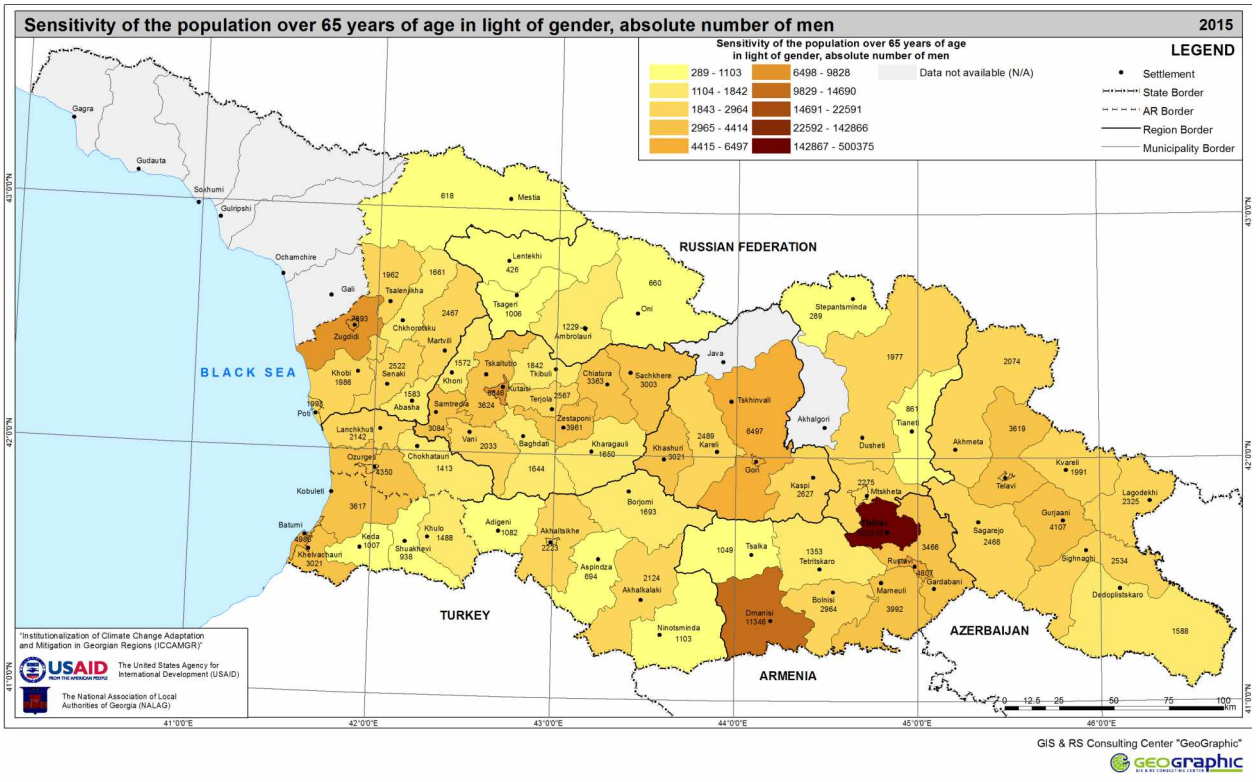
The urban population is particularly sensitive to extreme temperature and heat waves since densely settled urban areas experience an "urban heat island effect", in which "white-hot" asphalt and buildings further heat the air.

As Map 64 shows, the density of the population below the poverty line (i.e. a sensitivity indicator) is high in urban territories such as Tbilisi, Rustavi, Kutaisi, Batumi and Poti. In contrast to socio-economic indicators, however, the distribution of the population over 65 is more or less similar all over the country. After the main cities, the number of old people is high in the following municipalities: Marneuli, Gurjaani, Khashuri, Zestaponi, Terjola, Samtredia, Zugdidi, Ozurgeti and Khelvachauri. It should be noted that, as of 2015, there is no available information on the population over 65 for the "new" self-governing cities[196] of Gori, Telavi, Mtskheta, Akhaltsikhe, Zugdidi and Ozurgeti.

This demographic group is very vulnerable to those climate change-related diseases that are particularly active during extreme temperatures.

Given that the population over 65 is mainly gathered in densely populated cities, this population group should receive particular attention during the planning and implementation of adaptation measures in relevant municipalities in order to support these population groups tolerate the potential problems due to climate change. These include appropriate arrangement of populated areas' infrastructure, improvement of health system flexibility and effectiveness, provision of relevant information to these vulnerable groups.

[196] These "self-governing cities" were created in 2014 as a result of self-governance reform. As a result, this data is not yet present in the database of the Ministry of Health and Social Security.

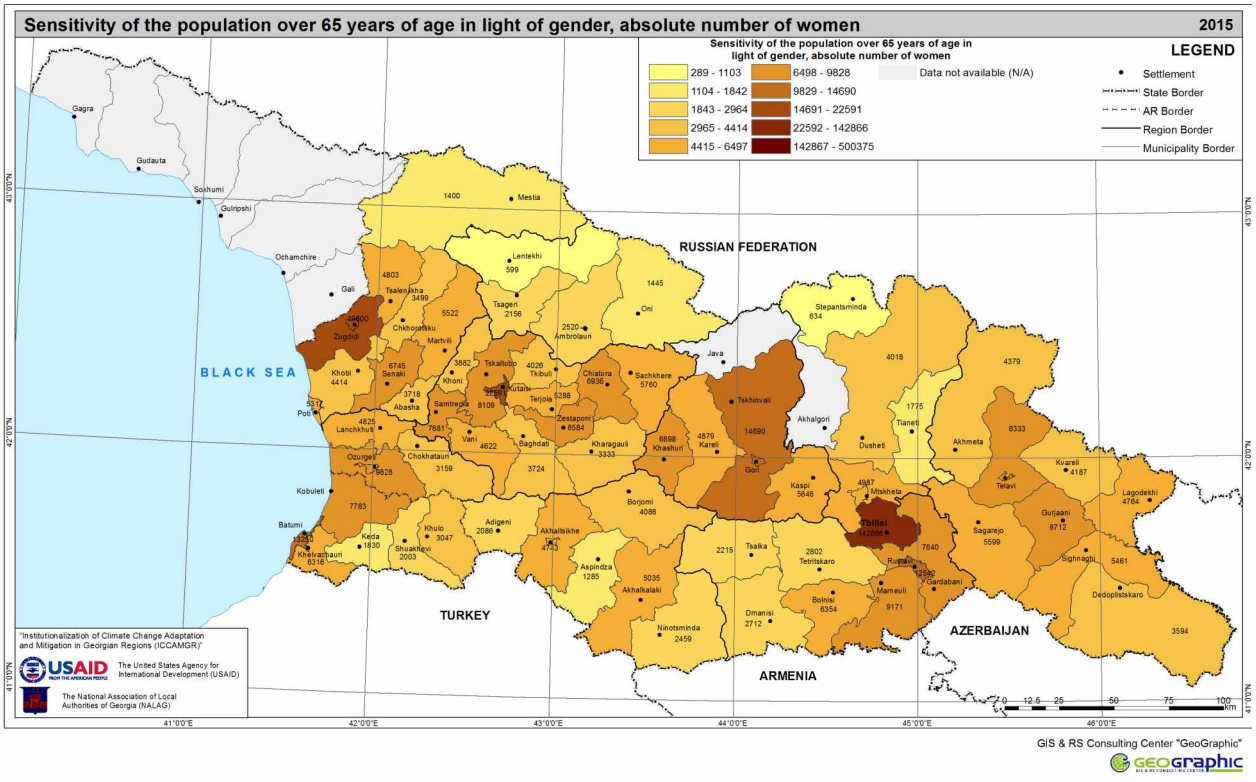


Map 65. Sensitivity of the population over 65 in light of gender (absolute number of men)

As Map 65 shows, the number of men over 65 is unequally distributed in the municipalities. The highest rate is evidenced in Tbilisi, then in Dmanisi, Zugdidi, Kutaisi, Batumi and Gori. In the rest of municipalities the number fluctuates between 289 and 4,144.

Men over 65 are vulnerable to different impacts of climate change, such as high extreme temperatures and more frequent natural disasters. This is due to their age, their lowered ability adapt to different external factors and, often, because of deteriorating health.

To increase the adaptation ability of men over 65, the health care system needs to become more flexible and effective. It is also necessary to teach adaptive behavior to this demographic group, and manage urban infrastructure in a way to enable them to more comfortably tolerate the climate change exposures. In addition, increasing the amount allocated through the pensions' system would help to alleviate their economic situation.



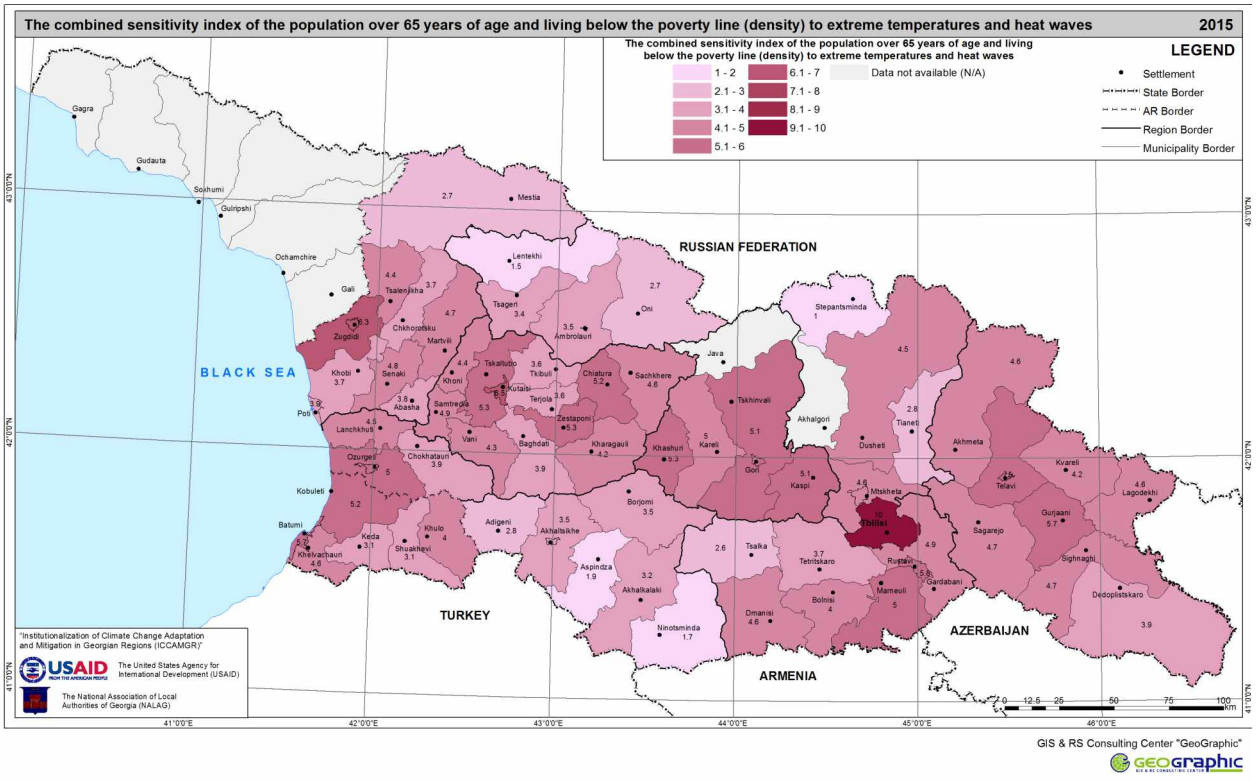
Map 66. Sensitivity of the population over 65 years of age in light of gender (absolute number of women)

As Map 66 shows, the number of women over 65 is unequally distributed in the municipalities. The highest rate is evidenced in Tbilisi, followed by Dmanisi, Zugdidi, Kutaisi, Batumi and Gori. In the rest of municipalities, the number varies between 289 and 6,497.

Women over 65 are more vulnerable than men to different aspects of climate change manifestation: high extreme temperatures, more frequent natural disasters, sharp changes in weather among others[197]. This is due to their age, their lower adaptation ability to different external factors, physiological and physical factors and, often, because of deteriorating health. A comparison of Maps 7 and 8 shows that, nationally, there are more women than men over 65. The only exception is Dmanisi, where the number of men over 65 is higher than that of women. Since women are more vulnerable to different manifestations of climate change, those municipalities where this demographic group is larger are particularly sensitive to climate change.

To increase the adaptation ability of women over 65, the health care system needs to become more flexible and effective. It is also necessary to teach adaptive behavior to this demographic group, and manage urban infrastructure in a way to enable them to more comfortably tolerate the climate change exposures. In addition, increasing the amount allocated through the pension system would help to alleviate their economic situation.

[197] Gender, Climate Change and Health, WHO. op. cit.



Map 67. The combined sensitivity index of the population over 65 years of age and the population living below the poverty line (density) to extreme temperatures and heat waves

To create the combined sensitivity map, after normalizing the absolute number of the population over 65 and below the poverty line, weights were attached to the indicator of the population over 65 (60%), and to the indicator of the population below the poverty line (40%)[198]. By combining these two data points, researchers calculated the aggregated sensitivity index, on the basis of which the map was designed.

The urban population is very sensitive to extreme temperatures and heat waves because densely populated areas experience an "urban heat island effect", in which "white-hot" asphalt and buildings heat the air further. Thus, to mark out the population in urban areas, in addition, the absolute number of the population over 65 and below poverty line, a aggregated sensitivity index was developed that used relative numbers to show density. As demonstrated from the combined map, the aggregated sensitivity index is particularly high in densely populated cities: Tbilisi, Rustavi, Kutaisi, and Batumi. High indexes are demonstrated in Zugdidi, Gurjaani, Telavi, Marneuli, Gori, Kaspi, Khashuri, Kobuleti, Ozurgeti, Samtredia, Chiatura and Zestaponi. As with the other maps, the absence of data for the newly established self-governance cities means that these cities are not marked out on the maps, although these cities, too, presumably must show high indices. Tbilisi shows a very high sensitivity for both combined indicators, because for both indicators it has a particularly high rate.

The combined sensitivity map shows that western Georgia is far more sensitive than eastern Georgia. Particular attention should be shown by local leadership of Imereti, Samagrelo, Guria and Adjara, which have several municipalities with high number indices of socially unprotected groups.

[198] Weights were attached on the basis of an expert summary: the population over 65 is far more sensitive to extremely high temperature than the poor population.

4. IMPACTS OF CLIMATE CHANGE ON GEORGIA'S MUNICIPALITIES

4.2.1. Impacts of climate change on tourism

In order to assess the impact of climate change on tourism, two main parameters were used: the climate change pattern and tourism sensitivity indexes. The degree of the impact of climate change on tourism within the municipalities of Georgia was determined on that basis. The climate exposures to which tourism is most sensitive were selected as a climate exposure indicator. In terms of sensitivity to climate conditions, there is an essential difference between two main tourism types: winter and summer tourism.

Winter tourism includes: relatively old resorts, such as Bakuriani (Borjomi municipality) and Gudauri (Kazbegi municipality); new alpine skiing centers, such as Hatsvali and Tetnuldi (Mestia municipality), Goderdzi (Khulo municipality), Betania (Didgori district of Tbilisi) and Aragva (Akhalkalaki municipality); and also promising winter resorts, such as Bakhmaro (Chokhatauri municipality) and Gomismta (Ozurgeti municipality).

In terms of climate change, winter tourism centers everywhere are sensitive to the amount and quality of snow. However, the problems winter tourist centers face also vary by region. In eastern and southern Georgia (Gudauri and Bakuriani among others), the main problems are associated with the shortage of snow in the winter season. While western and northern regions, especially the regions of mountainous Adjara and Guria, are known for overly abundant precipitation in wintertime. For example, the snow cover in some places of Bakhmaro resort may run up to 5-6 meters in winter.

Finally, the most risky and general climatic parameter for all centers – change in the average annual number of days with snow cover – was selected as an indicator of the impact of climate change on winter tourism in the regions of Georgia.

Summer tourism in Georgia is diverse. The most popular types of summer tourism in Georgia can be grouped as follows:

1. Medical health tourism (seashore, lowland and highland resorts and pleasure resorts);
2. Educational tourism (travel for the purpose of learning about the country's nature, history, culture, regional ethnography and folklore);
3. Rural tourism and agrotourism (wine tours among others);
4. Business tourism; and
5. Ecological tourism.

The summer tourism season lasts from one to three months, depending on the region. The temperature becomes relatively comfortable for tourists in summer resorts and the main tourist regions comparatively late, in June-July. The tourist flow reaches its peak in August, and starts to decline by mid-September. Given such a short season, when tourist travel lasts ten days on average, the number of clear or sunny days is of great importance. Abundant precipitation becomes the cause of low revenues and can endanger the tourist season. Therefore, comparative change of the average annual precipitation in summer months has been selected as an indicator of the impact of climate change on tourism in the regions of Georgia.

Researchers used tourism sensitivity by municipality and the climate change indicators in summer and winter tourism to develop the indexes of the impact of climate change on tourism:

1. For winter tourism

$$TIIw = TSI \times SD$$

Where TIIw is the impact of climate change on the winter tourism index; TSI is the tourism climate change sensitivity index; and SD is the change in the average number of days with snow cover – projections for Future 1 (2021-2050) and Future 2 (2071-2100) (see Maps 68 and 80).

2. For summer tourism

$$TIIs = TSI \times Ps$$

Where TIIs is the impact of climate change on the summer tourism index; TSI is the tourism climate change sensitivity index, and Ps is the comparative change in the average annual number of rainy days in the summer months – projections for Future 1 (2021-2050 and Future 2 (2071-2100) (see Maps 69 and 81).

By using these indexes, two aggregated maps of the impact of climate change in the municipalities of Georgia have been compiled (see Maps 70 and 82). These maps reflect the aggregated potential impacts of climate change on tourism for these projected periods in the Georgian municipalities.

4.1.2. Impacts of climate change on cultural heritage

Under comparatively stable climate conditions, many monuments of cultural heritage, both movable and immovable, have managed to withstand the test of time. However, a number of studies highlight that climate change accelerates damage to such monuments. Cultural heritage is at risk for gradual damage through deteriorating climate conditions, such as increased wind and water erosion, sharp temperature changes, as well as the increased frequency of natural disasters and their scale. Action on the first factor requires special analysis and further conservation work, while responding to the second requires implementation of complex measures that involves local authorities where possible.

It should be mentioned that Georgia, as a country with complex mountain relief, is at risk of increasing natural disasters as a result of climate change, the most noteworthy of which are avalanches, stone falls, landslides, mudflows and inundation as a result of flooding and coastal erosion among others.

Avalanches and floods, two of the climate change impact risk factors mentioned, have spatial characteristics, involving flood risk zones and avalanche risk zones; while other potential natural disasters lack spatial characteristics of distribution. Please see subchapter on natural disasters 3.5 and 4.5.

It is possible to measure the extent of the impact of climate change on immovable monuments by the number of monuments within predicted flood and avalanche risk zones. In the event a UNESCO World Heritage Site or a site from the UNESCO Tentative List is in such an area, the climate change impact is designated as "Especially Negative", A and B categories. Other categories are: Very High (6 and above); High (5); Average (4); Low (3); Small (2); Smallest (1). The impact of climate change on the immovable historic and cultural monuments in the municipalities of Georgia is presented on Map 84: The potential impact of climate changes (floods and avalanches) on immovable historic and cultural monuments until the end of the 21st century.

It is possible to measure the extent of the impact of climate change on museums by the number of museums within the risk zones of predicted floods and avalanches. Comparison of the territorial distribution of museums, avalanches and floods shows that no museum located within the municipalities of Georgia falls within predicted flood and avalanche risk zones (see Map 85).

Please see Table 6 below of different natural disasters that threaten monuments in Georgia:

Table 6. Natural disasters threatening immovable monuments of the cultural heritage of Georgia

Municipality	Monument	Category	Natural hazard
Martvili	Martvili Church	National importance	Negative geological processes (generally landslide phenomena)
Aspindza	Vardzia Monastic Complex	UNESCO Tentative List	Gravitational processes: stone falls, rock falls and block faulting
Akhmeta	Alaverdi Cathedral	UNESCO Tentative List	Mudflows and river bank erosion, flooding
Borjomi	Timotesubani Monastery	National importance	Flash Floods
Gori	Uplistsikhe Rock-cut City	UNESCO Tentative List	Severe flooding
Dusheti	Shatili Medieval Fortress Village	UNESCO Tentative List	Landslides and gravitational phenomena, mudflows, avalanches, floods and erosive processes
Dusheti	Mutso Fortress-Village	UNESCO Tentative List	Landslides and gravitational phenomena, mudflows, avalanches, floods and erosive processes
Zugdidi	Kortskheli Church (10th-11th century)	Local importance	Landslide processes
Telavi	Ikalto Monastery Complex	National importance	Flash floods
Kaspi	Iron Complex	National importance	Flooding, erosion
Mtskheta	Shiomghvime Monastery Complex	National importance	Gravitational processes
Mtskheta	Jvari Monastery	UNESCO World Heritage Site	Gravitational processes
Mtskheta	Bebristsikhe Fortress	Local importance	Gravitational processes and flooding
Signagi	Bodbe Monastery	National importance	Landslides
Khobi	Kheti (Kortskho) St. Theodore Church	Local importance	Ground contraction processes
Khobi	Zemo (Upper) Bia Archangel's Church	Local importance	Ground contraction processes
Khobi	Khobi Monastery Complex	National importance	Ground contraction processes
Chiatura	Katskhi Pillar "Katskhi Sveti"	National importance	Landslide and gravitational processes

4.1.3. Impacts of climate change on protected areas

As the United Nations Convention on Biological Diversity states, "Protected areas are the cornerstone of biodiversity conservation; they maintain key habitats, provide refuge, allow for species migration and movement and ensure the maintenance of natural processes across the landscape[199]".

Protected areas have preserved rare forms of living and non-living nature (landscapes, ecosystems, natural monuments), which were established as a result of interaction between different natural factors, and have maintained balance due to different characteristics, including a stable climate.

As a result of climate change, this balance has become endangered. Not only are the climatic conditions of the protected areas changing, but so too are the other natural factors that condition them (i.e. relief, accessibility and amount of water resources and soil among others). Finally, the impact of climate change on landscapes and ecosystems has a multiplier effect. Thus, it can be concluded that protected areas are sensitive to almost all climate exposure indicators (see climate change exposure indicators in Table 1).

The degree of the impact of climate change in protected areas is measured by a combination of two indexes: the protected areas sensitivity and climate exposure (aggregated climate change exposure). These parameters are reflected in the following formula:

PAII = PASI x CC

Where PAII = the protected areas' climate change impact index; PASI = protected areas' sensitivity index; and CC = climate change aggregated index per municipality; for Future 1: 2021-2050 and Future 2: 2071-2100.

The varying impact of climate change on protected areas is shown by municipality on two special maps (see Map 71 and 83).

[199] Convention of Biological Diversity (CBD): https://www.cbd.int/protected/overview (accessed March 20, 2016).

4.2.1 Methodology of assessment of potential impact of climate change on agriculture

An accurate forecast of the multifactor climate change impact on agriculture requires both significant time and long-term research. It is a complex and problematic issue, but reasonably convincing results can be achieved by using existing standards and recognized methods and by taking into account the main parameters only.

The potential impact of climate change was assessed for the two projection periods: Future 1 (2021-2050) and Future 2 (2071-2100). Three climatic parameters (climate exposure indicators) were used to assess the potential impact of climate change:

a) Temperature and precipitation change: temperature and precipitation change parameters are used for the most vulnerable and critical period for a plant's growth and development, namely the summer period.

   To measure temperature change, the correlation of the value of absolute temperature changes in summer months for the projection periods with the average perennial value of the summer temperatures for the baseline period (1960-1990) was derived because even where the value of the absolute temperature increment is the same, the temperature increment impact will vary for different regions and municipalities.

   The impact of seasonal precipitation change per hectare (in the summer months) was considered in relation to the irrigation rate/water amount to be supplied to an agricultural plant, because a change in precipitation will alter the irrigation rate. It should be mentioned that every 1 mm of precipitation corresponds to 10 m^3 of water per hectare.

b) Wind speed change: the absolute wind speed value for each municipality is derived according to the data of the Georgian Institute of Hydrometeorology of the Georgian Technical University and represents the sum of the wind speed value and its projected change from the baseline period[200]. To forecast wind erosion on the basis of this parameter and taking into account the annual precipitation change, the eroded soil volume change indicator was derived.

To determine the climate change impact on agriculture, the sensitivity indicators and indices should be combined with the climate change exposure indicators:

The sensitivity of agricultural crops to moisture change was combined with the temperature and precipitation change in summer months, which conditions the moisture change:

$$O_w = S^{0,2} \cdot (\Delta T / T)^{0,4} \cdot (\Delta W / M)^{0,4}, \quad (7)$$

Where O_w = the climate change impact on agricultural crops in relation to moisture change; S = sensitivity of agricultural crops to moisture change, depending on (a) the sensitivity of the irrigation rate of agricultural crops in the baseline period (2015) to moisture change, (b) utilization of the designed irrigation and drainage systems and (c) actual utilization of irrigation and drainage systems; T = temperature increment in summer months of the projected period (^{0}C); T = average temperature of summer months of the baseline period (^{0}C); W = change of moisture amount per hectare caused by the precipitation change in summer months, to be calculated by the following formula:

$$\Delta W = 10 \cdot \Delta P, \ (m^3) \quad (8)$$

[200] E. Sukhishvili. "Average annual wind speed", Tbilisi, 1985.

Where P = precipitation change in mm; M = irrigation rate m3 per hectare. The produced data are presented on Maps 72 for Future 1 (2021-2050) and 85 for Future 2 (2071-2100).

Sensitivity of agricultural lands to water and wind erosion was combined with the precipitation change indicator (exposure indicator) and the indices of eroded soil area change for the projection periods, which is affected by wind speed change;

$$O_{ER}=S^{0,2} \cdot (\Delta W / M)^{0,4} \cdot (G_{PT} / G_B)^{0,4} , \quad (9)$$

Where O_{ER} = climate change impact on agricultural lands in relation to water and wind erosion enhancement; S = sensitivity of agricultural lands to water and wind erosion dependent on the ratio of eroded areas due to water and wind erosion during the baseline period (2015) to total agricultural land areas in each municipality; W/M = moisture change for the projection periods. It is implied that a change in the amount of moisture supplied to an agricultural plant causes a change in the irrigation rate and as a result, a change of the irrigation (water) erosion impact; G_{PT}/G^B = ratio of the quantity of ground transported by the climatic factors of wind erosion in the projection (G_{PT}) and baseline (G_B) periods.

The ground amount transported by climatic factors (G) is calculated by the formula:

$$G=3,86V^3 / (10PE)^2 \quad (10)$$

Where V = average annual wind speed, m/sec; PE = climate index calculated by the following expression:

$$PE=0,316 [P/(1,8T+22]^{0,4} \quad (11)$$

Where P = average annual precipitation total, mm, T = average annual temperature, ^{0}C.

The results are presented in Map 73 for Future 1 (2021-2050) and 86 for Future 2 (2071-2100).

The erosion intensity is calculated as 1 ton of soil loss per ha. In modern farming, the plowing depth ordinarily reaches 15–20 cm and the weight of plowed soil (inverted topsoil) approaches 2,250 t/ha. Here the ordinary technology applied in Georgia is considered, which does not imply “beardless” plowing in most cases. If we assume that the erosion speed per annum reaches 33 t/ha on average, then 0.25 cm soil will be lost every year, while the loss of the entire topsoil will take 60–70 years.

It should be noted that annual agricultural crops, given their biological traits, fail to protect the topsoil from erosion due to downpours and surface runoffs in the early vegetation period. In the said period, the soil most of all needs to be subjected to conservation measures, which largely consist of intensive soil loosening, surface furrowing, and cutting broken beds. On sloped surfaces, e.g. for corn (or maize), instead of cutting broken beds for corn planting, the piling of soil up around the maize base will suffice; this will retain water flow in hollows formed within the land area, thereby enhancing the soil infiltration capacity and water seepage into the soil.

4.2.2. Impacts of climate change on agriculture

In the medium- and long-term outlook, climate change can have a significant impact on the change in the water application requirement of plant and soil conditions (its moisture content, erosion processes, productivity, etc.), as well as on the agro-calendar and crop zoning.

Water supply to agricultural crops: according to meteorological data, in 2021-2050 both the average annual as well as summer temperatures will increase. In addition, summer precipitation will decline everywhere, except for Abasha, Zugdidi, Kaspi, Lanchkhuti, Lentekhi, Martvili, Mestia, Ozurgeti, Samtredia, Senaki, Keda, Kobuleti, Stepantsminda, Chkhorotsku, Tsalenjikha, Kharagauli, Khelvachauri, Khobi and Khoni municipalities. An agricultural plant is most vulnerable to climate change (temperature and precipitation) in the vegetation period. The summer seasonal temperature, together with the precipitation decline in the same period, under conditions of non-irrigation of agricultural crops will affect their growth and cause their destruction unless the appropriate adaptive measures are taken. In the same period, average wind speed will vary significantly, with some municipalities expecting an increase in wind speed, and others forecast to encounter a decrease[201].

In 2021–2050, in the municipalities where irrigation systems are in operation, the existing irrigation regime and irrigation rates generally meet the water requirements of a plant. In individual municipalities, the irrigation rate may increase. Precipitation decline may positively affect operation of drainage systems. In the municipalities where a precipitation increase is projected, an insignificant prolongation of rainwater stagnation time will be observed.

In 2071–2100, the temperature growth tendency will be more pronounced; the precipitation total, both annual and in the summer period, will decrease in all municipalities, while the wind speed variability trend will be the same as in 2021-2050.

In 2071–2100, the summer temperature increase and the precipitation decline in the same period will presumably reach a level where an increase in the quantity of irrigations will be required. In the municipalities where only a drainage network is in place, the arrangement of double-action (irrigation-drainage) or organization of local irrigation systems may become necessary. In the municipalities where irrigation systems do not exist, or their network is insufficient, such systems should be put in place or expanded.

Topsoil protection: due to a projected precipitation decline in 2021-2050, water erosion should decrease. In some municipalities, summer precipitation by this period will increase. However, this growth will be so insignificant against the baseline period that it will not affect the level of erosion. On the other hand, due to the temperature increase in the same period, an increase in the irrigation rate or the number of irrigations will intensify irrigation erosion.

Wind speed growth, temperature increase and precipitation decline will condition the probable development of wind erosion. This is particularly dangerous for the municipalities noted for wind erosion in the baseline period. It should be mentioned that even if the wind speed decreases, soil desiccation due to a temperature increase and precipitation decline would encourage the occurrence and development of wind erosion. The absence of windbreaks also aggravates the erosion processes[202, 203],.

[201] Georgian Climate and Agroclimate Atlas, Tbilisi, 2011.

[202] G. Kharaishvili, "The impact of field-protective forest belts on the yield of Georgian agricultural crops and agronomical rules of their plantation", Tbilisi, 2004.

[203] K. Targamadze , and L. Parjanadze, "Protective forest belts and their national economic significance under conditions of Georgia", Tbilisi, 1955.

4.2.3 Methodology of assessment of potential climate change impacton forest ecosystems

To assess the potential impact of climate change on forest ecosystems in the two projected periods, Future 1 (2021-2050) and Future 2 (2071-2100), the aggregated sensitivity indicator (number of forest fires and damaged areas) was compared with the following climate exposure indicators:

- Seasonal (summer) temperature change in the two projected periods (exposure indicator normalized from 1 to 10).
- Seasonal (summer) precipitation change in the two projected periods (exposure indicator normalized from 1 to 10).

On the basis of weighting of these indicators, an aggregated climate exposure index (temperature: 50%, precipitation: 50%), normalized from 1 to 10, was derived and linked to the forest sensitivity index.

Similar to the methodology utilized in the agricultural sector, the present methodology makes it possible to assess the impact of climate change on forests for the two projection periods: Future 1 (2021-2050) and Future 2 (2071-2100), as compared to the baseline period.

4.2.4 Impacts of climate change on forest ecosystems

Despite the fact that climate change has a multi-faceted impact on forest landscapes and ecosystems, the present report deals only with the impact of seasonal (summer) temperature and precipitation changes in the context of an increase in the risk of forest fires; see Map 74 for Future 1 (2021-2050) and Map 87 for Future 2 (2071-2100).

Georgian forests are noted for their biodiversity. The country accommodates endemic and relict species of preserved trees and plants[204], such as the Kolkhetian box and yew. The existing ecosystem has been established due to a balanced aggregate interaction of different natural factors and a stable climate.

Climate change endangers the existing equilibrium. Significant change is possible not only in climatic conditions of forests, but also other natural components (relief, availability and amount of water resources, soil, etc.) conditioned by the sustainable functioning of forest ecosystems.

Hence, it can be concluded that the forest ecosystem, like protected areas (see Sections 3.1.3 and 4.1.3 on protected areas), is sensitive to almost all climate exposures. In general, to assess the climate change impact on forests, in addition to the frequency and number of forest fires and subsequently damaged areas, other sensitivity indicators can also be used such as a change in the forest range and areas, a change in the frequency and number of phytopathological diseases.

Consequently, the short-term direct effects of climate change on forest ecosystems can be the following: extension of the vegetation period, spread and incidence of diseases, and increase in the frequency of forest fires and the areas affected by them[205]. In addition, the disruption of the balanced functioning of the forest ecosystem and subsequent forest degradation would bring about the following: increase in greenhouse gas emissions, increase in the number of natural disasters, reduction in the number and availability of water resources.

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[204] G. Gavasheli, Aboriginal trees and shrubs of Georgian forests, Tbilisi, 1987.

[205] N. Ahouissoussi, J.E. Neumann, and J. P. Srivastava, eds. "Building Resilience to Climate Change in South Caucasus Agriculture", World Bank, 2014. https://openknowledge.worldbank.org/bitstream/handle/10986/18033/9781464802140.pdf?sequence=1\ (accessed March 20, 2016)

4.3.1. Impacts of climate change on agricultural products processing

The potential climate change impacts on the industrial sector are both short- and long-term, and the most severe impacts are projected to be experienced by the agricultural sector.

Currently, the agricultural sector is the main economic stalwart of the Georgian economy as over 50 percent of the population is employed in this sector. According to GeoStat's 2014 report, agriculture comprised 9.4 percent of the national GDP[206], the fifth sector in terms of its contribution to the GDP of Georgia. The parameters discussed here are both primary and secondary processing enterprises as well as registered business providers. The researchers were not able to access disaggregated descriptive data for these groups.

Within the framework of this research, among others, the following agricultural risks were considered: (a) impact of water and wind erosion on land productivity; and (b) impact of moisture change on agricultural crops (see Sections 3.2 and 4.2). However, potential socio-economic losses caused by those risks have not been analyzed. To analyze potential financial losses in the agriculture sector, as was indicated above, the information concerning the location in the municipalities of agro-industrial enterprises, their type of production, industrial processes and the number of employed workers should be obtained. The retrieval of such uniform information according to all municipalities is not carried out in the agricultural sector.

The researchers assumed that the municipalities home to multiple agro-industrial enterprises will be potentially more vulnerable to climate change, especially the municipalities where various climate change exposure risks have a high impact on agriculture.

Due to the lack of existing municipal data, such as the exact number of people employed in the agricultural sector as well as the sector's precise revenues, the relevant municipalities' economic dependence on the agricultural sector cannot be determined. Therefore, potential losses due to climate change impact cannot be determined. Several international researchers have reported that climate change, especially the projected increases in the number of warm days and a decline in the number of frost days, can benefit agriculture[207]. In particular, a mild winter increases the enterprise's productivity, enables testing and the use of new types of cereals, and promotes the development of animal husbandry (because calorie consumption decreases for the animals and they have better conditions to develop with reduced fodder). However, the specifics of the Georgian industrial sector must also be noted in future policy interventions.

The impact of climate change on the agricultural sector is both direct and immediate. For example, increases in spring rainfall will interfere with the normative sowing time, which will affect overall production cycles and potentially threaten operations dependent on receiving raw materials. In addition, agriculture is more vulnerable than any other industrial sector to extreme weather events such as droughts, windstorms, snow, heavy precipitation as well as hailstorms. Moreover, each of the listed natural hazards may yield completely different results[208].

Precipitation decline, extreme temperature rise, and vegetation period replacement might have a negative impact on agro-industrial enterprises because this will cause delays in the raw material supply and correspondingly limit the effective operation of the enterprises using local raw materials.

[206] National Statistics Office of Georgia, GeoStat, Share of Agriculture in GDP (%) http://www.geostat.ge/index.php?action=page&p_id=428&lang=eng (accessed March 19, 2016).
[207] Natural Resources Canada, Risks and Opportunities: Socioeconomic Sector: http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/ch7/10377 (accessed March 20, 2016).
[208] EEA, Climate change, impacts and vulnerability in Europe 2012, op. cit.

In addition to these negative impacts, climate change may also positively support the development of a multi-faceted industrial sector in several municipalities. For example, the projected temperature increases may support the development of the industrial sector in municipalities that normally face severe climatic conditions, for example the Samtskhe-Javakheti region where winter starts early and is characterized by a relatively high number of days with extreme, subzero temperatures. In another instance, temperature increases in municipalities with severe climactic conditions may contribute to the growth of raw materials and productivity in the agricultural sector. It is favorable for the productivity and health impacts of the construction sector in winter, late autumn and early spring, as employees in this sector are working mostly outdoors. In addition, in winter months, energy demand decreases therefore the employer's heating costs also fall.

4.3.2. Impacts of climate change on the construction sector

The construction sector is rapidly developing in Georgia as indicated by a GeoStat report citing that between 2011-2014, regionally based construction projects increased almost threefold[209]. In addition, the number of people employed in the sector, as well as annual investments, has significantly increased over the past five years, continuing the growth trend.

Currently, there is a lack of available data on the number of people employed in the sector as well as the enforcement of health and safety regulations. Therefore, the climate change impacts on the construction industries located within the municipalities, cannot be precisely determined, however its main potential impacts can be stated as affecting the:

- Environment or structure of the facility under construction/to be constructed; and the
- Health and safety of employees.

The potential impacts of climate change on the construction sector could take many forms, yielding different results in both the short-term and long-term period. The multiple impacts with the variable sensitivity of the sector to extreme weather events such as droughts, windstorms, and heavy rainfall as well as reduced or increased precipitation, among others, should be considered. However, each of these extreme weather events can produce completely different results. Increases in precipitation levels and heavy rainfall can severely damage buildings. To prevent the worst outcomes, it is recommended that private investors and national counterparts invest in new construction techniques and more stable building materials to ensure that structures can withstand extreme weather conditions over the long-term.

Employers must ensure a safe working environment for employees and climate change can affect working conditions through extreme cold or extreme heat. In wintertime, especially during outdoor work, employees should be provided with clothing for extreme cold conditions, while in summertime, when temperatures reach above 36°C, outdoor work should be conducted outside of hours of intense heat (early morning or in the evening). In case the working hours cannot be changed, the workplace has to be appropriately organized. For example, in order to be protected from the sun an awning can be arranged on the worksite with team members supplied with drinking water. It is also recommended that employers develop and introduce appropriate social benefits for their employees.

[209] National Statistics Office of Georgia, Main Statistics, GeoStat, Construction, 2015, http://www.geostat.ge/?action=page&p_id=466&lang=geo (accessed March 20, 2016).

Working in municipalities characterized by high air temperatures and an increase in the number of hot days is of particular danger for employees. These changes are projected in the future under some climate change scenarios, for example, in some municipalities of the Imereti Region.

4.3.3. Impacts of climate change on mining and processing sectors

The projected increase in the amount of heavy rainfall in municipalities located within zones prone to landslide and mudflows creates a hazardous environment for existing enterprises and hinders economic development of municipalities. For example, river overflows increase the risk of enterprises functioning in the vicinity (see also Sections 3.5 and 4.5 on natural disasters).

The increased energy costs due to need for air conditioning as a result of potential temperature increases in the summers will adversely impact Georgia's energy balance. Additional adverse impacts are potential damages to industrial infrastructure as well as delays in the supply of raw materials. For example, the mining and processing industries that require a sustainable water supply might experience difficulties in certain climate conditions.

As mentioned in other sectors, reliable data detailing the location and type of the mining and processing industries, as well as the number of employees, is not available. Therefore, this study may only cite the general climate change-related risks to the existing enterprises operating in the processing sector.

The potentially most dangerous climate change impacts to the mining and processing sectors are mudslides, heavy rainfalls, windstorms and snowdrifts that impede production processes. The increased risk of natural disasters caused by climate change endangers the industrial infrastructure and additional investments in first response detection, safety, and monitoring are necessary for diminishing potential climate change risks to these industries.

Statistical information for the mining industry is also scarce. According to GeoStat statistics for 2015, there are 396 mining operations in the country, and mining is often a critical economic mainstay for several municipalities and a significant source for future economic growth. Given that the spatial data on the mining enterprises was unavailable, the physical sensitivity of these operations and the potential impacts of climate change could not be precisely assessed.

4.4.1 Methodology of assessment of climate change impacts on the energy sector

The potential impacts of climate change were assessed for the following projected periods: Future 1 (2021-2050) and Future 2 (2071-2100). In order to assess potential climate change impacts, each climate change sensitivity index was multiplied by the corresponding climate change exposure indicators for Future 1 and Future 2. For each sensitivity index, a corresponding climate change exposure indicator was chosen.

The following climate change exposure indicators were used in the assessment for both Future 1 and Future 2:

- Forecasted change of estimated heating period (corresponding to the heating demand sensitivity index for commercial and residential sectors);
- Forecasted change of estimated cooling period (corresponding to the cooling demand sensitivity index for commercial and residential sectors);
- Forecasted change of extreme summer temperatures (corresponding to the cooling load sensitivity index for the commercial and residential sectors); and
- Forecasted change of extreme winter temperatures (corresponding to the heating load sensitivity index for the commercial and residential sectors).

The aggregated potential climate change impact on energy consumption is a sum of all commercial and residential sectors' climate change impact indexes (eight in total for each projection period). The data was normalized from 0 to 1.

The final impact of climate change contains three types of indicators:

- Relative: population for residential sector and number of employees for the commercial sector;
- Dynamic: climate change exposure that is represented as the climate change for Futures 1 and 2; and
- Absolute: represents the sensitivity to climate change and is based on available climate modeling data for the baseline year.

Climate change impacts on the energy sector were assessed using the above-mentioned methodology and applied to all Georgian municipalities for Future 1 and Future 2 (see Maps 75 and 88 for additional details).

4.4.2 Impacts of climate change on energy supply and energy consumption

According to the climate model forecasting, a projected decrease in the estimated heating period and an increase in the estimated cooling period is expected in Georgia. However, in the midterm period, by 2050, the energy costs are moderate, as the projected increased demand for cooling in the summer period is partly compensated by the projected decreased demand for heating in winter. The projected impacts of climate change differ per municipality. In some municipalities, the projected climate change will benefit the population through reduced heating costs, while in other municipalities, the increased cooling period will lead to an increase in the consumption of electricity, such as in the Kakheti and Imereti.

This study assessed the projected climate change impacts separately to estimate the demands in energy consumption for both cooling and heating. The projected aggregated climate change impacts would be insignificant if aggregated, as the increased demand for cooling partially would be compensated by decreased demand for heating.

In the medium and long term, climate change can impact the energy balance, in particular the potential output of power plants, such as hydro power plants. A reduction in energy generation will create an energy deficit that may increase the need to import electricity, which includes potential risks for energy independence and the social economic development of the country.

THERMAL POWER PLANTS

Since thermal power plants require large volumes of water for cooling purposes during the generation cycle, a change in precipitation and increase in summer external temperatures might affect their operation and the security of electricity generation. However, since Georgia's future hydrological yield potential is not fully studied it is difficult to make a precise prediction.

Based on an energy consultant's estimation, a possible reduction of the water level for the Kura River would not impact the output of thermal power plants located in the Gardabani Municipality (Mtkvarienergetika Ltd, International Energy Corporation of Georgia Tbilisi Ltd, G-Power Ltd, Gardabani Thermal Power Plant Ltd). In summer months, the portion of electricity generated from the above-mentioned thermal power plants is small[210] and will remain so presumably, due to the hydropower development priority. According to the presentation of the "Three-Year Report of the Ministry of Energy", 10 hydropower plants (HPPs) with a total of 157 MW generation capacity were put into operation from 2013 to 2015. In addition, 60 MoUs were signed with the intention of implementing 88 projects, with a total capacity of 1,600 MW[211].

Even though according to the existing projection, a reduction of water discharge in the rivers for 2050-2100 is expected, this will not significantly affect the functioning of thermal power plants that use water from the Kura River. For the same period, it is likely that electricity consumption will increase along with economic development. However, increased demand can be met with new generating capacities.

According to the energy consultant's estimation, even in the case of increased generation of HPPs in summer, (for example for export needs) there will be enough water in the Kura River for their normal functioning.

HYDROPOWER PLANTS (HPPs)

The Rioni River Basin

In the Rioni River basin, the average annual temperature in the lowlands is between 9°C and 10°C and about 4°C and 5°C in the highlands. The total annual precipitation is about 1,000-1,500 mm in lowland areas and 1,600-1,800 mm in the highland areas. The highland river areas often experience floods and flash floods during the spring and summer months due to rainfall as well as the melting of snow. The Rioni River is at a low point from December through February.

The following hydropower plants are located on the Rioni River:

- Gumathesi 1 is located in the Kutaisi Municipality, the owner is JSC Energo Pro Georgia, placed into operation in 1958, with an installed generation capacity of 44 MW, average annual output 249 million kWh, reporting water consumption of 214 m^3/s[212].
- Gumathesi 2 is located in the Kutaisi Municipality, the owner is JSC Energo Pro Georgia, placed into operation in 1956, with an installed generation capacity of 22.8 MW, average annual output 127 million kWh, reporting water consumption of 214 m^3/s.
- Rionhesi uses the Rioni and Tskhenistskali Rivers and is also in the Kutaisi Municipality, the owner is JSC Energo Pro Georgia, it was put into operation in 1933, installed capacity of 48 MW, average annual output 325 million kWh, reporting water consumption of 100 m^3/s, maximal runoff 2300 m^3/s, minimal runoff 24 m^3/s[213].

[210] Electricity Energy Balances available ESCO (electricity operator) website http://esco.ge/index.php?article_id=8&clang=1, (accessed in December 2015).

[211] Ministry of Energy's three-year report available online (in Georgian only): http://www.energy.gov.ge/projects/pdf/news/Energetikis%20Saministros%20Angarishi%202015ts%201238%20geo.pdf (accessed in December 2015).

[212] E. Barnovi, M. Shotadze "Rapid Assessment of the Rioni and Alazani-Iori River Basins", Integrated Natural Resources Management in Georgia program, 2011.

[213] G. Chogovadze, N. Chikhladze, and G. Khiasashvili, History of Energy of Georgia, 1998.

- Vartsikhe Cascade, which includes four hydropower plants, uses the Rioni, Kvirila and Khanistskali Rivers and is included in the Tskaltubo Municipality. The owner is Vartsikhe 2005 Ltd., put into operation in 1976–1987, installed capacity 4x46=184 MW, average annual output 1,050 million kWh, reporting water consumption of 350 m^3/s. Cascade has a day and night regulation reservoir with total volume of 14.6 million m^3, but to date its active (useful) volume comprises 2.4 million m^3, due to silt brought down by the Rioni River.

According to the available forecasts, the average annual flow of the upper course of the Rioni River will increase by 26 percent compared to its current level and reach 1.71 billion m^3/year by 2050. However, by 2100 the water level is projected to be reduced by 36 percent compared to the 2050 level and would then equal about 1.05 billion m^3/year. These forecasts were made without considering potential glacier melting. Therefore, the hydropower plants utilizing water from the River Rioni might maintain or increase existing levels of generation output in the medium and long term as water from melted glaciers will further increase the river's runoff. However, the hydropower plants need to be rehabilitated and maintained.

The River Rioni basin covers the following municipalities: Ambrolauri, Oni, Lentekhi, Tsageri, Tkibuli, Sachkhere, Khoni, Vani, Bagdati, Kharagauli, Tskaltubo, Samtredia, Zestaponi, City of Kutaisi, Abasha, Senaki, Martvili, Khobi as well as the City of Poti. These municipalities are located in potential flood zones and the locally based energy distribution infrastructure owned by JSC Energo-Pro Georgia and GSE is at risk (see Figure 17). In the event of a natural disaster, segments of the population could be temporarily without power.

The Alazani River Basin

In the Alazani River Basin, the average annual temperature is 9^0C to 14^0C with average annual precipitation varying from 400 mm in the Dedoplistskaro Municipality to 993 mm in the Lagodekhi Municipality.

On the Alazani River, are to be found the Alazanhesi HPP with an installed capacity of 4.8 MW, and an average annual output of 25 million kWh and Alazanhesi-2 HPP with an installed capacity of 6 MW and an average annual output of 40 million kWh hours. These hydropower plants are included in the Gurjaani Municipality and owned by International Energy Corporation of Georgia Ltd. reporting water consumption of 19.8 m^3/s. Runoff recorded in the lower course of the Alazani is 104 m^3/sec in 1955-1970, was increased in 1996-2005 up to 111 m^3/s, i.e. water flow was being increased in average in 1-2 percent per every 10 years.

By 2100, researchers project an 8 percent decrease in the annual runoff for the Alazani River as compared to 1951-1980[214]. According to an assessment of the Rioni and Alazani basins performed by Eliso Barnovi and Mariam Shotadze, the mentioned decrease should not seriously impact the balance in the supply and demand of water, even if the demand for irrigation water is increased by 50 percent[215]. Thus, according to this study, entitled, "Rapid Assessment of the Rioni and Alazani-Iori River Basins", the generation capacity of the hydropower plants located in the Alazani River Basin is not expected to decrease.

The Iori River Basin

In the Iori River Basin, the average annual temperature ranges from 0^0C to 8^0C in the highland areas and is between 10^0C and 11^0C in lowland areas. The annual total precipitation is comprised between 1,300-1,400 mm in the highland areas and 400-500 mm in the lowland areas.

214 The Second National Communication to the UNFCCC, op. cit.

215 E. Barnovi and M. Shotadze "Rapid Assessment of the Rioni and Alazani-Iori River Basins", Integrated Natural Resources Management in Georgia program, 2011.

The following hydropower plants are located on the Iori River:

- Sionhesi (Tianeti Municipality): owned by JSC Energo Pro Georgia, installed capacity is 9.14 MW, and reported water consumption is 23 m^3/s.
- Martkhopihesi (Gardabani Municipality): owned by JSC Energo Pro Georgia, installed capacity is 3.83 MW, and reported water consumption is 13 m^3/s.
- Satskhenhesi (Gardabani Municipality): owned by JSC Energo Pro Georgia, installed capacity is 14 MW, and reported water consumption is 13 m^3/s.
- Tetrikhevhesi (Tbilisi Municipality): owned by Georgian Water and Power Ltd., installed capacity is 12.4 MW, and reported water consumption is 13 m^3/s.

According to data from 1934-1993, the average multi-year runoff of the Iori River was 15.1 m3/s, (there are no more recent hydrological data)[216]. According to the modeling used in the Second National Communication to the UNFCCC, an 11 percent decrease in the annual runoff is expected by 2100. In addition to these circumstances, if water consumption by residential, industrial and agriculture sectors is increased by 10 percent there will be a lack of water during the months from January through April and September through November, which will most likely result in a 5-6 percent decrease of output in the hydropower plants located on the Iori River. Since the above-listed power plants are connected to Georgia's electrical transmission grid, a decrease in their generation output will most likely not impact the end users as a power deficit could be balanced by utilizing output from other power plants.

Climate change has the following basic impacts on energy consumption:

- Increase in the energy consumption of buildings in the residential and commercial sectors, resulting in increased energy consumption.
- Increase in summer peak consumption that is due to increased demand for cooling. In the municipalities where the heating period is long and the cooling period is short, a significant increase of energy consumption is not expected.
- Increase of penetration rate of cooling technologies, such as air conditioners and other cooling technologies. The projected increased cooling period and extreme hot temperatures will most likely encourage the relevant populations to install air conditioners or other cooling technologies.

Georgia's electrical grid is dominated by hydropower generation, which is seasonal by nature. Therefore, during the summer months Georgia has a surplus in electricity, a portion of which is exported. Currently, for different reasons, this resource is not fully used and often part of the water is discharged and not used for electricity generation. If Georgia's generation capacity was further supplemented and the electrical grid strengthened, it would allow for increased electricity trade to neighboring countries. Increased summer energy consumption can compete with potential electricity export and hydropower plants would have to sell electricity on the local market, which presumably will increase the average electricity purchase price and consumer tariffs[217].

The majority of memorandums of understanding (MoUs) signed between the national government and various companies investing in electricity generation projects include a statute that during the three winter months a certain portion of energy generated by power plants should remain within the local market. This statute was appropriate because the winter peak of energy consumption was dominant. However, in the future, the potential of a significant increase of electricity consumption in summer months should be considered during negotiations with investors interested in constructing hydropower plants and respective regulations should be added. The trend of transition from the peak occurring in the winter to the peak occurring in the summer already exists.

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[216] Ibid.

[217] Hydropower plants (HPPs) have high fixed and small variable costs, therefore electricity generation cost of those HPP that are built in the Soviet times and investment cost of which is already recovered is inexpensive. In case of newly constructed HPP, the investor is willing to recover their investment in the following years, in part through fees. This is the main reason why fees for electricity from new HPP are much higher than for the older generation of HPP.

According to the projected climate change impacts for Future 1 (2021-2050), the municipalities can be divided into two groups:

- Group 1 (Future 1): Municipalities where projected climate change has a greater impact on the demand for heating than on the demand for cooling[218] ; and
- Group 2 (Future 1): Municipalities where projected climate change has a greater impact on the demand for cooling than on the demand for heating[219] .

Consequently, climate change may benefit the municipalities included in Group 1 in potential energy saving costs, while the municipalities included in Group 2 will face additional expenses due to the projected increased demand for cooling.

For the climate change impacts projected for Future 2 (2071-2100), the municipalities can also be divided into two groups:

- Group 1 (Future 2): Municipalities where projected climate change has a greater impact on the demand for heating than on the demand for cooling[220] ; and
- Group 2 (Future 2): Municipalities where the projected climate change has a greater impact on the demand for cooling than on the demand for heating[221] .

In the short term, climate change will not have a significant impact on any of the groups mentioned above. However, the rate of penetration of cooling technologies will increase with projected economic growth trends, resulting in increases in energy consumption to meet the demand for cooling. Projected economic growth will also have an impact on the penetration rate of individual central heating systems, which will increase the consumption of natural gas. A targeted policy with a series of measures (see Section 5.4) is necessary to reduce the projected increase in energy consumption and improve the living standards of the population.

In a midterm perspective, in Future 1 (2021-2050), a decrease in energy consumption, basically of wood and gas, is expected in municipalities where climate change has a greater impact on the demand for heating than on the demand for cooling. The projected decrease of gas consumption is important for Georgia, since this fuel is imported from neighboring countries and the reduction in imports strengthens Georgia's energy security, while adding economic and environmental benefits such as reduced emissions. In the municipalities where climate change has a greater impact on the demand for cooling than the demand for heating, an increase of electrical energy consumption is expected.

In the long term, Future 2 (2071-2100), a decrease of energy consumption is expected in the municipalities where the projected climate changes will have a greater impact on the demand for heating than the demand for cooling. However, it is not known which basic fuel will be used in the long term. The rate of penetration of renewable-energy technologies, as well as energy-efficient technologies most likely will be increased and much more natural gas could be saved. Increase in energy consumption is expected in the municipalities from Group 2 (Future 2). However, similarly to Group 1 (Future 2), it is also unknown what kind of energy or technologies will be used for cooling. The expected impacts of climate change on energy consumption can be significantly reduced by wide use of renewable technologies, for example geothermal heat pumps. As the increased usage of renewable technologies is a popular global trend, the rate of penetration of renewable technologies will be significantly increased in Georgia as well, which will reduce the expected impacts of climate change on energy consumption and mitigate climate change by reducing emissions.

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[218] The municipalities of Gori, Telavi, Mtskheta, Bolnisi, Akhmeta, Kazbegi, Lagodekhi, Dusheti, Sachkhere, Martvili, Tsalenjikha, Tsalka, Kvareli, Khulo, Chkhorotskhu, Dmanisi, Vani, Oni, Chiatura, Kareli, Lentekhi, Adigeni, Telavi city, Tetritskaro, Ambrolauri, Kada, Mtskheta city, Ambrolauri city.

[219] The municipalities of Zugdidi, Tbilisi city, Gardabani, Marneuli, Kutaisi city, Gurjaani, Sagarejo, Samtredia, Tskhaltubo, Khelvachauri, Senaki, Abasha, Poti city, Khoni, Khulo, Chokhatauri, Zestaponi, Ozurgeti, Tkibuli, Lanchkhuti, Terjola, Signagi, Kharagauli, Ozurgeti city, Akhaltsikhe, Akhaltsikhe city, Gori, Ninotsminda, Aspindza, Dedoplistskaro, Akhalkalaki,

[220] The municipalities of Adigeni, Ambrolauri, Aspindza, Akhaltsikhe, Akhalkalaki, Akhmeta, Bagdati, Borjomi, Tsageri, Dmanisi, Dusheti, Gori, Kaspi, Lentekhi, Martvili, Mtskheta, Mestia, Ninotsminda, Oni, Ambrolauri city, Gori city, Mtskheta city, city Telavi, Kareli, Sachkhere, Shuakhevi, Telavi, Terjola, Tianeti, Tkibuli, Vani, Tsalka, Chiatura.

[221] The municipalities of Tbilisi city, Abasha, Chokhatauri, Dedoplistskaro, Gardabani, Gurjaani, Lagodekhi, Lanchkhuti, Marneuli, Ozurgeti, Batumi city, Poti city, Ozurgeti city, Kutaisi city, Rustavi city, Zugdidi city, Keda, Kobuleti, Sagarejo, Samtredia, Senaki, Signagi, Tetritskaro, Tsalenjikha and Tskaltubo.

The dynamic regime of generation and reactivation of geological and hydrological natural hazard processes in Georgia in certain geological environments reveals an inclination to certain processes that are primarily conditioned by climate factors. In this case, we consider some integral meteorological elements of climate (atmospheric precipitation, air temperature, humidity, etc.) and not the established static background weather conditions of a given place. In particular, the elements that in short periods can influence changeable values in a non-stationary regime depend on the main trend of global climate change and on geographic peculiarities of a given region. It became necessary to develop a long-term prognosis of climate change in connection with limiting values of meteorological elements provoking natural hazards. In this regard, the climatologists of the National Environmental Agency developed the long-term prognoses for Future 1 (2021-2050) and Future 2 (2071-2100) for separate regions of Georgia and their municipalities. Data for 1960-1990 served as the baseline level. Based on these data, within the time intervals suggested by the climatologists in the long-term projection, all statistical data available from meteorological stations on mean annual positive and negative alterations from the multi-annual values and on recurrence frequency of daily rainfalls within the intervals acknowledged were treated as the standard for generation of a geological process in different regimes. The aim of these calculations was to provide comprehensive information on landslides, mudflows, floods and riverbank erosion for all municipalities.

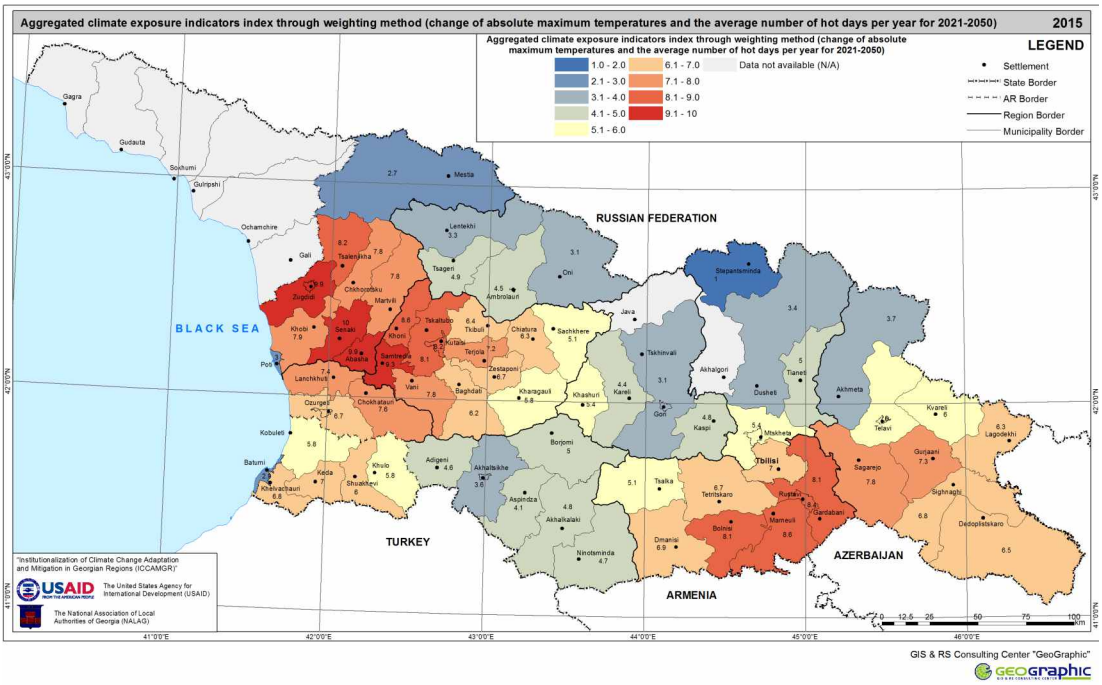
Based on the statistical information received and the projections suggested by the climatologists, the projection for natural hazards for all municipalities was developed. The relevant positive and negative alteration of coefficients for the two projection periods Future 1 and Future 2 were also calculated in relation to the mean annual changes in precipitation, and as to the daily recurrence frequency of rainfalls. While calculating the alteration coefficients, the ratio of the received figure of the target period (for instance 2021-2050) to the baseline figures (1960-1990) were taken into account.

Maps 76 and 77 show the prognoses for natural hazards for all municipalities for Future 1 (2021-2050), while Maps 89 and 90 are for Future 2 (2071-2100).
1.5

4.6.1 Methodology of the climate change impact assessment

Proceeding from the selected unified indicators, the social sector has a high sensitivity to climate change, which is conditioned by having a large portion of the population both over 65 and living below the poverty line. Some municipalities are far more sensitive to climate change than others. At the same time, it should be noted that climate change exposures impact Georgian municipalities differently. To take this into account in future projections and climate impact assessment, the sensitivity indicators were compared with the climate change exposure indicators for the two projection periods.

To assess the impact of climate change on the social sector, the study selected such climate exposure indicators as the average value of extreme temperatures and the number of hot days over Future 1 (2021-2050) and Future 2 (2071-2100). Weights were attached to these indicators: 40 percent to the average value of extreme temperature, and 60 percent[222] to the number of hot days. See the aggregated climate exposure maps for these two periods in Figures 22 and 23.



GIS & RS Consulting Center "GeoGraphic"

Fig. 22. Aggregated climate exposure indicators index through weighting method (change of absolute maximum temperatures and the average number of hot days per year for 2021-2050)

In order to make a better assessment of climate impact on both the selected groups, i.e. the density of the number of people below the poverty line and over 65 years of age the sensitivity indicators were combined with aggregated climate exposure indices (See Section 3.6 on sensitivity indicators).

The combined indices of climate exposure and sensitivity indicators, i.e. the density of the number of people below poverty line and over 65 years of age, were used to draft combined impact maps, as shown in Maps 79 and 92: aggregated impact for Future 1 (2021-2050) and Future 2 (2071-2100). On Maps 78 and 91, the climate change impact is considered by taking gender into account.

According to the climate change impact maps, municipalities are shown according to impact level. This type of grouping allows better visualization of municipalities that face similar impacts, and supports the development of recommendations.

[222] Weights were attached on the basis of expert conclusions: an increase in the number of hot days when temperature exceeds 25°C significantly influences human health compared with the average value of extreme temperatures. Therefore, the following weights were selected: 60% for the number of hot days and 40% for the average value of extreme temperatures.

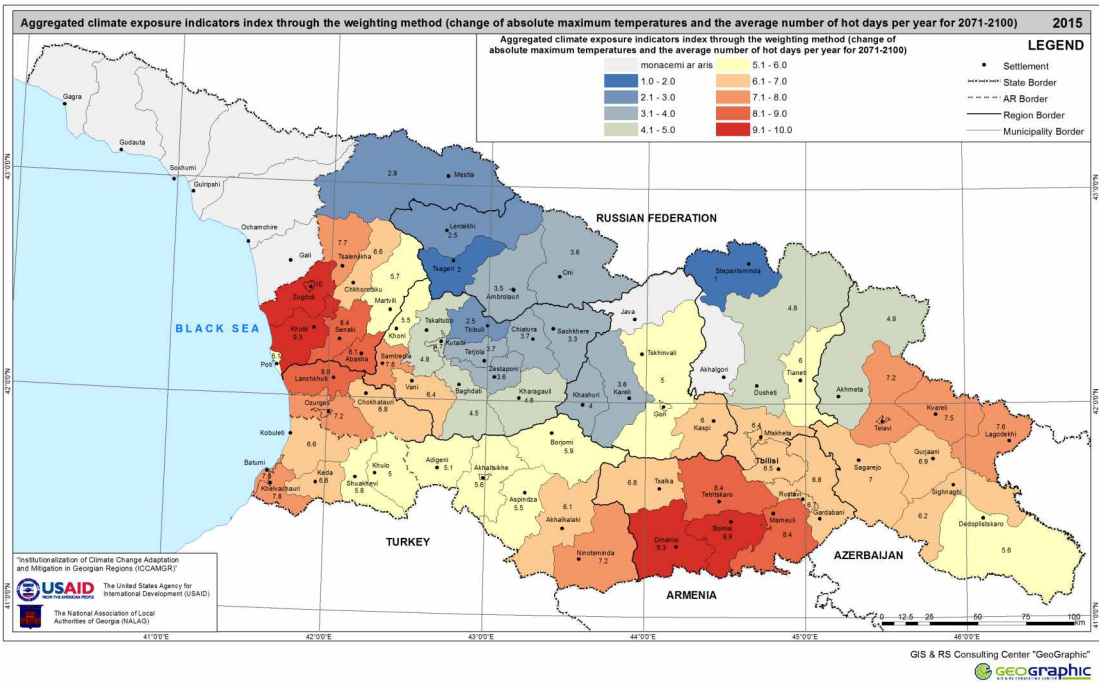


Fig. 23. Aggregated climate exposure indicators index through the weighting method (change of absolute maximum temperatures and the average number of hot days per year for 2071-2100)

Consideration of the problem from a gender perspective was conditioned by two factors: the first is that women are more sensitive towards climate change[223]; the second is that the existing data and Maps 61, 62, 65 and 66 indicate that the share of women in the population below the poverty line and over 65 years of age exceeds the number of men in almost all municipalities of Georgia. The exception is Dmanisi, where the proportion of men over 65 is higher.

To draw the above-mentioned aggregated impact maps with a gender perspective, the density of women over 65 years of age and below the poverty line were selected as indicators. That was done considering that the selected climate exposure indicators, such as absolute maximum temperatures and the average annual number of hot days, have particular impact on urban areas. The weighting attachment was carried out in line with the same principle as it was for the whole population.

The aggregated impact maps on women also grouped municipalities according to impact level. This allows for better visualization of municipalities with similar impact levels, and supports the development of recommendations that take into account the gender perspective.

To assess the impact of the growth of the risk of natural disasters on these groups in the municipalities over Future 1 and Future 2 the absolute number of the population below the poverty line and over 65 years of age was used, as demonstrated in Maps 59, 62, 63 and 65. For more information, please see Section 4.6.2 below.

[223] Ibid.

As mentioned above, the proportion of the population over 65 years of age will continue to grow until 2050, when it is likely to reach 26 percent of the total population. Hence, the ageing of the population in Georgia, or the growth of the proportion of elderly people in the population, will become denser, posing significant challenges to the country, its economy, healthcare and social security systems. This might be aggravated by the fact that the prevalence (general morbidity) and incidence (first cases of morbidity) of climate-related diseases may also increase, which in the elderly population will cause a high distribution of cardiovascular diseases, such as ischemic stroke and arterial hypertension among others.

At present, it is difficult to assess the long-term future situation for the population below the poverty line. At the same time, it should be noted that, in the short-term perspective, no significant improvements of the social conditions of the population are forthcoming, although it is possible that the general healthcare program may positively increase access of the poor to health services. Therefore, the study, including the drafted maps, does not consider the effects of an ageing population and possible changes in the social structure.

In general, the climate change impact for Future 1 and Future 2 is variable. For example, if the impact is above average or less in such municipalities as Dmanisi, Batumi, Telavi during Future 1, it could increase and become high in the same municipalities in Future 2. This indicates that climate change is likely to get worse over time. There are also municipalities where the impact remains at the same level for both periods, such as Gurjaani, Marneuli and Chokhatauri. The study also identified municipalities where the impact of climate change will decrease in the Future 2, such as Kutaisi, Samtredia and Senaki, and is conditioned by reductions in the values of climate exposure, i.e. the absolute maximum temperatures and the average number of hot days. Finally, Maps 78-92 show municipalities where the impact of climate change is not high and is likely to remain unchanged for Future 1 and Future 2, such as Mestia, Lentekhi, Oni, Kazbegi and Aspindza. This is mainly due to the low population numbers and density of selected vulnerable groups in those municipalities. Such low population numbers mean that adaptation measures in the social sector towards heat waves might not be urgent. Nevertheless, since it is not known what the number of poor and populations over 65 will be in the future, such measures are still desirable, especially given that tourism in some of these municipalities, such as Mestia and Kazbegi, is high, which requires additional measures.

In addition, the growing risk of natural disasters heightens the impact on socially unprotected populations, because of changes in average annual precipitation and rain periodicity during day and night during the projection periods. It is clear that the same two socially vulnerable groups, such as the elderly population and populations living below the poverty line, are most vulnerable to natural disasters compared to the rest of the population.

On the basis of this analysis, municipalities with a rating of 7 or higher were combined in a "high impact" group, while those with a rating of 6 to 7 were "above-average impact". Those at "average impact" had a rating from 5 to 6, while the "low impact" group had less than 4.

For Future 1 (2021-2050):

- High impact municipalities
    - o In eastern Georgia: Tbilisi, Rustavi, Marneuli, Gardabani, Sagarejo and Gurjaani; and
    - o In western Georgia: Zugdidi, Senaki, Kutaisi, Samtredia, Tsalendjikha, Martvili, Abasha, Tskaltubo, Zestaponi and Khoni.

- Above-average impact municipalities
    - o In eastern Georgia: Dmanisi, Bolnisi, Telavi, Lagodekhi, Signagi and Khashuri; and
    - o In western Georgia: Chiatura, Vani, Chkhorotsku, Khobi, Khelvachauri, Kobuleti, Ozurgeti, Lanchkhuti and Chokhatauri.

- Average impact municipalities
    - o In eastern Georgia: Mtskheta, Kaspi, Tetritskaro, Kvareli, Dedoplitskaro and Kareli; and
    - o In western Georgia: Bagdati, Kharagauli, Sachkhere, Terjola, Tkibuli, Keda, Shuakhevi and Khulo.

- Low impact municipalities
    - o In eastern Georgia: Tianeti, Dusheti, Stepantsminda, Akhmeta, Gori, Borjomi, Adigeni, Akhaltsikhe and Aspindza; and
    - o In western Georgia: Oni, Ambrolauri, Tsageri, Lentekhi, Mestia, Batumi and Poti.

For Future 2 (2071-2100):

- High impact municipalities
    - o In eastern Georgia: Tbilisi, Dmanisi, Rustavi, Marneuli, Gardabani, Bolnisi, Telavi, Gurjaani and Lagodekhi; and
    - o In western Georgia: Zugdidi, Batumi, Khobi, Senaki, Tsalenjikha, Samtredia, Lanchkhuti, Ozurgeti and Kobuleti.

- Above-average impact municipalities:
    - o In eastern Georgia: Mtskheta, Kaspi, Tetritskaro, Gori, Sagarejo, Kvareli and Signagi; and
    - o In western Georgia: Vani, Chokhatauri, Tskaltubo, Martvili and Abasha.

- Average impact municipalities:
    - o In eastern Georgia: Dedoplistskaro, Akhmeta, Dusheti, Tsalka, Akhalkalaki, Akhaltsikhe, Borjomi, Khashuri and Kareli; and
    - o In western Georgia: Keda, Shuakhevi, Khulo, Bagdati, Zestaponi, Kharagauli, Chiatura, Khoni, Chkhorotsku and Poti.

- Low impact municipalities:
    - o In eastern Georgia: Stepantsminda, Tianeti, Ninotsminda, Aspindza and Adigeni; and
    - o In western Georgia: Tkibuli, Terjola, Sachkhere, Oni, Ambrolauri, Tsageri, Lentekhi and Mestia.

The same scoring system was used to assess the impact of climate change on women. "High impact" municipalities had an impact rate of 7 or more. "Above average impact" municipalities scored from 6 to 7, "average impact" from 5 to 6, and "low impact" less than 4.

For Future 1 (2021-2050):

- High impact municipalities
    - o In eastern Georgia: Tbilisi, Rustavi, Gardabani, Marneuli, Bolnisi, Sagarejo, Gurjaani; and
    - o In western Georgia: Zugdidi, Senaki, Kutaisi, Samtredia, Tsalenjikha, Martvili, Abasha, Tskaltubo, Vani, Khoni.

- Above-average impact municipalities:
    - o In eastern Georgia: Telavi, Lagodekhi, Signagi; and
    - o In western Georgia: Chiatura, Zestaponi, Terjola, Chkhorotsku, Khobi, Khelvachauri, Ozurgeti, Lanchkhuti, Chokhatauri.

- Average impact municipalities:
    - o In eastern Georgia: Mtskheta, Kaspi, Tetritskaro, Dmanisi, Kvareli, Dedoplistskaro, Khashuri, and Kareli; and
    - o In western Georgia: Bagdati, Kharagauli, Sachkhere, Tkibuli, Kobuleti, Keda, Shuakhevi, and Khulo.

- Low impact municipalities:
    - o In eastern Georgia: Tianeti, Dusheti, Stepantsminda, Akhmeta, Gori, Borjomi, Adigeni, Akhaltsikhe, Aspindza, Akhalkalaki and Tsalka; and
    - o In western Georgia: Oni, Ambrolauri, Tsageri, Lentekhi, Mestia, Batumi and Poti.

For Future 2 (2071-2100):

- High impact municipalities
    - o In eastern Georgia: Tbilisi, Dmanisi, Marneuli, Tetritskaro, Bolnisi, Gurjaani and Lagodekhi; and
    - o Zugdidi, Batumi, Khobi, Senaki, Tsalenjikha, Samtredia, Abasha, Lanchkhuti and Khelvachauri.

- Above average impact municipalities
    - o In eastern Georgia: Mtskheta, Kaspi, Gardabani, Rustavi, Sagarejo, Telavi, Kvareli and Signagi; and
    - o In western Georgia: Kutaisi, Chokhatauri, Ozurgeti and Kobuleti.

- Average impact municipalities:
    - o In eastern Georgia: Dedoplistskaro, Akhmeta, Dusheti, Tianeti, Tsalka, Akhalkalaki, Akhaltsikhe, Borjomi, Ninotsminda, Khashuri and Kareli; and
    - o In western Georgia: Keda, Shuakhevi, Khulo, Vani, Tskaltubo, Khoni, Chkhorotsku, Martvili and Poti.

- Low impact municipalities:
    - o in eastern Georgia: Kazbegi, Tianeti, Kareli, Aspindza and Adigeni;
    - o in western Georgia: Tkibuli, Zestaponi, Kharagauli, Terjola, Bagdati, Sachkhere, Oni, Ambrolauri, Tsageri, Lentekhi and Mestia.

Municipalities that, in addition to natural disasters, also face a more difficult social, economic and demographic situation, such as where the number of people over 65 and below the poverty line is higher, as indicated in Maps 59 and 63, are more vulnerable from a social point of view.

To better visualize the problems of social deprivation and natural disasters; maps were aggregated for both baseline and projection periods (see Figures 21, 24 and 25). As Figures 24 and 25 show, the social, demographic and economic vulnerability of the population below poverty line and over 65 years of age is increasing in the future due to natural disaster risks, such as landslides, mudslides and stone slides among others, for both Future 1 and Future 2.

In those municipalities where the number of women over 65 and below the poverty line is high, the reduction of the risk of natural disasters is acutely perceived because these groups are most vulnerable[224] .

In those municipalities where the future risk of natural disasters is likely, the socio-economic and demographic background and context may not be immediately obvious, for example in Mestia, Kazbegi and Dusheti municipalities. Nevertheless, the municipal leadership should take into account the danger of future risks connected with the growth in the number of elderly people and take necessary steps to lessen the potential impact.

As this analysis shows, the impact of climate change on the social sector is significant, particularly in the case of extremely high temperatures. This is conditioned by the high number of socially vulnerable groups, i.e. those over 65 and below the poverty line in the municipalities and, in particular, in densely populated cities where the problem is aggravated by the heat-island effect.

Yet another significant problem lies in broader socio-economic deprivation, especially where there are high numbers of poor people, and the lack of preparedness in public institutions to face the challenges posed by climate change, such as low awareness amongst representatives of the healthcare and social system and weak infrastructure among other things.

[224] UN WomenWatch, "Women, Gender Equality and Climate change", 2004, www.un.org/womenwatch (accessed March 20, 2016).

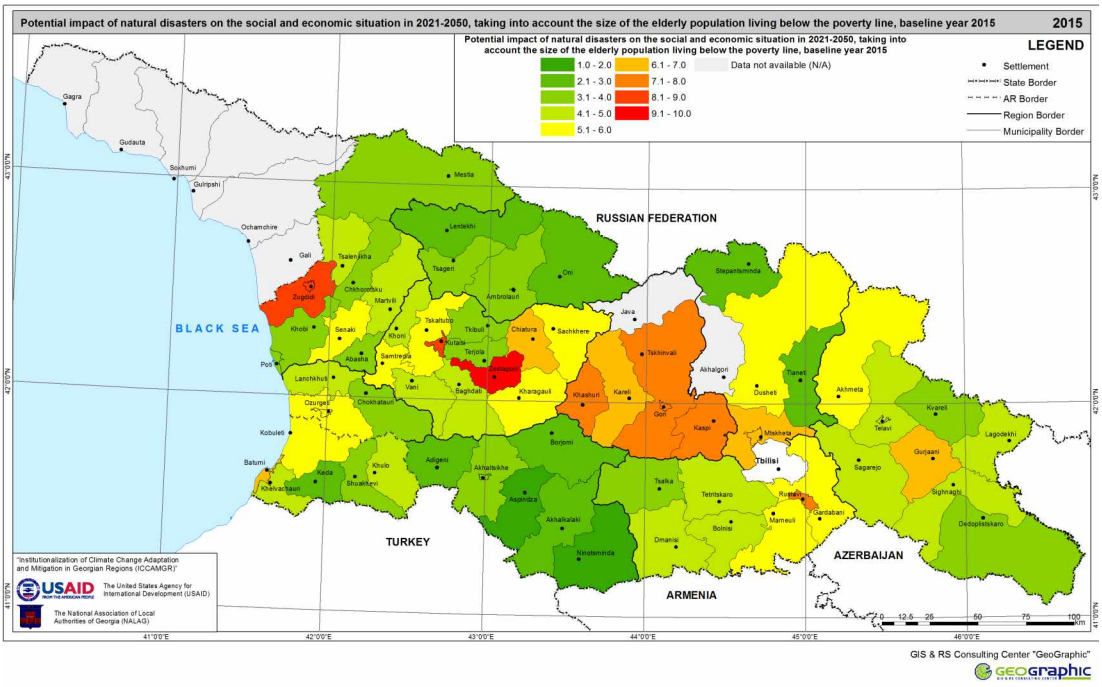


Fig. 24. Potential impact of natural disasters on the social and economic situation in 2021-2050, taking into account the size of the elderly population living below the poverty line, baseline year 2015

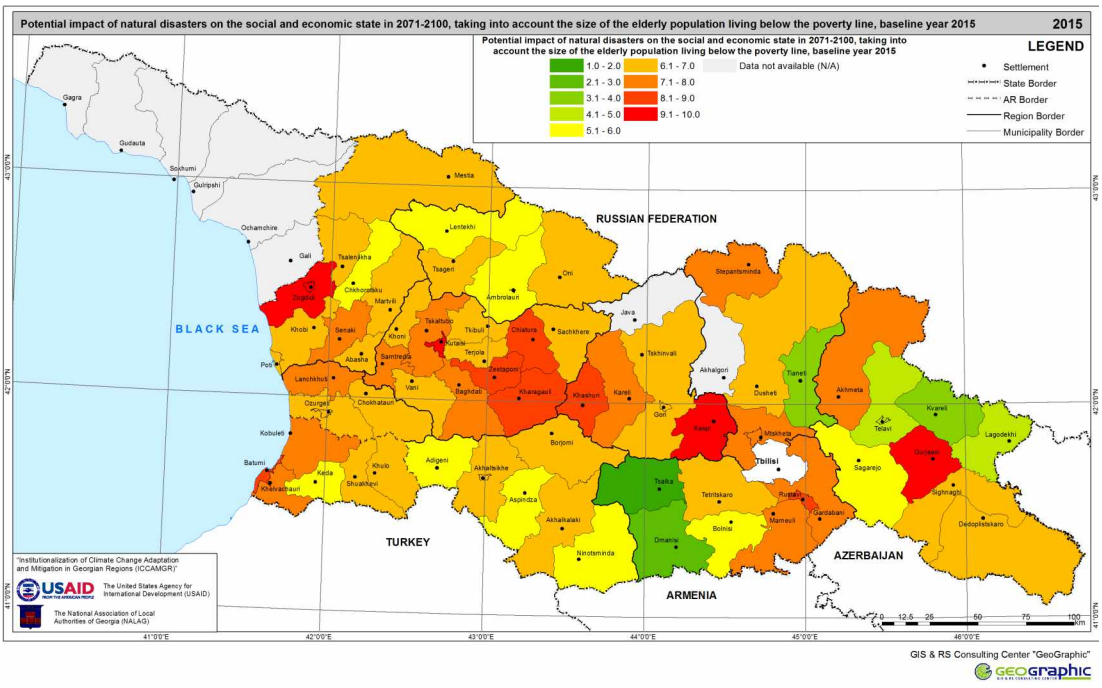
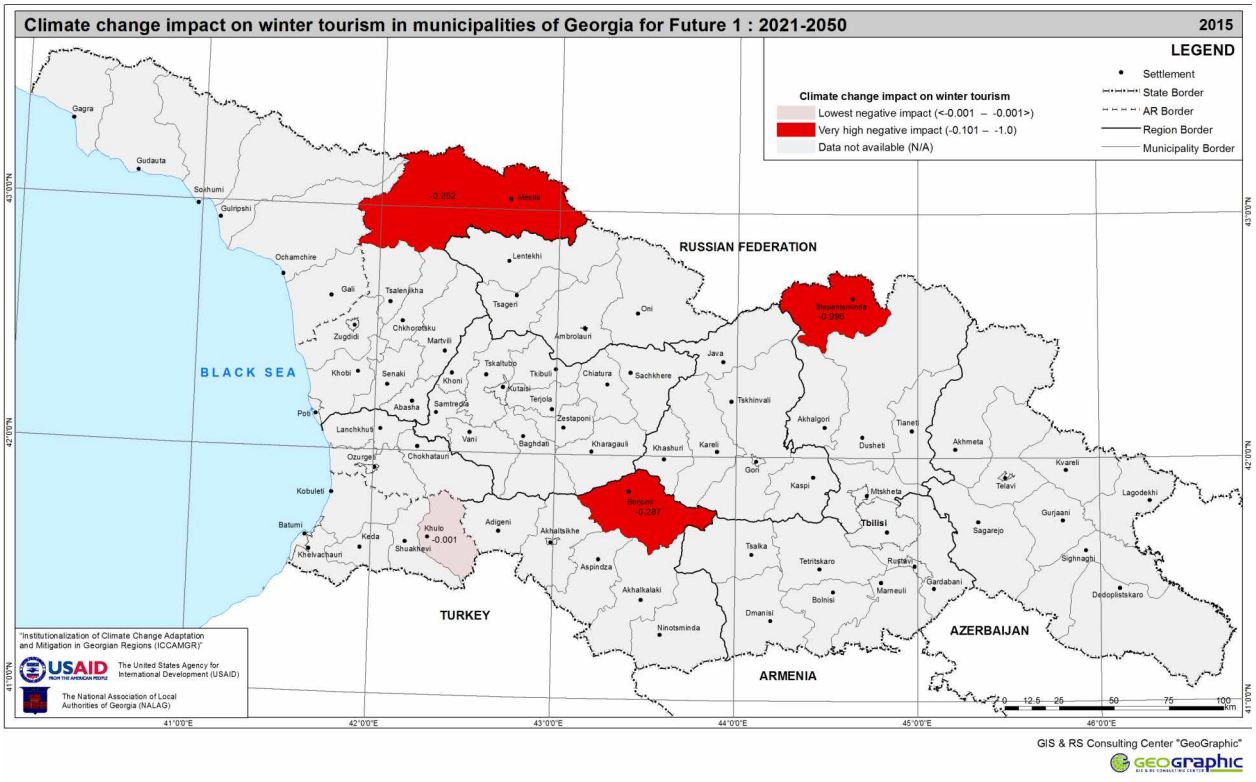


Fig. 25. Potential impact of natural disasters on the social and economic state in 2071-2100, taking into account the size of the elderly population living below the poverty line, baseline year 2015

Climate change impact maps for Future 1 (2021-2050)



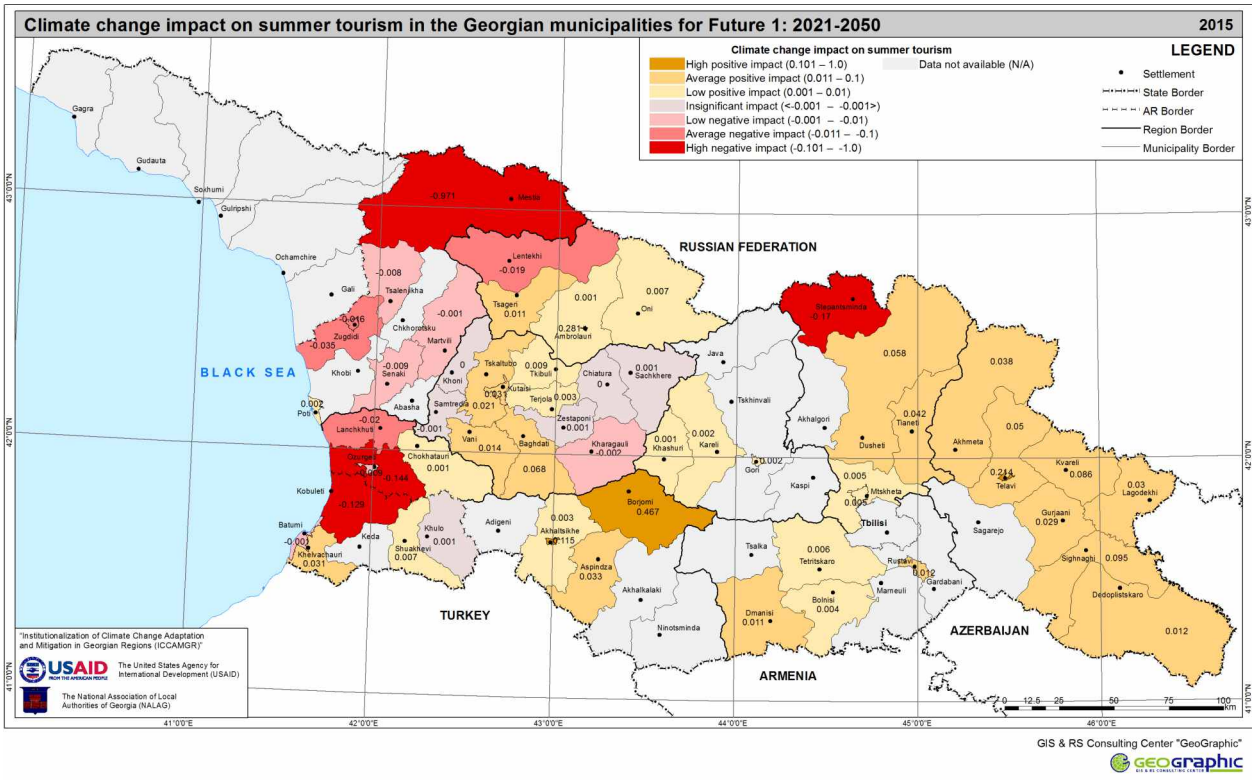
Map 68. Climate change impact on winter tourism for Future 1 (2021-2050)

The map shows the varying potential impact of climate change on winter tourism in the municipalities of Georgia, based on the climate change projection, Future 1 (2021-2050).

Winter tourism is sensitive to climatic conditions, in terms of the length of the snow season, the stability of the snow cover, the amount of snow etc. However, the character of climate change and the importance of winter tourism differ distinctly between municipalities. Therefore, to measure the extent of the impact of climate change on winter tourism, two indicators were selected: (a) municipal sensitivity to tourism, and (b) the average annual number of snow days in the period of 2021-2050. The climate change impact on winter tourism in Georgian municipalities was assessed on the basis of the index produced by the multiplication of these two parameters.

Future 1 showed a clear decline in the number of snow cover days in all regions. As a result, due to the lack of snow, winter tourist centers will face serious issues because of the shortened tourist season and the reduced number of tourists.

Climate change most seriously affects the major centers of winter tourism: Gudauri (Kazbegi municipality), Bakuriani (Borjomi municipality), and Hatsvali and Tetnuldi (Mestia municipality) which were assigned the category ("very high negative impact"). In Khulo municipality, the impact is negative but much less severe, in the category "lowest negative impact" as the municipality's winter tourist resort, "Goderdzi", was established recently and its economic potential has not yet been studied sufficiently..



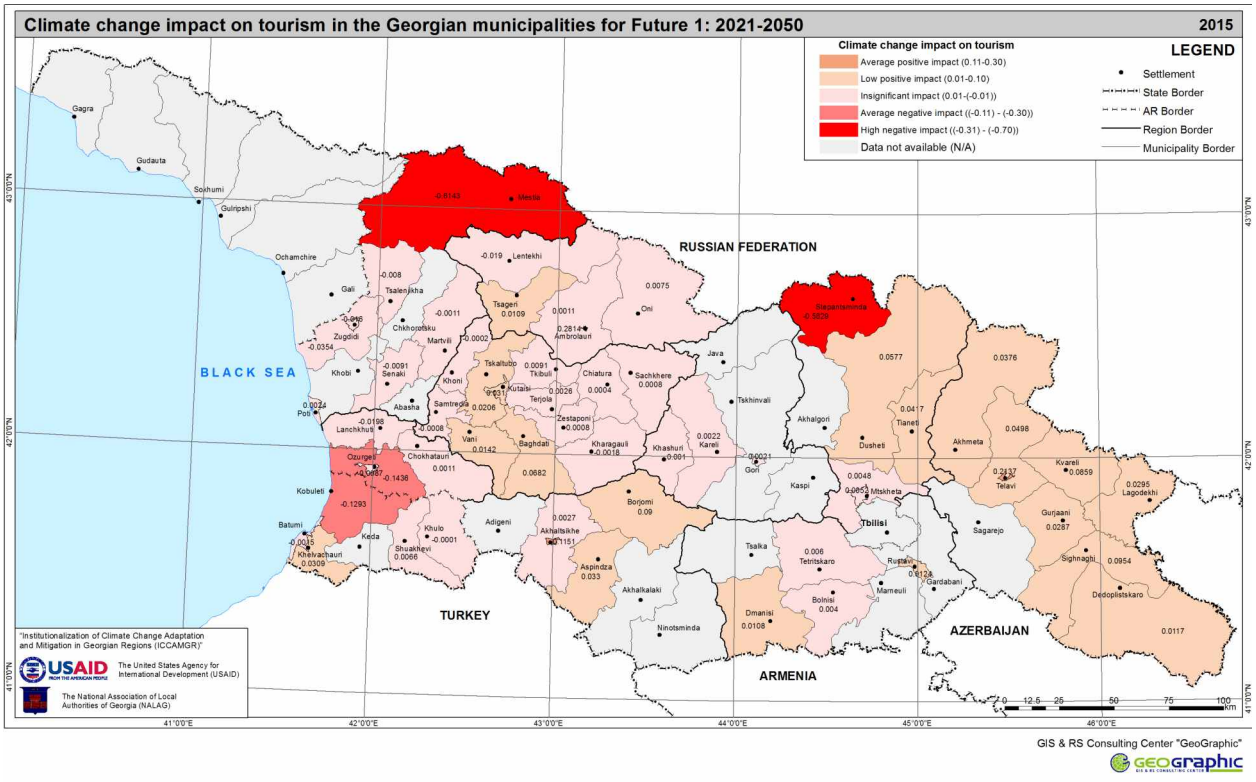
Map 69. Climate change impact on summer tourism for Future 1 (2021-2050)

The map shows the varying potential impact of climate change on summer tourism in the municipalities of Georgia, based on the climate change projection for Future 1 (2021-2050).

In order to measure the extent of the impact of climate change on summer tourism, two indicators were selected: municipal sensitivity to tourism and the change in precipitation in summer months in 2021-2050. The impact of climate change on summer tourism in Georgian municipalities was assessed on the basis of the index produced by the multiplication of these two parameters.

As seen from the map, a very high negative impact can observed in the municipalities where precipitation sharply increases in summer. These include: Mestia, Kobuleti, Ozurgeti and Kazbegi municipalities ("high negative impact"). Zugdidi and Lanchkuti municipalities are classified as having an "average negative impact", since they have seaside resorts where summer precipitation already poses problems. Borjomi municipality, where summer precipitations decline in the projected period, is classified as "high positive impact". In general, climate change is estimated to have a positive or neutral impact on tourism in east Georgian regions. In contrast, west Georgia municipalities are almost equally distributed in terms of positive and negative impact, although the relatively important tourist centers will experience a more negative impact.

The air temperature increase, which is characteristic of almost all regions, negatively affects tourist centers in lowland areas. The number of tourists is expected to decline in the peak summer season in all of them. On the other hand, increased air temperatures will lead to the prolongation of the summer season everywhere at the expense of other seasons of the year.



Map 70. Climate change impact on tourism for Future 1 (2021-2050)

The map presents the potential impact of climate change on tourism in the municipalities of Georgia for Future 1 (2021-2050). The impact of climate change on tourism is calculated by combining the indicators of the climate change impact on summer and winter tourism (mean value).

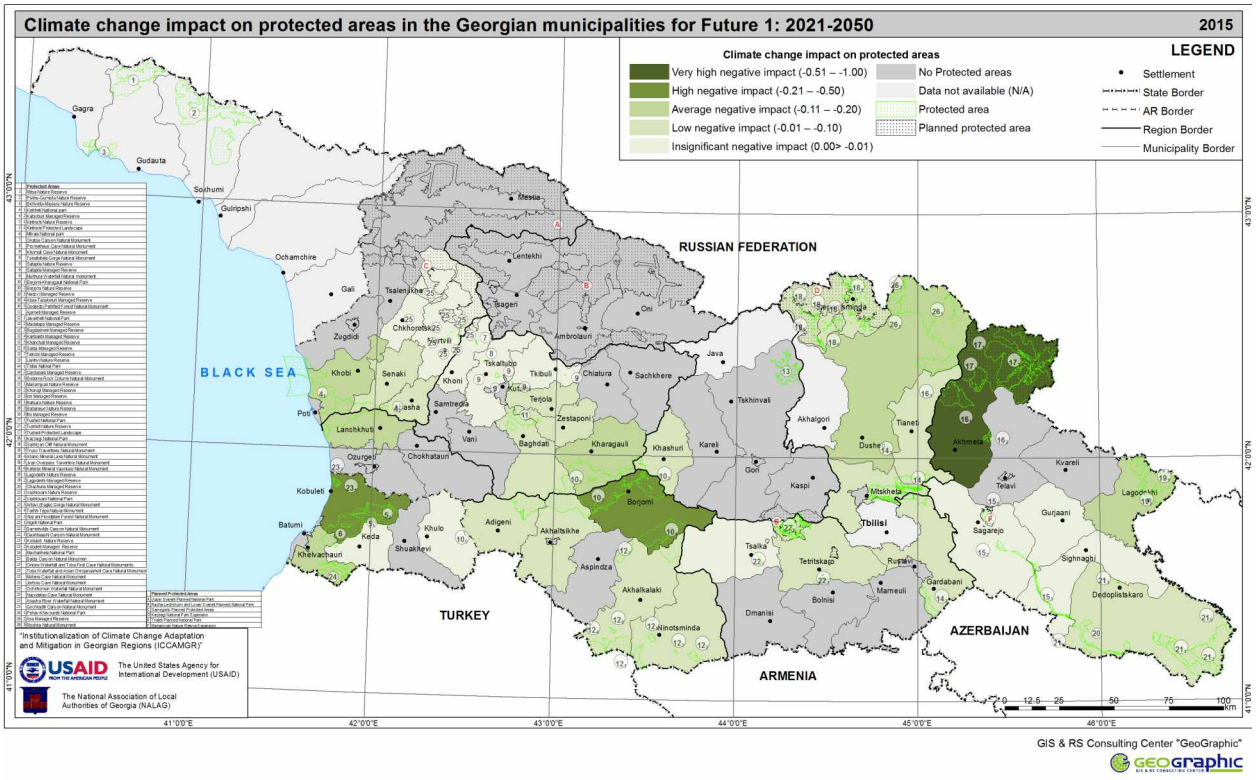
One of the more marked negative components of the impact of climate change on winter tourism is a change in the mean annual number of snow days. In Future 1 (2021-2050), this indicator tends to decline across the country. The trend is particularly painful for the municipalities where winter tourist centers are located, particularly Kazbegi, Mestia and Borjomi municipalities. In the first two municipalities, the impact of climate change on the prospects of tourism as a whole were assessed as falling into the "high negative" category. Borjomi municipality falls from the "very high positive" category of summer tourism, projected for 2021-2050 to the "low positive" combined category for the period 2021-2050 for both categories: summer and winter tourism.

The increase in precipitation in summer and autumn that is forecast for 2021-2050 will affect the general tourism prospects for seaside resorts. In particular, this will most negatively affect Kobuleti and Ozurgeti municipalities, which fall into the "average negative impact" category. An air temperature increase and summer precipitation decrease is forecast in a number of municipalities; this will prolong the tourist season on the one hand, while reducing the number of tourists in the peak tourist season, on the other. In general, the impact will be positive ("low positive impact"). The cities of Ambrolauri, Telavi and Akhaltsikhe are categorized as "average positive impact". The large number of municipalities categorized as "insignificant positive impact" can be explained by the low level of development of tourism in most municipalities.

The average negative impact on tourism of some Black Sea coastal municipalities is explained by the forecast increase in rainfall in summer (2021-2050).

In summer, rainfall tends to increase sharply in Mestia, Kobuleti, Ozurgdti and Kazbegi municipalities ("high negative impact"). Zugdidi and Lanchkhuti municipalities are characterized as "average negative impact", as they have seaside resorts where summer rainfall is already a problem today. Borjomi municipality is categorized as "high positive impact" because of the forecast decline in summer precipitation. In general, climate change in East Georgia is estimated as having a positive or neutral impact on tourism. West Georgian municipalities are almost equally distributed in terms of positive and negative impact, although the relatively important tourist centers experience a more negative impact.

The air temperature increase trend is less negative for tourist centers in lowland areas. Although increased temperatures at the peak of the summer tourist season will cause a decline in the number of tourists, they will also lead to the prolongation of the summer tourist season at the expense of other seasons (spring, autumn) of the year.


Climate change impact on protected areas in the Georgian municipalities for Future 1: 2021-2050
2015
LEGEND
Climate change impact on protected areas
Very high negative impact (-0.51 – -1.00)
High negative impact (-0.21 – -0.50)
Average negative impact (-0.11 – -0.20)
Low negative impact (-0.01 – -0.10)
Insignificant negative impact (0.00> -0.01)
No Protected areas
Data not available (N/A)
Protected area
Planned protected area
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
ARMENIA
AZERBAIJAN
Gagra
Gudauta
Sokhumi
Guliripshi
Ochamchire
Gali
Tskaltubo
Khobi
Senaki
Poti
Lanchkhuti
Kobuleti
Batumi
Khelvachauri
Keda
Shuakhevi
Khulo
Adigeni
Akhaltsikhe
Borjomi
Aspindza
Akhalkalaki
Ninotsminda
Dmanisi
Bolnisi
Tsalka
Tetritskaro
Marneuli
Gardabani
Rustavi
Tbilisi
Mtskheta
Kaspi
Gori
Kareli
Khashuri
Kharagauli
Baghdati
Vani
Zestaponi
Terjola
Samtredia
Lanchkhuti
Chokhatauri
Ozurgeti
Akhalgori
Tskhinvali
Dusheti
Tianeti
Akhmeta
Telavi
Kvareli
Lagodekhi
Gurjaani
Sagarejo
Sighnaghi
Dedoplistskaro
Stepantsminda
Kazbegi
Lentekhi
Oni
Ambrolauri
Tsageri
Chkhorotsku
Zugdidi
Jvarili
Tsalenjikha
Chiatura
Sachkhere
Kutaisi
Tkibuli
Java
Abasha
Khoni
Terjola
Baghdati
Kharagauli
Khashuri
Kareli
Gori
Kaspi
Mtskheta
Tbilisi
Akhalgori
Tskhinvali
Dusheti
Tianeti
Akhmeta
Telavi
Kvareli
Lagodekhi
Gurjaani
Sagarejo
Sighnaghi
Dedoplistskaro
Tetritskaro
Rustavi
Gardabani
Marneuli
Bolnisi
Dmanisi
Tsalka
Aspindza
Akhalkalaki
Ninotsminda
Akhaltsikhe
Adigeni
Borjomi
Khulo
Shuakhevi
Keda
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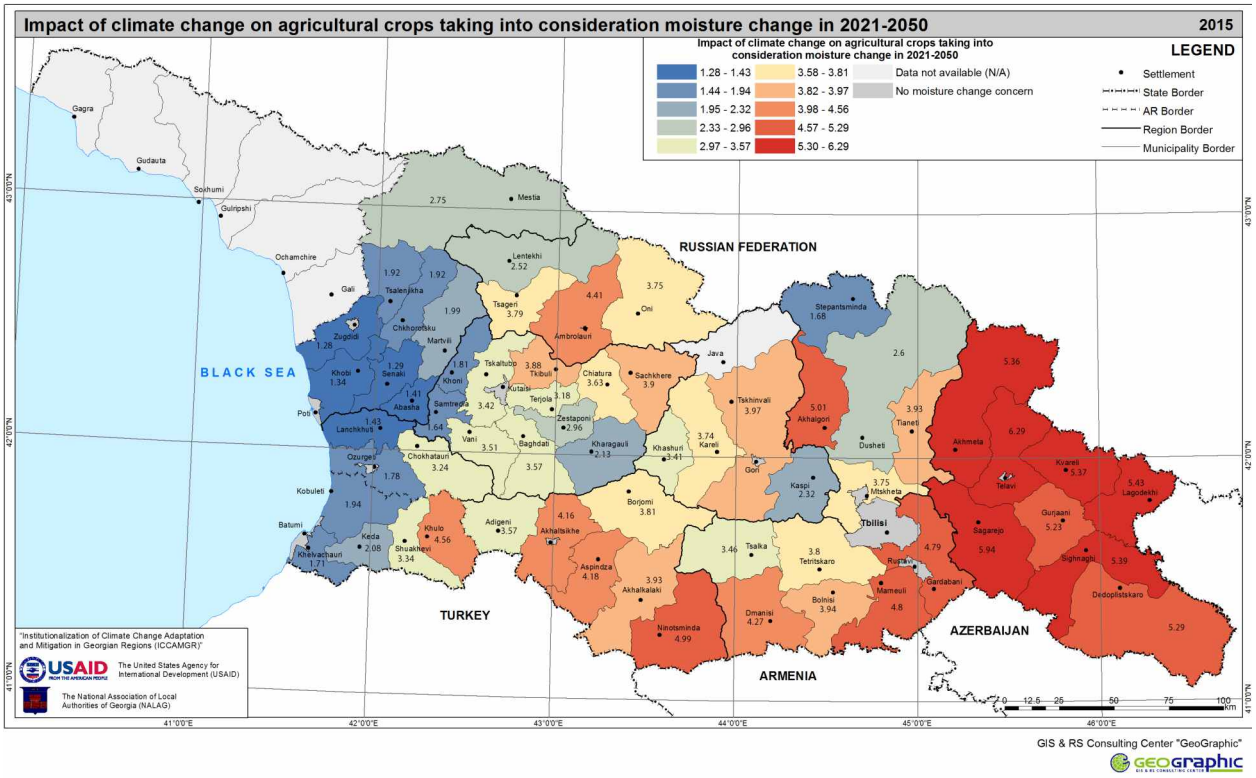
Lanchkhuti
Samtredia
Terjola
Zestaponi
Vani

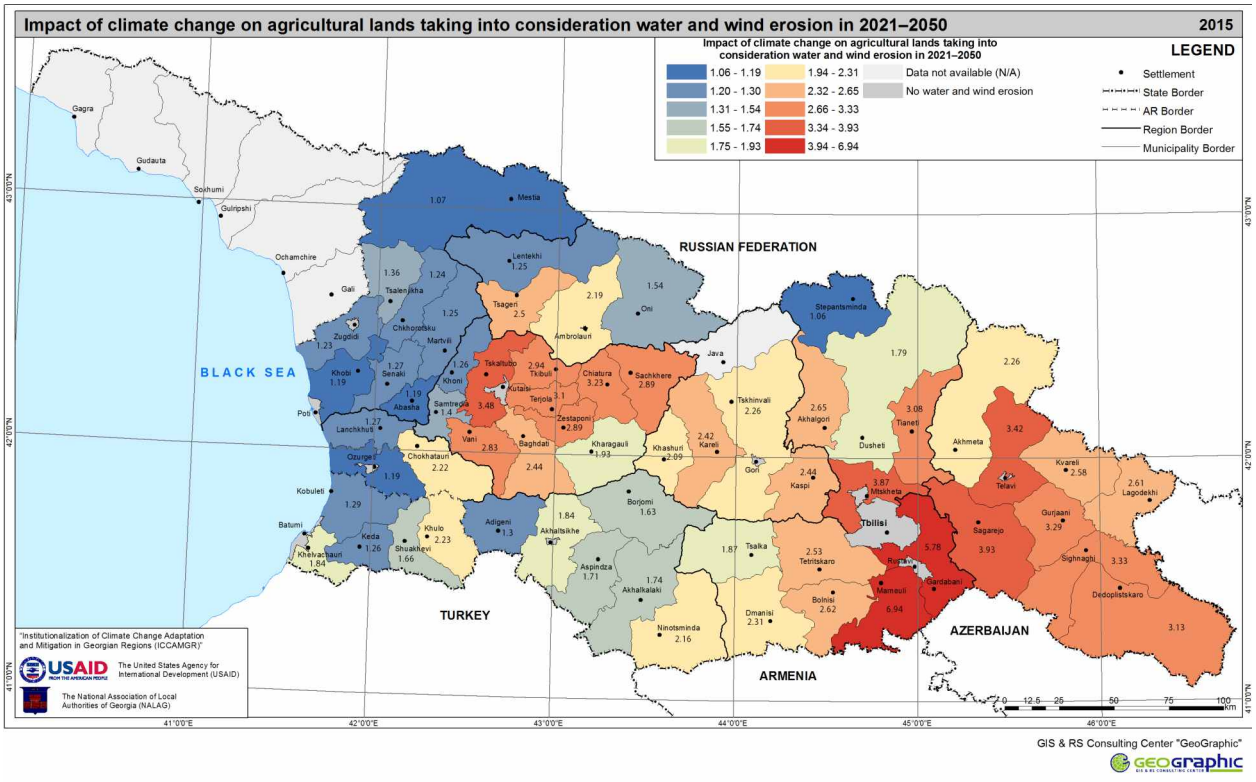


Map 72. Impact of climate change on agricultural crops taking into consideration moisture change in Future 1 (2021-2050)

Map 72 presents the anticipated impact of climate change on agricultural crops for each municipality, taking into consideration moisture change for Future 1 (2021-2050). An aggregated index of moisture change impact has been calculated taking into account the sensitivity index and two exposition indicators —temperature increase in summer months and precipitation change in the same period. Temperature increase is found by comparing the absolute temperature increment of summer months with the average perennial temperature value of summer months of the relative baseline period. Hence, even where the absolute temperature increment is the same, the temperature increase impact for each region and municipality will be different. The precipitation change indicator is defined as the ratio of moisture change resulting from the precipitation change against the rate of water to be applied to the agricultural crop during vegetation period during the baseline period.

The average value of climate change impact, considering the moisture change for Georgia will equal 3.44. By region, the impact measurements are as follows. For Kakheti the average value is 5.54, highest in Telavi (6.29) and lowest in Kvareli (5.23); in Mtskheta-Mtianeti the average is 3.39, highest in Akhalgori (5.01), lowest in Kazbegi (1.68); for Kvemo Kartli the average is 4.1, with the highest in Gardabani (4.79), lowest in Tsalka (3.41); in Shida Kartli the average is 3.36, highest in Gori (3.97), lowest in Kaspi (2.32); Samtskhe-Javakheti an average of 4.11, the highest in Ninotsminda (4.99), and lowest in Adigeni (3.57); Imereti average is 3.06, highest in Tkibuli (3.88), lowest in Samtredia (1.64); Samegrelo-Zemo (Upper) Svaneti average is 1.74, with the highest in Mestia (2.75), lowest in Zugdidi (1.28); Racha-Lechkhumi and Kvemo (Lower) Svaneti average is 3.62, highest in Ambrolauri (4.41), lowest in Lentekhi (2.52); Guria average is 2.15, highest in Chokhatauri (3.24), lowest in Lanchkhuti (1.53); and Ajara average is 2.73, with the highest in Khulo (4.56), and lowest in Khelvachauri (1.71).

In the municipalities where the impact index exceeds 3.5, the water application rate should be increased to compensate for the precipitation variability. In other municipalities, the existing water supply regime can be retained.



Map 73. Impact of climate change on agricultural lands taking into consideration water and wind erosion in Future 1 (2021–2050)

Map 73 shows the risk of aggravation of water (irrigation) and wind erosion on agricultural lands for each municipality in connection with projected climate change in 2021–2050. According to a predicted decline in precipitation, water erosion will decrease. Irrigation or water erosion occurring as a result of watering is attributable to the excessive water application rate. In connection with a predicted decline in precipitation, the irrigation rate (norm/standard) of watering is to be increased for the entire period of vegetation, which will result in greater irrigation erosion. Increasing wind erosion is connected with the following climate parameters: wind speed change, precipitation reduction and temperature increase.

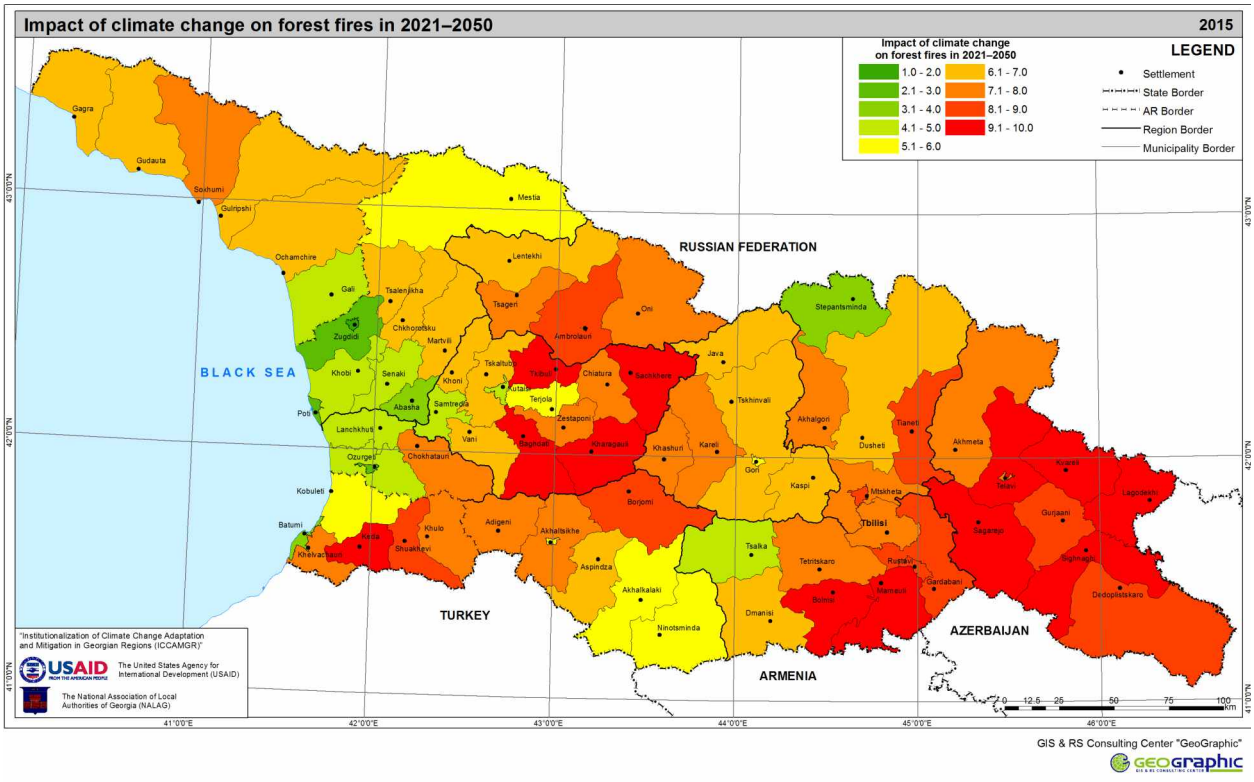
An aggregated erosion impact index is calculated based on the sensitivity index and two exposure indicators: (a) moisture change as a result of precipitation variability and (b) enhanced wind erosion caused by wind speed change.

The mean value of climate change impact for Georgia, taking erosion into account, equals 2.29. By region, the impact measurements are as follows. For Kakheti the average is 3.07, the highest in Sagarejo (3.93), lowest in Akhmeta (2.25); for Mtskheta-Mtianeti 2.49 average, with the highest in Mtskheta (3.87) and lowest in Kazbegi (1.06); Kvemo Kartli average of 3.68, highest in Marneuli (6.94), lowest in Tsalka (1.87); Shida Kartli has an average of 2.3, the highest in Kaspi (2.44), and lowest in Khashuri (2.09); Samtskhe-Javakheti average is 1.73, highest in Ninotsminda (2.16) and lowest in Adigeni (1.31); Imereti 2.58 average, highest in Tskaltubo (3.48) and lowest in Samtredia (1.40); Samegrelo-Zemo (Upper) Svaneti, average of 1.23, highest in Tsalenjikha, 1.36, lowest in Mestia (1.07); Racha-Lechkhumi and Kvemo (Lower) Svaneti average is 1.87, highest in Tsageri (2.5), lowest in Lentekhi (1.25); in Guria, 1.56 average, highest in Chokhatauri (2.22), lowest in Ozurgeti (1.19); Ajara has a 1.66 average, highest in Khulo (2.23),and lowest in Keda (1.26).

It should be noted that the impact of water erosion in all municipalities considerably exceeds the impact of wind erosion.

In all irrigated municipalities, to mitigate water (irrigation) erosion, the national irrigation technology standards should be strictly adhered to and unnecessary water losses must be reduced.

To mitigate the effects of wind erosion, windbreaks must be arranged and vegetation cover on the land surface should be preserved.



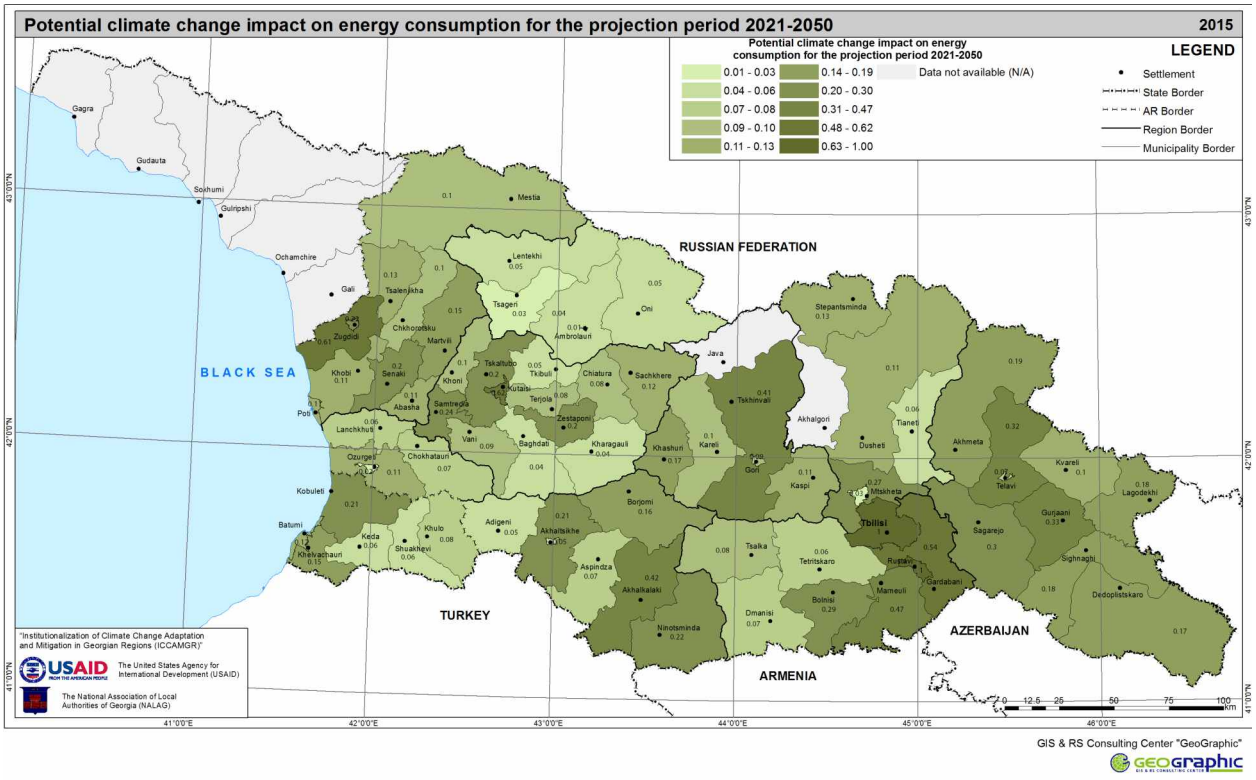
Map 74. Impact of climate change on forest fires in Future 1 (2021–2050)

Map 74 presents the aggregate projected impact indexes derived by the equilibrium geometric mean of summer temperature (50%) and precipitation change (50%) on forest fires in each municipality in 2021–2050. The map is based on the sensitivity of forest to fires in the baseline period.

Map 74 was drawn on the basis of information from the baseline period (2000-2015) on forests' sensitivity to fires. The forests' sensitivity is derived from aggregated data on the number of forest fires for the baseline period of 2000-2015 (achieved by satellite observation) and on their spatial comparison with 5 m-resolution vector layer of forest cover. As a result of the aggregation of the forest sensitivity indicators with climate change (precipitation and temperature) indicators, normalized forest fire numbers have been derived. Such numbers consider projected changes in temperature and precipitation, which may affect the number of forest fires in the projected period. It is assumed that a decrease of precipitation and increase of temperatures will aggravate forest fire risk.

By analyzing the aggregate impact index standardized from 1 to 10, it can be concluded that the most probable increase of forest fire risk in Future 1 (2021–2050) is expected in the forested areas of eastern Georgia, as well as in the woodlands stretching along and around Surami Ridge in western Georgia. The forest fire risk will also increase in highland Ajara and Racha-Lechkhumi.

Recommended fire management actions include the following: removal and safe utilization (burning) of fire-prone dry logging residues accumulated in forest tracts of each municipality; arranging fire prevention buffer zones between wood tracts and the adjoining agricultural land; promoting the use and dissemination of traditional fire management practices/knowledge in the population; carrying out an inventory of forest and forest state monitoring; developing a harmonized, long-term time series development of a comprehensive forest fire database; and taking careful note of satellite and field observations.

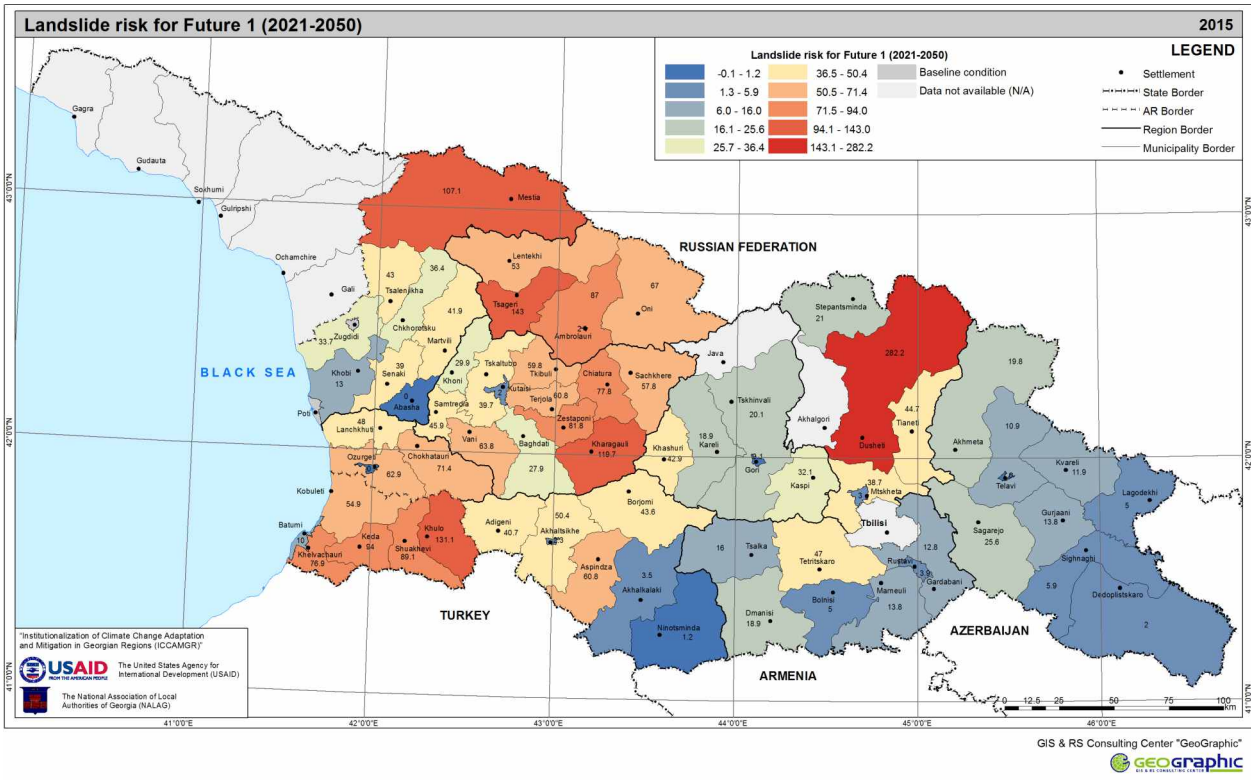


Map 75. Potential climate change impact on energy consumption in Future 1 (2021–2050)

According to climate model projections, a reduction of the heating period and an increase of the cooling period is expected in Georgia. However, in the medium-term period, the energy and economic expenses for 2050 are relatively moderate, as the increased cooling demand in the summer is compensated by decreased heating demand in winter. Climate change impacts vary per municipality. In certain municipalities, the expected climate change will bring benefits in the face of a reduced heating period, while in others the increase of the cooling period and thus the increase of electricity consumption is expected, such as in the Kakheti and Imereti regions.

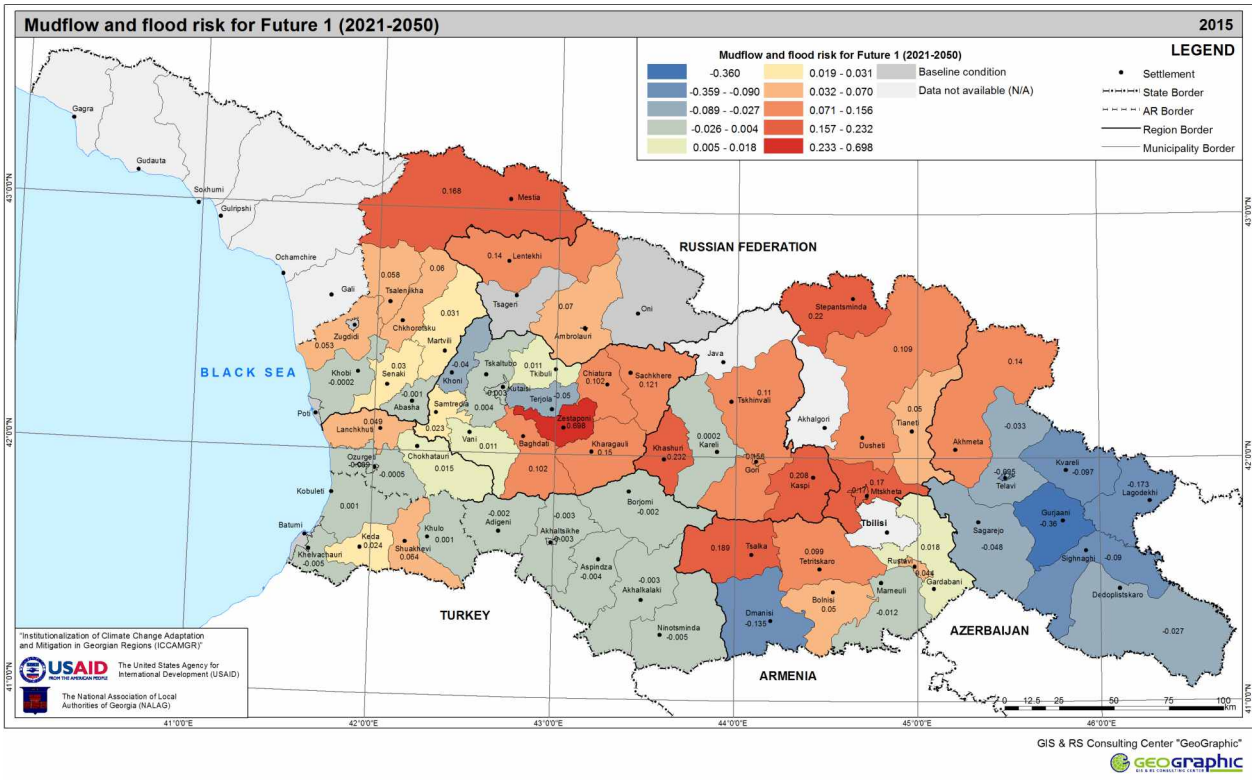
Map 75 illustrates potential climate change impacts per municipality for Future 1 (2021-2050). The map also shows the need for adaptation: the higher climate change impact, the more necessary the adaptation measures in order to avoid negative impacts on the economy, the population and the environment.

The highest climate change impact on the energy sector is expected in the Self-governing Cities of Tbilisi and Rustavi as well as in Zugdidi municipality. Thus, these municipalities require adaptation measures. Also, the impacts are quite high in Gardabani, Marneuli, Akhalkalaki and Gori municipalities.



Map 76. Landslide risk for Future 1 (2021-2050)

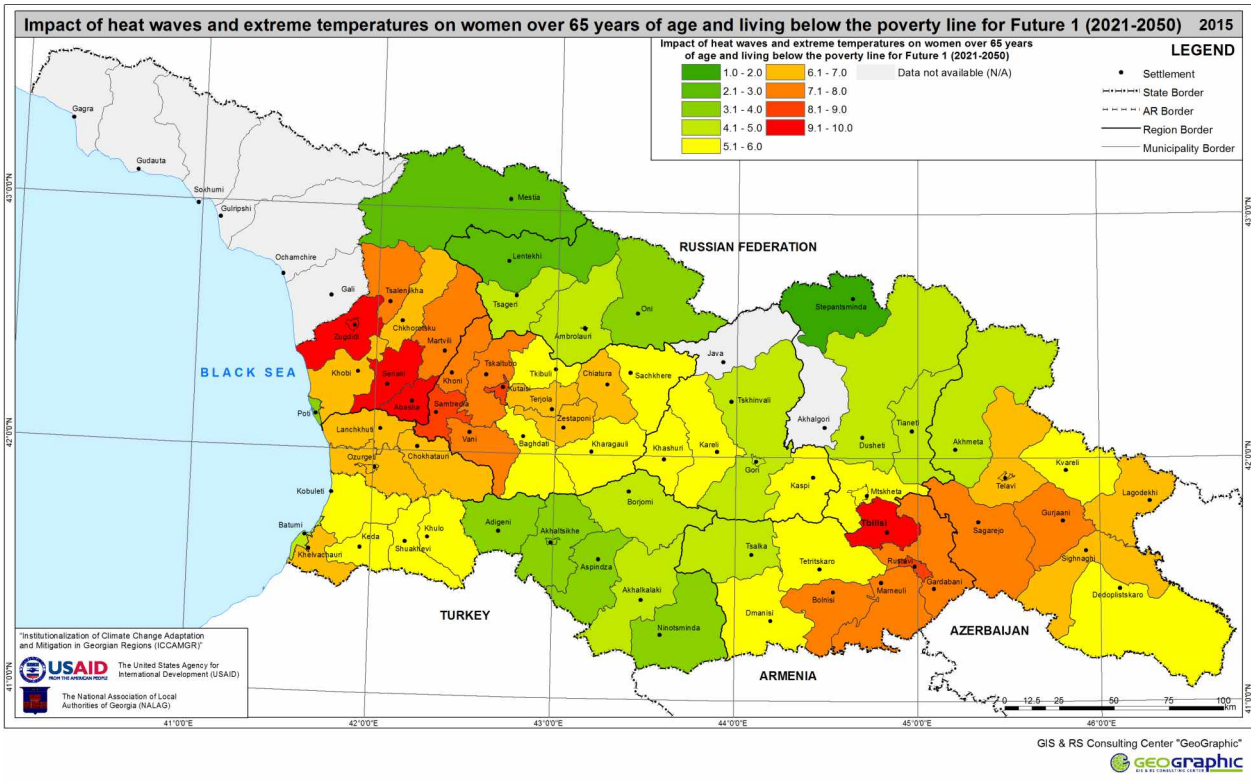
The map shows the level of risks of landslides. Based on statistical data and climate projections developed by climatologists, the prognoses for natural hazards for all municipalities were developed with the calculations of coefficients of the relevant positive and negative variations from mean annual precipitation for the period 2021-2050. The ratio of the figure calculated for the period of 2021-2050 to the baseline mean annual data for the period 1960-1990 was taken into account in the calculation of the alteration coefficients. Based on existing data, the map shows municipalities where development scales of landslides for 2021-2050 will be lower than the baseline data (Ninotsminda, Akhalkalaki, Dedoplistskaro, Abasha, Batumi city, Rustavi city and others). Municipalities where landslides will remain at the baseline level are also shown (Kareli, Gori, Khobitsalka, Bolnisi, Marneuli, Gardabani, Mtskheta city, and Kutaisi city) and the municipalities where landslides may occur are in red (Dusheti, Mestia, Tsageri, Khulo) are in orange and light orange (Shuakhevi, Keda, Khelvachauri, Ambrolauri, Oni, Vani, Kharagauli Zestaponi, Chiatura, Sachkhere).



Map 77. Mudflow and flood risk for Future 1 (2021-2050)

The map shows recurrence level of threat risks. Based on statistical data and climate projections developed by climatologists, the prognoses for natural hazards for all municipalities were developed with the calculations of coefficients of the relevant positive and negative variations from mean annual precipitation for the period 2021-2050. The ratio of the figure calculated for the period of 2021-2050 to the baseline mean annual data for the period 1960-1990 was taken into account in the calculation of the alteration coefficients.

Based on existing data, the map shows municipalities where development of mudflows-freshet and flood processes for 2021-2050 will be lower than the baseline data in blue, these include Dmanisi, Terjola, Signagi, Ninotsminda, Dedoplistskaro. There are also municipalities where the processes will remain at the baseline level represented in lighter blue: Khelvachauri, Kareli, Marneuli, Akhalkalaki. And municipalities where greater mudflow and flood processes will be activating are seen in orange for Zestaponi, Lentekhi, Dusheti, Kazbegi, Mestia and light orange for Akhmeta, Kaspi, Mtskheta and Khashuri among others.



Map 78. Impact of heat waves and extreme temperatures on women over 65 years of age and below the poverty line in Future 1 (2021–2050)

To calculate the impact of heat waves for the period from 2021-2050 on two separate socio-demographic groups of women, a combined sensitivity index for the indicators (a) over 65 years of age and (b) below the poverty line population density[225] was correlated with the aggregated climate exposure index[226]. To better understand the climate change impact on these groups, municipalities were grouped according to impact levels.

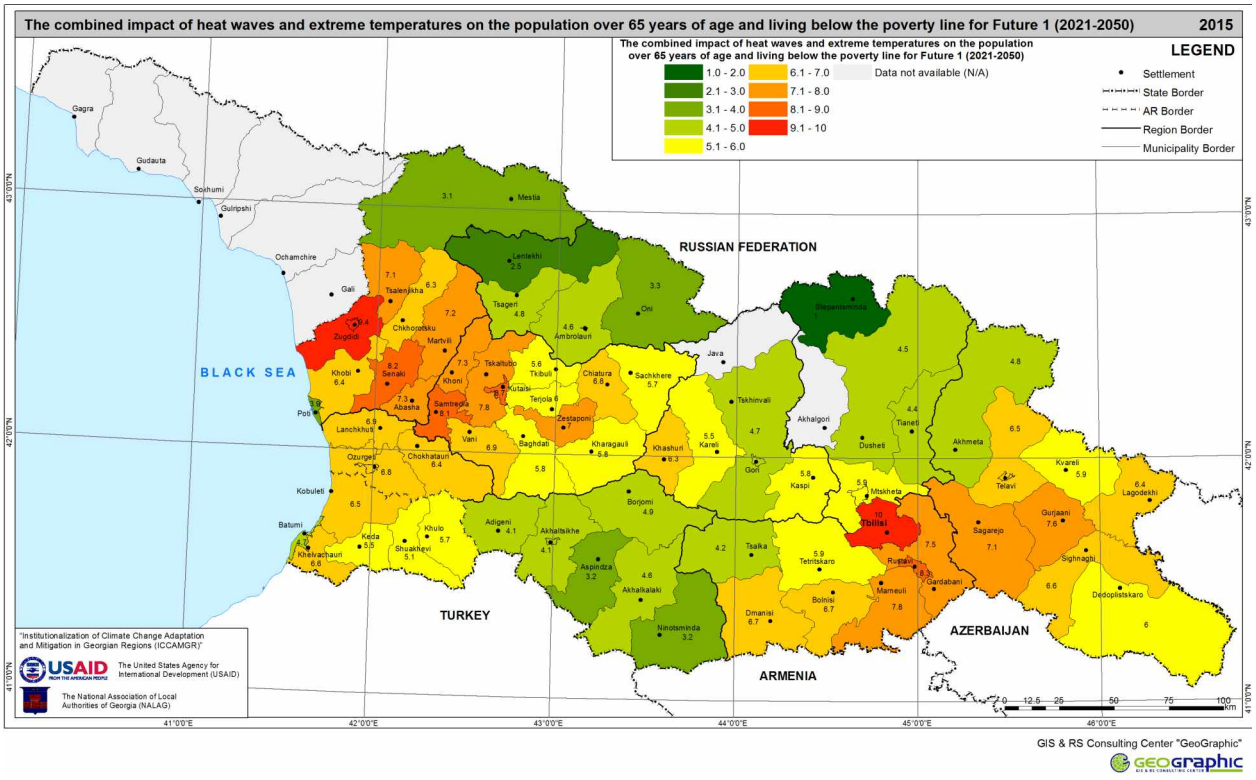
Because of their financial and social situation, as well as physiological profile, women are very vulnerable to the different aspects of climate change exposures, such as high extreme temperatures, bad weather and more frequent natural disasters among others. It should also be noted that in all municipalities except Dmanisi the majority of the population over 65 consists of women.

Therefore, due to the changes in absolute maximum temperatures and the average annual number of hot days by 2021-2050 an acute deterioration is expected in the number of high-impact municipalities. These include Tbilisi, Rustavi, Gardabani, Marneuli, Bolnisi, Sagarejo and Gurjaani in eastern Georgia; and Zugdidi, Senaki, Kutaisi, Samtredia, Tsalenjikha, Martvili, Abasha, Tskaltubo, Vani and Khoni in western Georgia.

Above medium impact: Telavi, Lagodekhi and Signagi in eastern Georgia; Chiatura, Zestaponi, Terjola, Chkhorotsku, Khobi, Khelvachauri, Ozurgeti, Lanchkhuti and Chokhatauri in western Georgia.
Medium impact: Mtskheta, Kaspi, Tetritskaro, Dmanisi, Kvareli, Dedoplistskaro, Khashuri and Kareli in eastern Georgia; and Bagdati, Kharagauli, Sachkhere, Tkibuli, Kobuleti, Keda, Shuakhevi and Khulo in western Georgia.
Low impact: Tianeti, Dusheti, Stepantsminda, Akhmeta, Gori, Borjomi, Adigeni, Akhaltsikhe, Aspindza, Akhalkalaki and Tsalka in eastern Georgia; Oni, Ambrolauri, Tsageri, Lentekhi, Mestia, Batumi and Poti in western Georgia.

According to the above, adaptive measures to extreme temperatures and heat waves are more necessary in high impact and above medium impact municipalities, i.e. municipalities falling between 7-10 on the scale. Such adaptive measures should be taken by 2020, as far as possible.

[225] The urban population is very sensitive to extreme temperatures and heat waves of the "urban heat island effect" in densely populated areas or urbanized territories, in which "white-hot" asphalt and buildings heat the air further.
[226] Climate change exposure indicators are combined by a weighing method that combines changes in absolute maximum temperatures and average annual numbers of hot days by 2021-2050.



Map 79. Impact of heat waves and extreme temperatures on population over 65 years of age and below the poverty line for Future 1 (2021–2050)

To calculate the impact of heat waves for the period from 2021-2050 on two separate socio-demographic groups, a combined sensitivity index for the indicators (a) over 65 years of age and (b) below the poverty line population density[227] was correlated with the aggregated climate exposure index[228]. To better understand the climate change impact on these groups, municipalities were grouped according to impact levels.

Because of their financial and social situation, as well as physiological profile, women are very vulnerable to the different aspects of climate change exposures, such as high extreme temperatures, bad weather and more frequent natural disasters among others.

Therefore, due to the changes in absolute maximum temperatures and the average annual number of hot days, by 2021-2050 an acute deterioration is expected in a number of high-impact municipalities. These are Tbilisi, Rustavi, Gardabani, Marneuli, Bolnisi, Sagarejo and Gurjaani in eastern Georgia; and Zugdidi, Senaki, Kutaisi, Samtredia, Tsalenjikha, Martvili, Abasha, Tskaltubo, Vani and Khoni in western Georgia.

In other municipalities for the same projection period:

Above medium impact: Telavi, Lagodekhi and Signagi in eastern Georgia; and Chiatura, Zestaponi, Terjola, Chkhorotsku, Khobi, Khelvachauri, Ozurgeti, Lanchkhuti and Chokhatauri in western Georgia;

Medium impact: Mtskheta, Kaspi, Tetritskaro, Dmanisi, Kvareli, Dedoplistskaro, Khashuri and Kareli in eastern Georgia; Bagdati, Kharagauli, Sachkhere, Tkibuli, Kobuleti, Keda, Shuakhevi and Khulo in western Georgia;

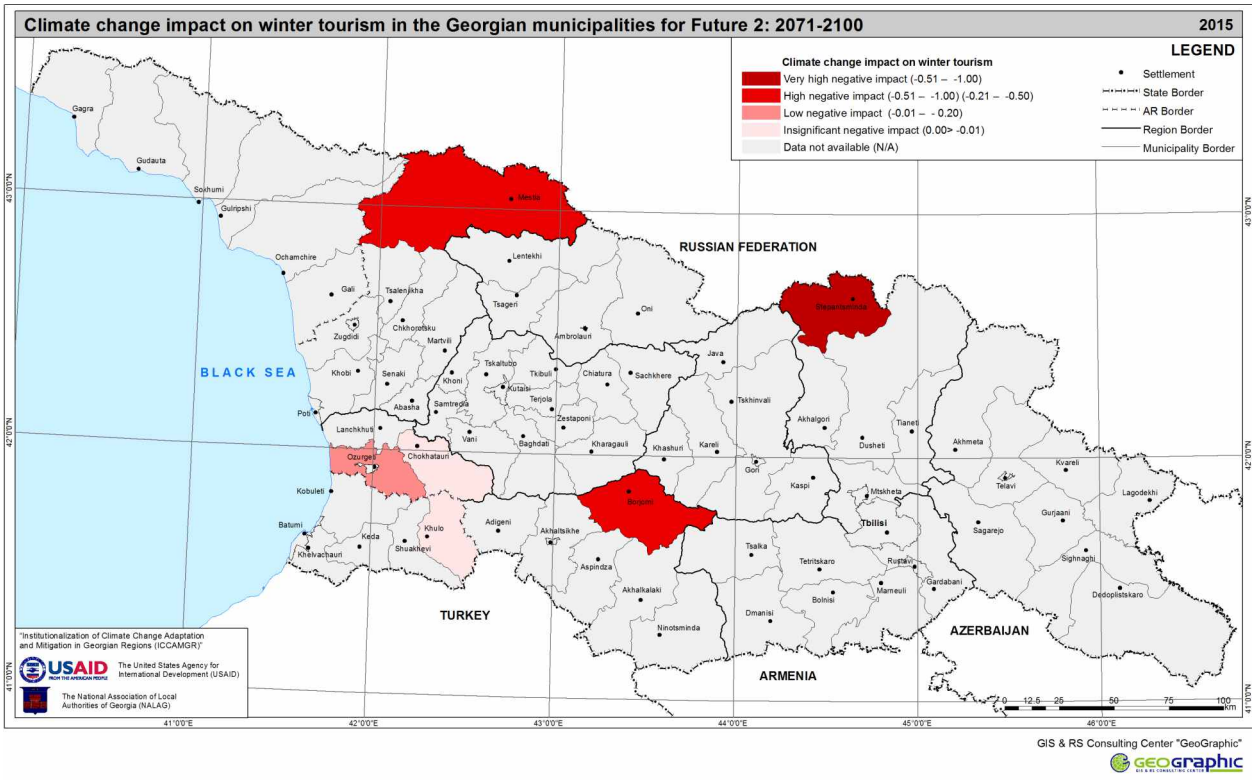
Low impact: Tianeti, Dusheti, Stepantsminda, Akhmeta, Gori, Borjomi, Adigeni, Akhaltsikhe, Aspindza, Akhalkalaki and Tsalka in eastern Georgia; Oni, Ambrolauri, Tsageri, Lentekhi, Mestia, Batumi and Poti in western Georgia.

According to the above, adaptive measures to extreme temperatures and heat waves are more necessary in high impact and above medium impact municipalities, i.e. municipalities falling between 7 and10 on the scale. Such measures should be taken by 2020, as far as possible.

[227] The urban population is very sensitive to extreme temperatures and heat waves of the "heat island effect" in densely populated areas or urbanized territories, in which "white-hot" asphalt and buildings heat the air further.

[228] Climate change exposure indicators are combined by a weighing method that combines changes in absolute maximum temperatures and average annual numbers of hot days by 2021-2050.

Climate change impact maps for Future 2 (2071-2100)



Map 80. Climate change impact on winter tourism for Future 2 (2071-2100)

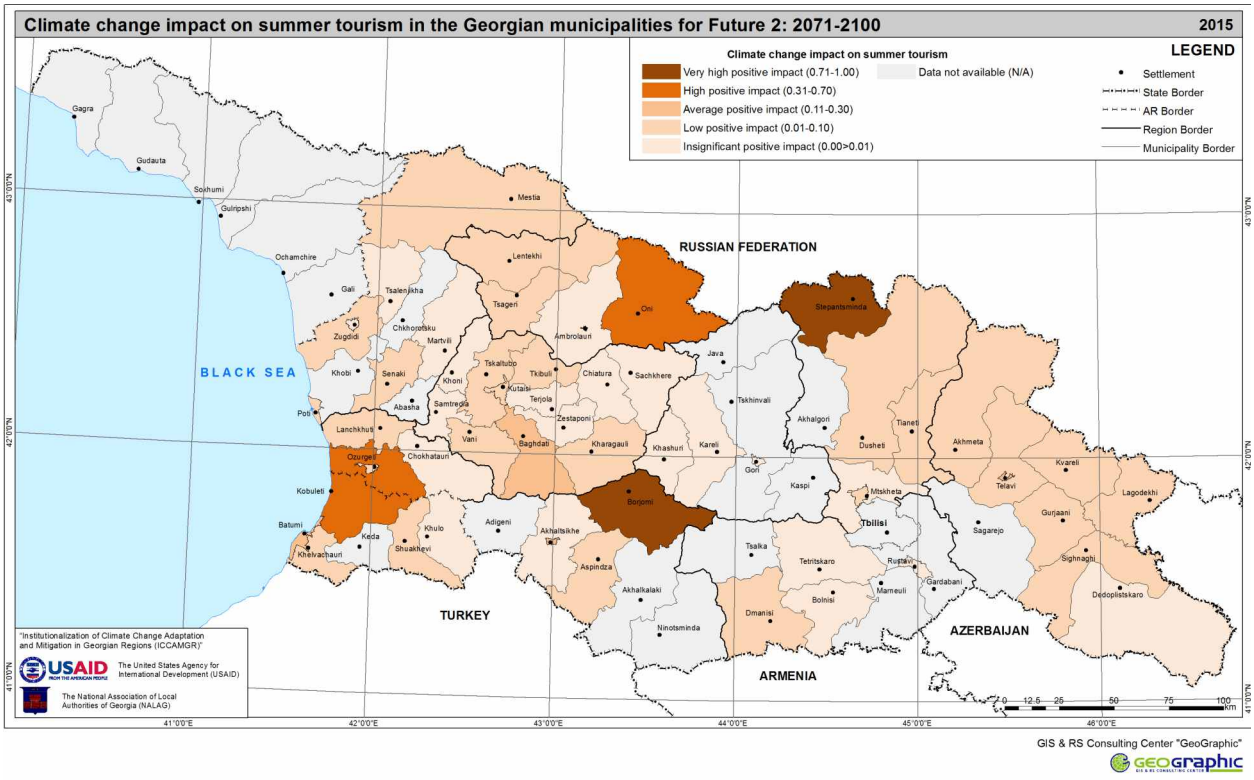
The map shows the impact of climate change on winter tourism in the municipalities of Georgia for 2071-2100. It is based on the change of the climate exposure indicator for Future 2 (2071-2100) and the tourism sensitivity in municipalities. The rate and character of climate change impact on winter tourism have been assessed by a combination of these two indicators.

According to Future 2 (2071-2100), the trends of climate change that will affect winter tourism during Future 1 (precipitation reduction, general temperature augmentation, reduced amounts of snow measured by number of snow days and snow cover size) will remain the same for the last 30 years of the century.

These trends will lead to a definite lack of snow in the winter tourist season, and will seriously affect the prospects for winter tourism. In particular, the number of tourists will significantly decrease in the major centers of winter tourism: Gudauri (Kazbegi municipality), Bakuriani (Borjomi municipality), Hatsvali and Tetnuldi (Mestia municipality). A comparatively negative impact will be observed in the Goderdzi Alpine Skiing Center (Khulo municipality). The most negative impact will affect Kazbegi municipality, which is assigned a “very high negative impact”).

Reduced amounts of snow will affect to a lesser degree new winter tourism centers such as Bakhmaro (Chokhatauri municipality), Gomismta (Ozurgeti municipality) and their adjacent territory in Guria. Their proximity to the sea means that reductions in winter precipitation will be less pronounced. Another new area for winter tourism is the western slope of Samsara Range in Akhalkalaki municipality, which already has an alpine skiing center. The prospects of this center could not be properly assessed because Javakheti winter tourism is in its initial stage, which prevents us from determining the climate impact character of the region.

The negative impact of progressive reductions in the amounts of snow and snow days in winter tourist centers may be partially compensated by technical installations, such as snow makers among others. However, they will not essentially change the importance of snow for winter tourism. In this period, winter tourism will enjoy comparatively better conditions in the west-facing slopes of Khulo, Ozurgeti and Chokhatauri municipalities, which are affected by humid air masses that come in from the sea.



Map 81: Climate change impact on summer tourism for Future 2 (2071-2100)

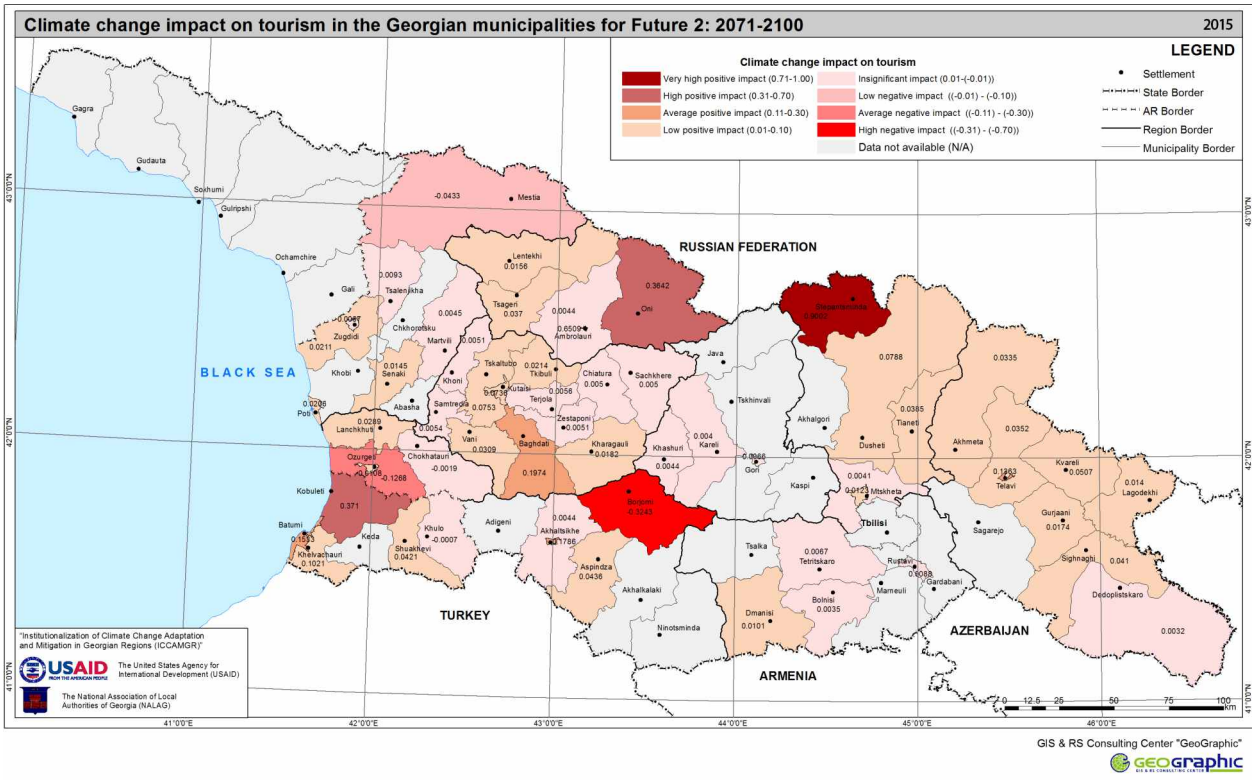
The map shows the impact of climate change on summer tourism in municipalities of Georgia for 2071-2100. It is based on the change of the climate exposure indicator for the projection period 2071-2100 and the tourism sensitivity rate in municipalities. The rate and character of climate change impact on summer tourism has been assessed by a combination of these two indicators.

According to Future 2 (2071-2100), the trends of the climate change that will affect summer tourism outlined during Future 1 (2021-2050) will remain the same for the last 30 years of the century. The general air temperature increases and reduced precipitation are characteristic of Future 2.

Precipitation reduction is, on the whole, a favorable factor for most of the municipalities, especially for such important tourism areas as Kazbegi, Borjomi, Mestia, Ozurgeti and Kobuleti municipalities. Abundant summer precipitation is the most restrictive factor for the number of tourists in these municipalities today and will remain as such in Futures 1 and 2.

Under current conditions, the essential problem for most tourist centers is the shortness of the summer tourism season. In this respect, increasing temperatures will have a clear positive influence in terms of prolonging the summer tourist season. This particularly affects highland tourism zones and seaside resorts (Kobuleti, Khelvachauri, Ozurgeti, Lanchkhuti, Zugdidi municipalities and the city of Batumi). Increased air temperatures, especially under high evaporation conditions, should result in the reduction of visitors in August, which is the most active period of the season. At the same time, however, they will create more comfortable climatic conditions in other periods, such as spring, early summer and autumn.

The positive impact of climate change will be less pronounced in the promising tourism regions in eastern Georgia: Mtskheta, Dusheti, Akhmeta, Telavi, Kvareli and Dedoplistskaro municipalities and Dmanisi, Bolnisi and Tetritskaro municipalities in Kvemo Kartli. The problem here will be an excessive temperature increase and the general climate (aggregate exposure) impact on protected areas in Akhmeta, Dedoplistskaro, Dusheti, and Tetritskaro municipalities.



Map 82: Climate change impact on tourism for Future 2 (2071-2100)

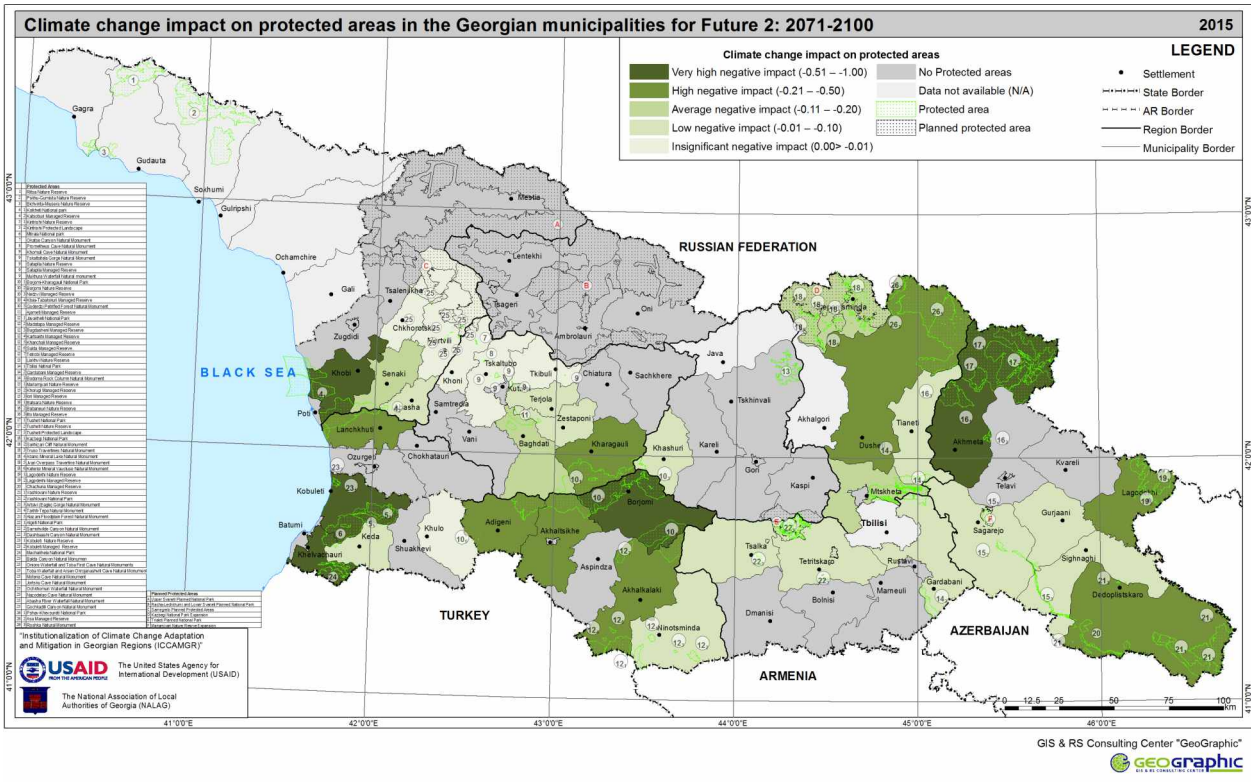
The map presents the potential impact of climate change on tourism in the municipalities of Georgia in Future 2 (2071-2100). The climate change impact on tourism is calculated by combining the climate change impact on summer and winter tourism.

According to Future 2 (2071-2100), the trend of climate processes that will affect tourism (precipitation reduction, general temperature increases and reduced amounts of snow (number of snow days and snow cover size) will remain the same in the last 30 years of the century. In Future 2, the climate change impact on tourism will undergo a moderate change in most regions, compared to Future 1. However, sizable shifts are expected within the sector, in particular in the prospects for summer and winter tourism.

The negative climate trends will have a pronounced adverse effect on winter tourism. In particular, the sharp snow reduction, which radically worsens the state of tourism in general in Mestia ("low negative impact") and Borjomi ("high negative impact") municipalities. However, the negative prospects for winter tourism will be significantly mitigated by the growth of summer tourism, i.e. through prolongation of the summer season. This process will be most clearly revealed in the case of Kazbegi municipality ("very high positive impact").

The decline in summer and winter precipitation will result in the change of category by Kobuleti municipality, which is host to important seaside resorts, from "average negative impact" to "high positive impact".

Dramatic changes in the impact rate in Oni municipality ("high positive impact") need to be explained. Summer tourism in this municipality has good development prospects, with resorts such as Utsera and Shovi having great potential. In addition, the municipality is mostly mountainous, its average annual air temperature is comparatively low, and temperature increases in the predicted period (+3.2^{0}C) will contribute to the season prolongation without causing a significant decline in the number of visitors in the peak summer season.



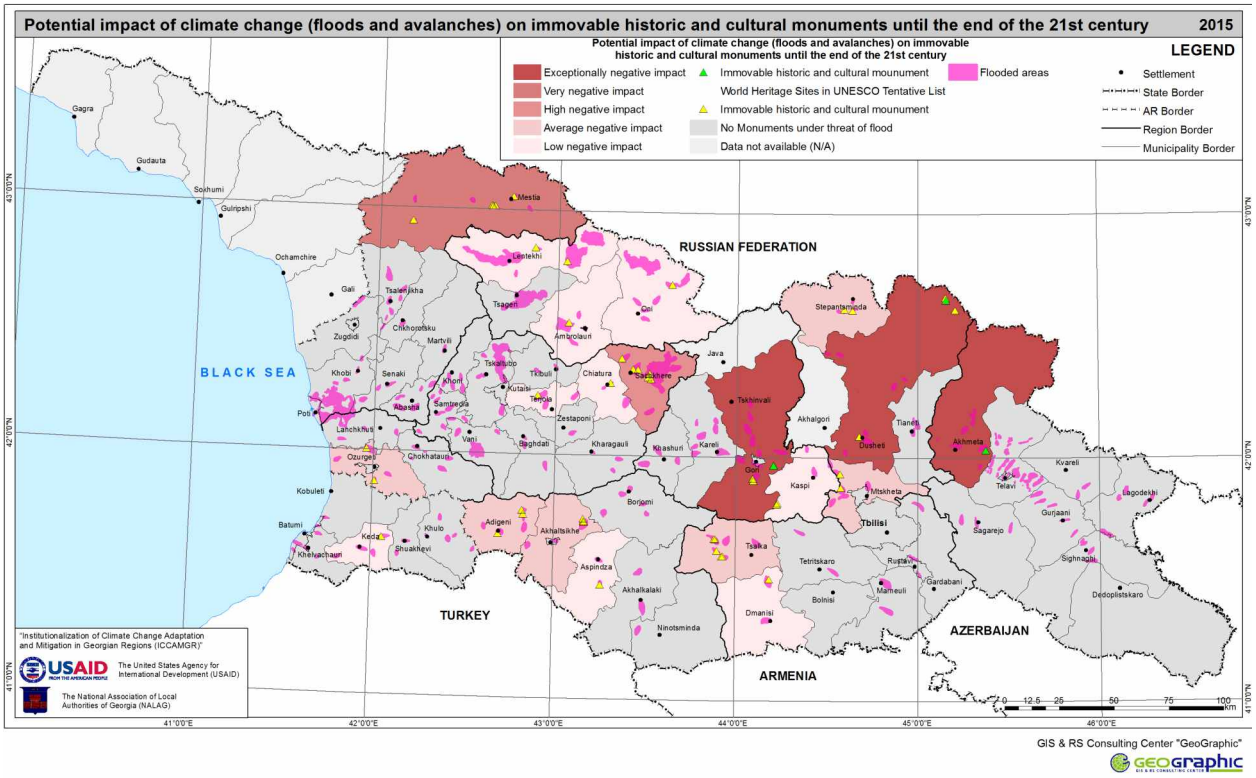
Map 83: Climate change impact on protected areas for Future 2 (2071-2100)

The map presents the potential impact of climate change on protected areas in Future 2 (2071-2100) by municipalities of Georgia. The climate change impact rate was assessed on the basis of a combined index of the municipal protected areas sensitivity rate and the climate change aggregate index.

The municipal sensitivity of protected areas is measured by the share of the protected areas in the total area of the municipality. The climate change aggregated index comprises the change of rates in climate exposure indicators for Future 2: average annual air temperature, average annual precipitation, average annual number of summer days, average annual number of frost days and average annual evaporation rates.

Climate change will have different impacts on the western and eastern parts of the country. Climate change in eastern Georgia will exacerbate the existing climate character: continentality, summer temperature excess and precipitation shortage, which in some areas (e.g. Gardabani, Sagarejo and Dedoplistskaro municipalities) will intensify desertification processes including within protected areas. In western Georgia, where natural landscapes have more of a subtropical character, similar changes (temperature augmentation, precipitation decline and evaporation growth) will change the living climate conditions of ecosystems and biological species. In both cases, the climate change impact on protected areas will be negative.

The climate change forecast for Future 2 (2071-2100) shows that the trends outlined in Future 1 (2021-2050) will remain the same. In addition to Kazbegi municipality, a “very high negative impact” will be observed in Borjomi, Kobuleti, Khobi and Khelvachauri municipalities. A “high negative impact” will be observed in Lagodekhi, Dedoplistskaro, Dusheti, Kharagauli, Akhalkalaki, Akhaltsikhe and Adigeni municipalities; and an “average negative impact” will be observed in Kazbegi, Mtskheta, Baghdati and Senaki municipality. The impact in other municipalities that have protected areas will be “low negative”.



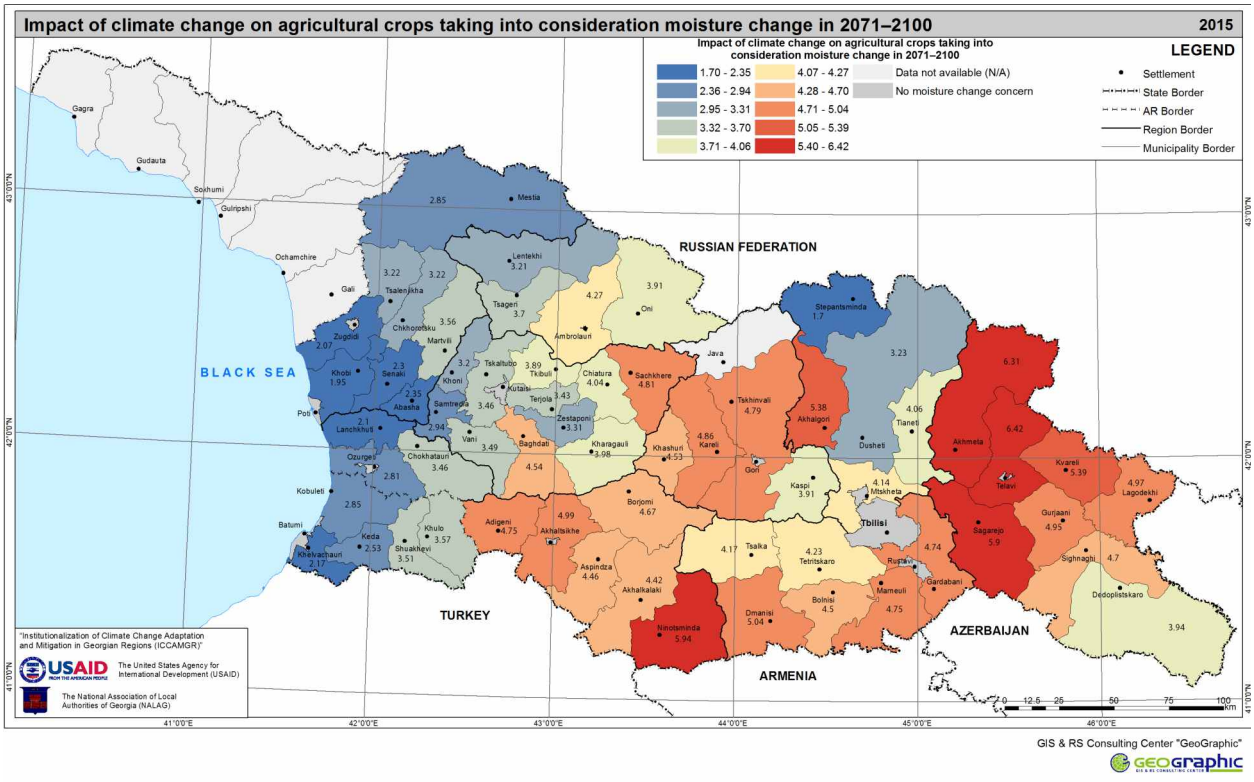
Map 84: Potential impact of climate change (floods and avalanches) on immovable historic and cultural monuments in Future 2 (2071-2100)

The map presents the potential impact of climate change on immovable monuments of cultural heritage in municipalities of Georgia. The climate change impact rate was assessed by the number of monuments falling within the risk zones of predicted floods and landslides, although qualitative indicators were also used together with the quantitative ones. In particular, if a municipality has a UNESCO World Heritage sites or a site from the UNESCO Tentative List[229], the municipality would be assigned to the "Exceptionally Negative Impact" category.

On the basis of this study, no monument was identified as being in the avalanche risk zone. Several monuments on the UNESCO World Heritage List, as well as monuments of national and local significance, are at risk of inundation as a result of river floods. These include Uplistsikhe Cave Town-Fortress in Gori municipality, which is on the UNESCO Tentative List. This monument near the River Kura is threatened by erosive processes caused by the river and inundation in the case of floods. The same danger awaits Alaverdi Cathedral in Akhmeta municipality, which is in the UNESCO Tentative List as well. Floods are also the main risk facing Shatili (Dusheti municipality), a highland village and fortress in Upper Khevsureti which is also on the UNESCO Tentative List.

Accordingly, Akhmeta, Dusheti and Gori municipalities fall within the "exceptionally negative impact" category. Mestia municipality, which has six monuments, is categorized as "very negative impact", while Sachkhere municipality, which has five monuments, falls into the "high negative impact" category. Kazbegi, Gori, Tsalka, Mtskheta, Akhaltsikhe, Adigeni and Ozurgeti municipalities fall into the "average negative impact" category, while the impact of floods in other municipalities is low.

[229] UNESCO World Heritage List.

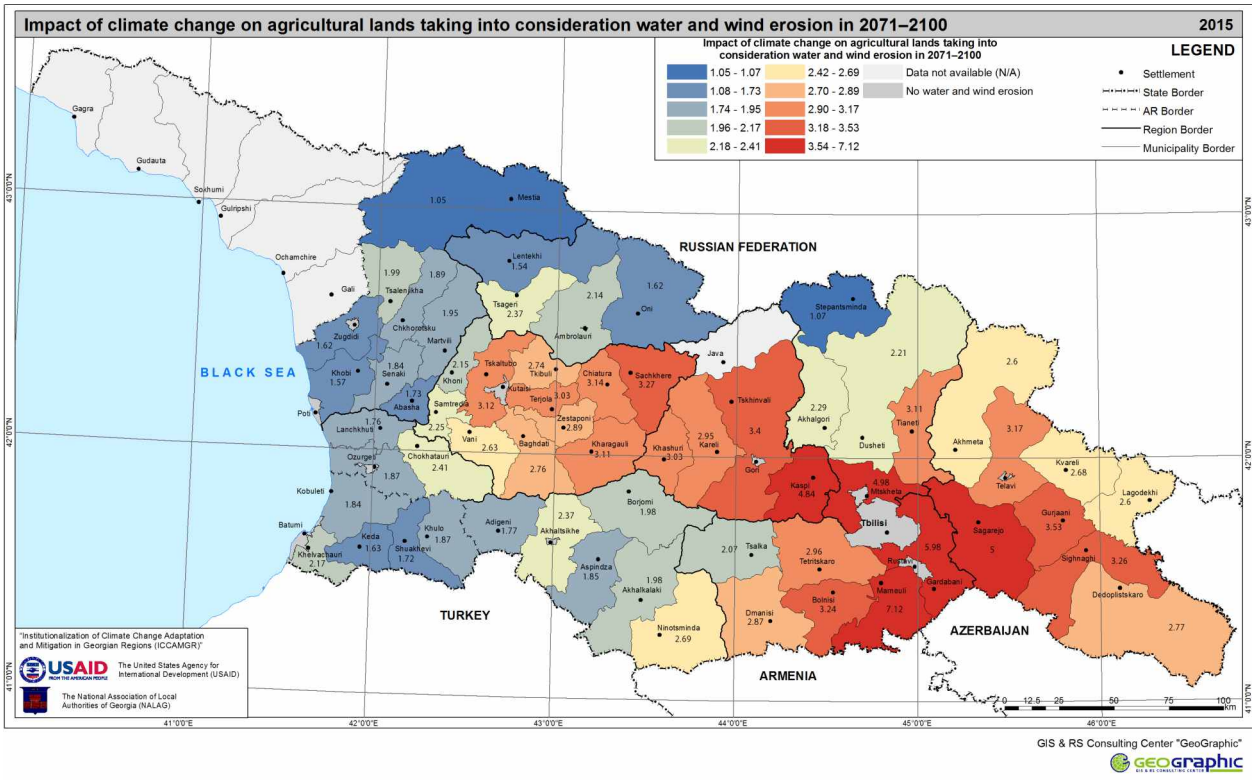


Map 85: Impact of climate change on agricultural crops taking into consideration moisture change in Future 2 (2071–2100)

Map 85 presents the anticipated impact of climate change on agricultural crops of each municipality, taking into consideration moisture change for Future 2 (2071-2100). An aggregated index of moisture change impact has been calculated taking into account the sensitivity index and two exposition indicators—temperature increase in summer months and precipitation change in the same period. Temperature increase is measured by comparing the absolute temperature increment of summer months with the average perennial temperature value of summer months of the relative base period. Hence, even when values of the absolute temperature increment are the same, the temperature increase impact for different regions and municipalities will be different. The precipitation change indicator is defined as the ratio of moisture change resulting from the precipitation change against the rate of water to be applied to agricultural crop plants during vegetation of the baseline period.

The mean value of climate change impact, taking moisture change into consideration, for Georgia will equal 3.94. By region, the impact measurements are as follows. For Kakheti the mean is 5.32, with the highest in Telavi (6.42) and lowest in Sighnaghi (4.70); Mtskheta-Mtianeti has an average of 3.7 (highest in Akhalgori (5.38) and lowest in Kazbegi (1.70); Kvemo Kartli average is 4.57 wit the highest in Dmanisi (5.04) and lowest in Tsalka (4.17); for Shida Kartli the average is 4.52 with the highest in Kareli (4.84) and lowest in Kaspi (3.91); Samtskhe-Javakheti has 4.87 as an average with the highest in Ninotsminda (5.94) and lowest in Akhalkalaki (4.42); Imereti average is 3.74, highest in Sachkhere (4.81), lowest in Samtredia (2.84); Samegrelo-Zemo (Upper) Svaneti has an average of 2.69, highest in Martvili (3.58), lowest in Khobi (1.95); Racha-Lechkhumi and Kvemo (Lower) Svaneti average 3.8 highest in Ambrolauri (4.27), lowest in Tsageri (3.7); Guria has average of 2.79, highest in Chokhatauri (3.46) and lowest in Lanchkhuti (2.1); and Ajara has an average of 2.93, highest in Khulo (3.57), lowest in Khelvachauri (2.17).

In the municipalities where the impact index exceeds 3.5, the water application rate should be increased to compensate for the precipitation variability. In other municipalities, irrigation rates (i.e. amount of water supplied to agricultural crops) could remain the same. To protect agricultural lands from erosion, it is recommended that for Future 2 (2071-2100), all agricultural lands of the country be irrigated by more sustainable means such as sprinkling irrigation or drop irrigation.



Map 86. Impact of climate change on agricultural lands taking into consideration water and wind erosion in Future 2 (2071–2100)

Map 86 shows the risk of aggravation of water (irrigation) and wind erosion on agricultural lands in connection with projected climate change in 2071–2100. According to a predicted decline in precipitation, water erosion will decrease. The irrigation or water erosion occurring as a result of watering is attributable to the excessive water application rate. In connection with a predicted decline in precipitation, the irrigation rate or the volume (norm/standard) of watering is to be increased for the entire period of vegetation, which will result in greater irrigation erosion. Meanwhile, enhanced wind erosion is connected with the following climate parameters: wind speed change, precipitation reduction and temperature increase.

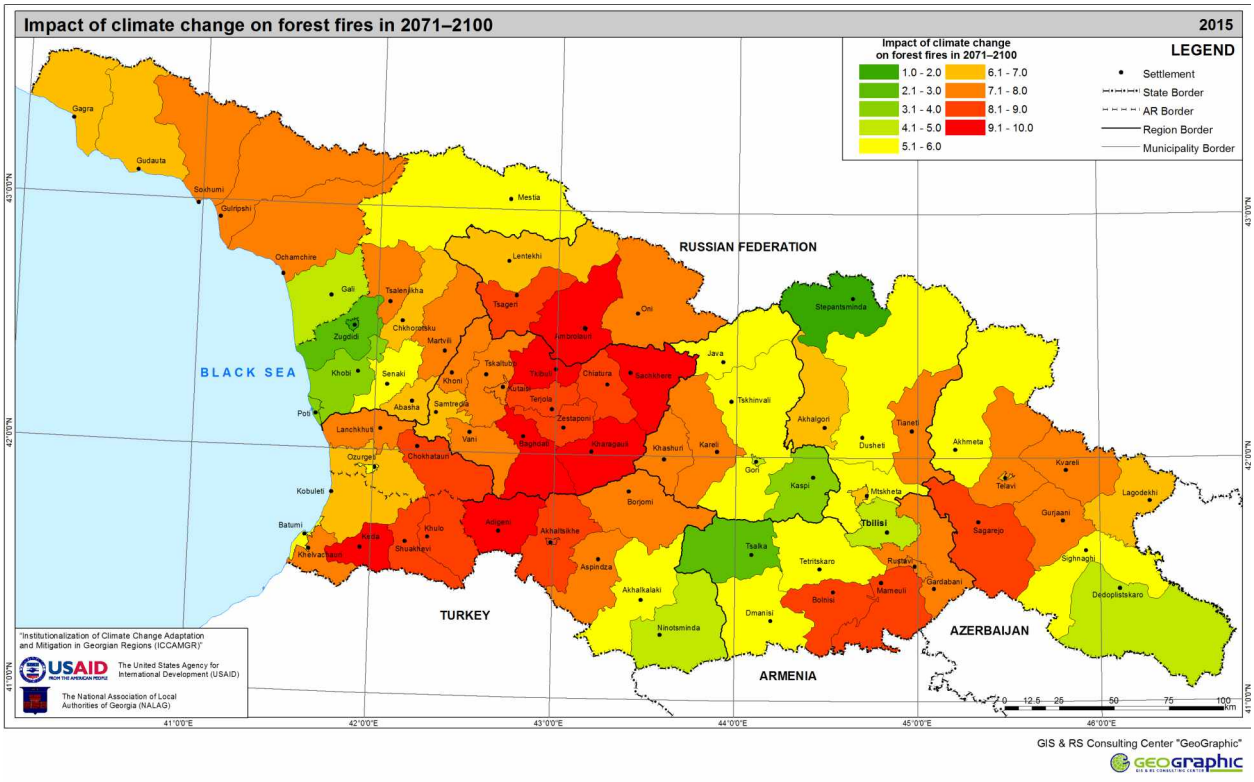
An aggregated erosion impact index is calculated based on the sensitivity index and two exposure indicators—humidity change as a result of precipitation variability and enhanced wind erosion caused by wind speed change.

The mean value of climate change impact for Georgia, taking into account erosion, equals 2.63. By region, the impact measurements are as follows. For Kakheti the average is 3.2, highest in Sagarejo (5.0) lowest in Akhmeta (2.6); Mtskheta-Mtianeti has an average of 2.74, the highest is in Mtskheta (4.98) and the lowest in Kazbegi (1.07); Kvemo Kartli averages 4.04, with the highest in Marneuli (7.12) and lowest in Tsalka (2.07); Shida Kartli averages 3.55 with the highest in Kaspi (4.84) and lowest in Kareli (2.95); Samtskhe-Javakheti has an average of 2.11 with the highest in Ninotsminda (2.69) and lowest in Adigeni (1.77); Imereti averages 2.83, highest in Sachkhere (3.27) and lowest in Khoni (2.15); Samegrelo-Zemo (Upper) Svaneti average is 1.70, highest in Tsalenjikha (1.99), lowest in Mestia (1.05); Racha-Lechkhumi and Kvemo (Lower) Svaneti average is 1.92, highest in Tsageri (2.37) lowest in Lentekhi (1.54); Guria average is 2.01, highest in Chokhatauri (2.41), lowest in Lanchkhuti (1.76); Ajara is 1.85, highest in Khelvachauri (2.17), lowest in Shuakhevi (1.72).

It should be noted that the water erosion impact in all municipalities considerably exceeds the enhanced wind erosion impact.

In all irrigated municipalities, to mitigate water (irrigation) erosion, the national irrigation technology standards should be strictly adhered to and unnecessary water losses should be reduced.

To mitigate the effects of wind erosion, windbreaks must be arranged and the vegetation cover on the land surface should be preserved.

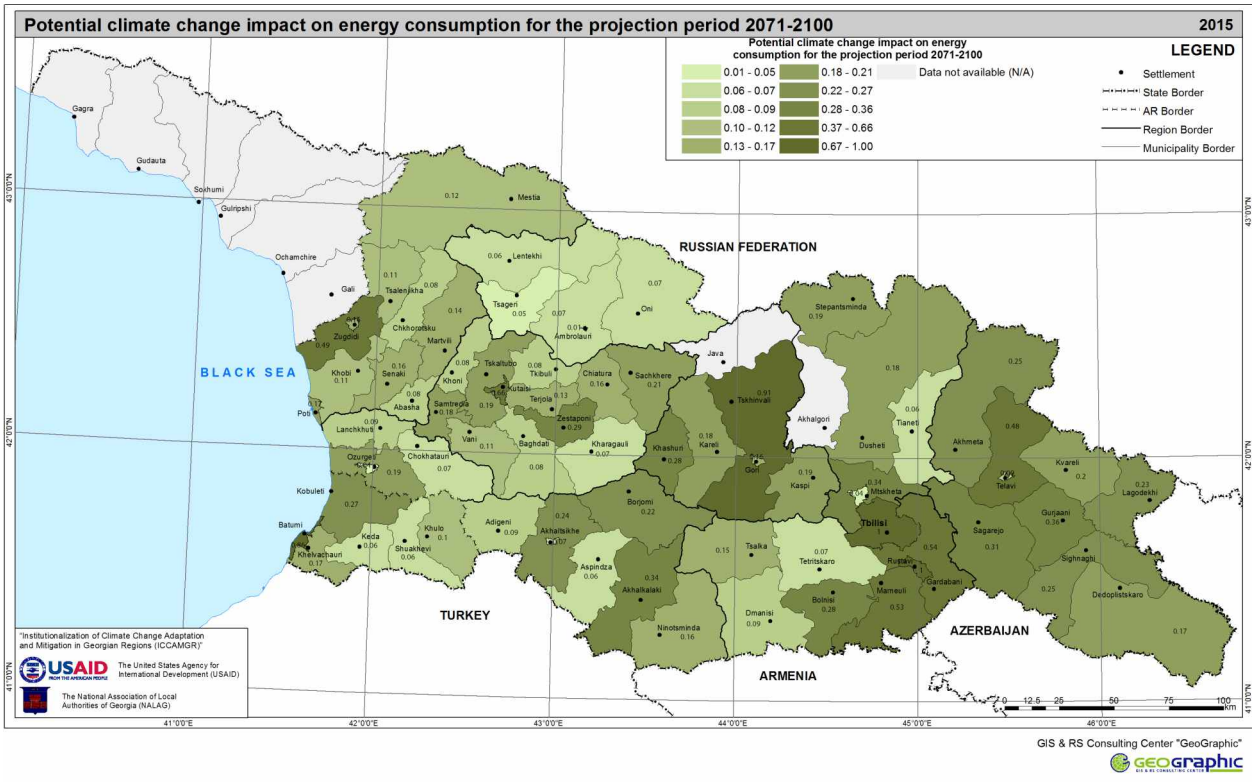


Map 87. Impact of climate change on forest fires in Future 2 (2071–2100)

Map 87 presents the aggregate projected impact index derived by the equilibrium geometric mean of summer temperature (50%) and precipitation change (50%) on forest fires in 2071–2100. Map 87 was drawn on the basis of information from the baseline period (2000-2015) on forests' sensitivity to fires. The forests' sensitivity are derived from aggregated data on the number of forest fires for the baseline period of 2000-2015 (achieved by satellite observation) and on their spatial comparison with 5m-resolution vector layer of forest cover. As a result of the aggregation of the forest sensitivity indicators with climate change (precipitation and temperature) indicators, normalized forest fire numbers have been derived. Such numbers consider projected changes in temperature and precipitation, which may affect the number of forest fires for the projected period. It is assumed that a decrease of precipitation and increase of temperatures will aggravate forest fire risk.

By analyzing the aggregate impact index standardized from 1 to 10, it can be shown that the most probable increase of the forest fire risk in Future 2 is expected to move from the forested areas of eastern Georgia and the woodlands stretching along and around Surami Ridge to western Georgia, to encompass the majority of Racha-Lechkhumi, Imereti, Samegrelo and Ajara highlands. There is also an impact expected on the forest-covered tracts of the Abkhazia and Svaneti Greater Caucasus Range.

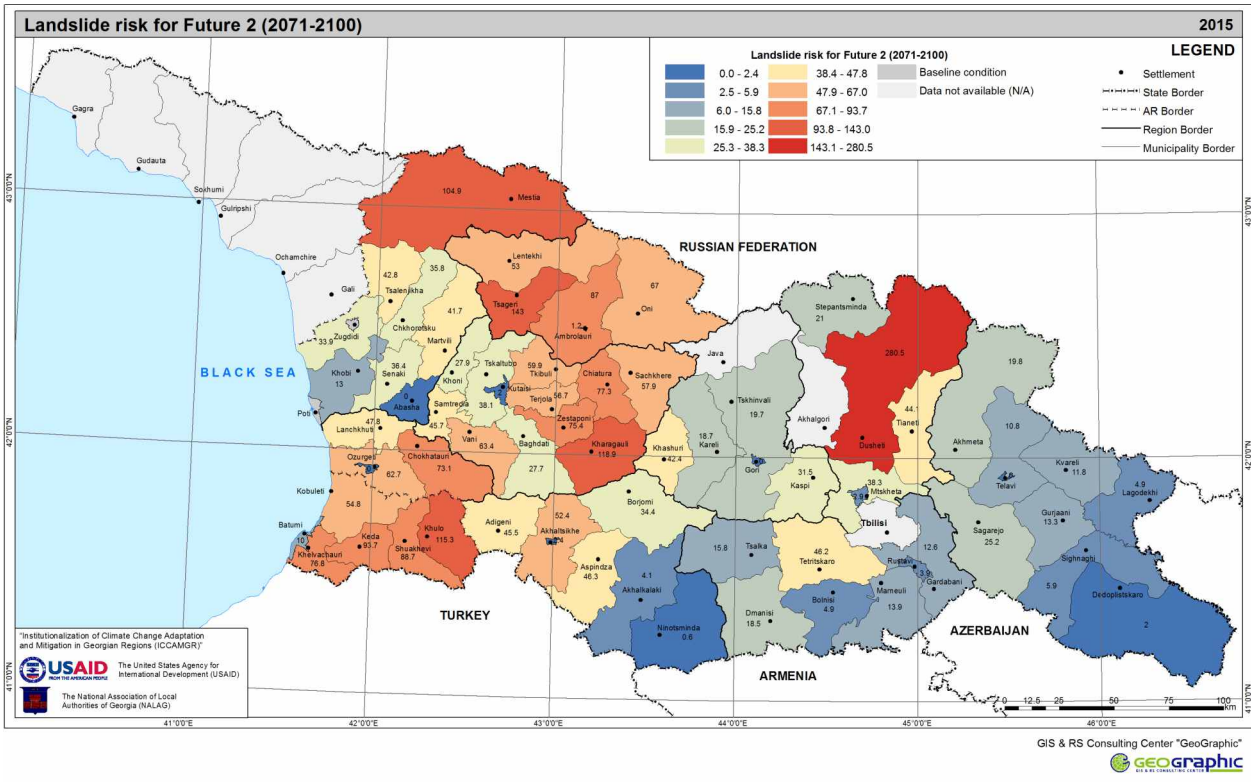
The recommended fire management actions include the following: removal and safe utilization (burning) of fire-prone dry logging residues accumulated in forest tracts of each municipality; arranging fire prevention buffer zones between wood tracts and the adjoining agricultural land; promoting the use and dissemination of traditional fire management practices/knowledge in the population; carrying out an inventory of forest and forest state monitoring; developing a harmonized long-term time series development of a comprehensive forest fire database; and taking careful note of satellite and field observations.



Map 88. Potential climate change impact on energy consumption for Future 2 (2071-2100)

According to the climate model projections, a significant impact on the energy sector is expected in the long-term perspective. Map 88 illustrates potential climate change impacts on energy consumption per municipality for the projection period 2071-2100. For the given period, high impact is expected in the self-governing cities of Tbilisi, Rustavi, Batumi, and Kutaisi as well as the Gori municipality. In these municipalities, a significant increase in the cooling period is expected. In addition, in Gori municipality, a significant decrease of the heating period is expected. Similarly, significant climate change impact on the energy sector is expected in Marneuli, Gardabani, Zugdidi and Telavi municipalities. These municipalities require adaptation measures. Consideration of the relevant recommendations, such as promotion of energy efficient technologies, will enable the municipalities to not only reduce the climate change impacts, but also to support the development of the energy sector, improve living standards and strengthen the country's energy security.

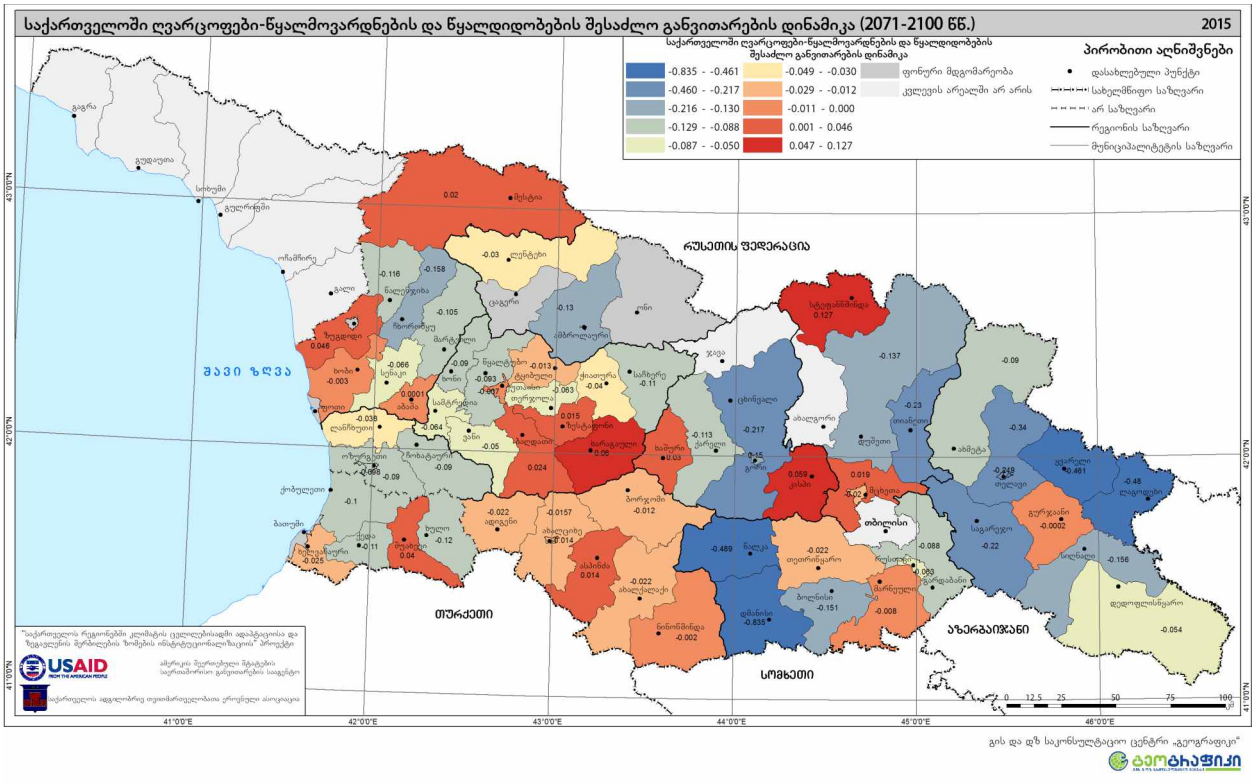
The lowest climate change impacts are expected in the self-governing cities of Ambrolauri, Mtskheta, and Ozurgeti and Tsageri municipalities. Overall, the adherence to recommendations will benefit the listed municipalities, support energy independence and improve the living standards of the population.



Map 89. Landslide risk for Future 2 (2071-2100)

The map shows recurrence level of risks of landslides. Based on statistical data and climate projections developed by climatologists, the prognoses for natural hazards for all municipalities were developed with the calculations of coefficients of the relevant positive and negative variations from mean annual precipitation for Future 2 (2071-2100). The ratio of the figure calculated for Future 2 to the baseline mean annual data for the period 1960-1990 was taken into account in the calculation of the alteration coefficients.

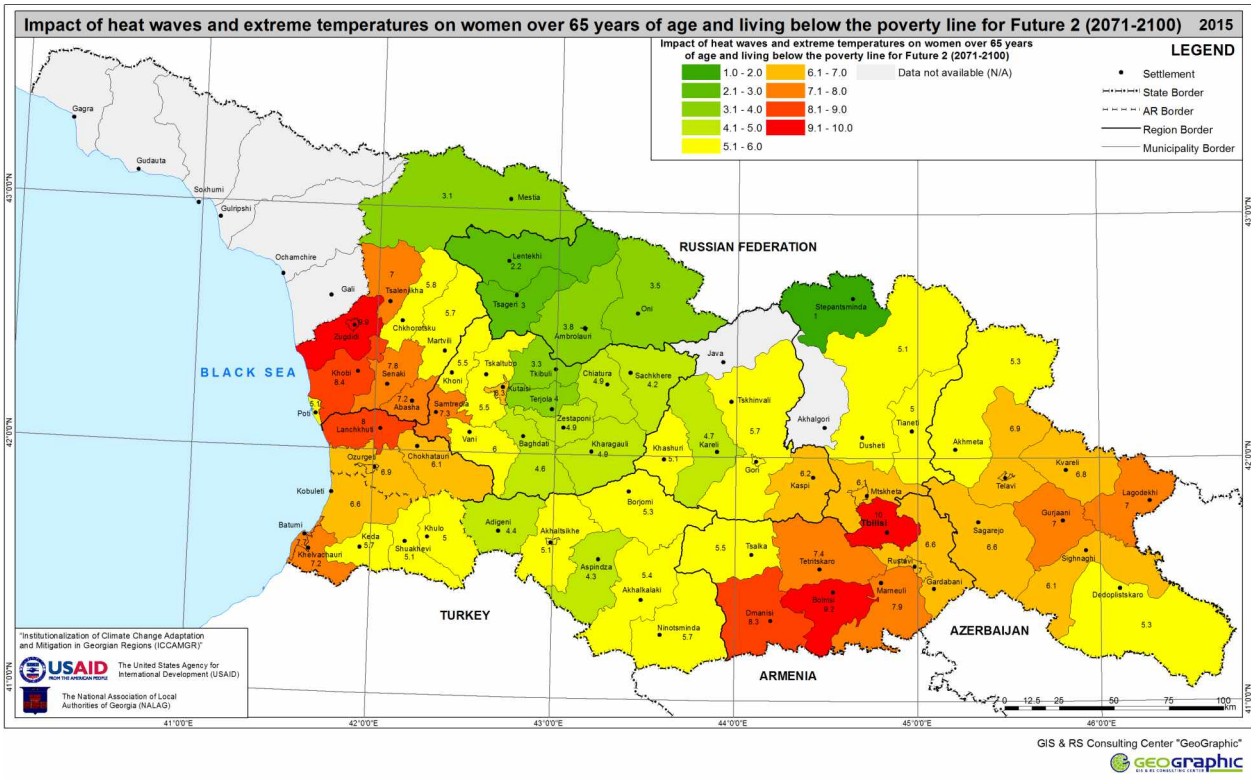
Based on existing data, the map shows municipalities where development scales of the landslides for Future 2 will be lower than the baseline data, these are shown in blue (Akhalkalaki, Dedoplistskaro, Poti city, Ozurgeti city, Ninotsminda, Gori city, Abasha, Rustavi city. There are also municipalities where the processes will remain at the baseline level; these appear in light blue (Dmanisi, Sagarejo, Kareli, Gori, Khobi, Tsalka, Bolnisi, Marneuli, Gardabani). Municipalities where the processes will be activating appear in orange (Mestia, Khulo, Kharagauli, Tsageri, Lentekhi, Dusheti) and others appear in red (Khelvachauri, Keda, Shuakhevi, Chokhatauri, Zestaponi, Alkaltsikhe).



Map 90. Mudflow and flood risk for Future 2 (2071-2100)

The map shows recurrence level of threat risks. Based on statistical data and climate projections developed by climatologists, the prognoses for natural hazards for all municipalities were developed with the calculations of coefficients of the relevant positive and negative variations from mean annual precipitation for Future 2 (2071-2100) in connection with daily recurrence of rainfalls. The ratio of the figure calculated for Future 2 to the baseline mean annual data for the period 1960-1990 was taken into account in the calculation of the alteration coefficients.

Based on the obtained data, the map indicates the municipalities where the development of mudflow-freshets and floods for the period of 2071-2100 will be lower than the baseline data shown in blue (Dmanisi, Zugdidi city, Tsalka). Also shown are municipalities where the processes will remain at the baseline level; these are in light blue (Keda, Signagi, Tskaltubo, Khoni, Oni and Ozurgeti), and the municipalities where the processes will be activating are in red and orange (Kazbegi, Mestia, Kharagauli, Gurjaani, Zugdidi, Khashuri, Zestaponi, Bagdadi).



Map 91. Impact of heat waves and extreme temperatures on women over 65 and living below the poverty line for Future 2 (2071-2100)

To calculate the impact of heat waves for the period from 2021-2050 on two separate socio-demographic groups of women, a combined sensitivity index for the indicators (a) over 65 years of age and (b) below the poverty line population density[230] was correlated with the aggregated climate exposure index[231]. To better understand the climate change impact on these groups, municipalities were grouped according to impact levels.

Because of their financial and social situation, as well as physiological profile, women are very vulnerable to the different aspects of climate change exposures, such as high extreme temperatures, bad weather and more frequent natural disasters among others. It should also be noted that in all municipalities, except Dmanisi, the majority of the population over 65 consists of women.

Therefore, by 2071-2100, due to changes in absolute maximum temperatures and the average annual number of hot days, an acute deterioration is predicted in the following high-impact municipalities: Tbilisi, Dmanisi, Marneuli, Bolnisi, Tetritskharo, Bolnisi, Gurjaani and Lagodekhi in eastern Georgia; and Zugdidi, Batumi, Khobi, Senaki, Tsalenjikha, Samtredia, Abasha, Lanchkhuti and Khelvachauri in western Georgia.

Above medium impact: Mtskheta, Kaspi, Gardabani, Rustavi, Sagarejo, Telavi, Kvareli and Signagi in eastern Georgia; and Kutaisi, Chokhatauri, Ozurgeti and Kobuleti in western Georgia.
Medium impact: Dedoplistskaro, Akhmeta, Dusheti, Tianeti, Tsalka, Akhalkalaki, Akhaltsikhe, Borjomi, Ninotsminda, Khashuri and Kareli in eastern Georgia; and Keda, Shuakhevi, Khulo, Vani, Tskaltubo, Khoni, Chkhorotsku, Martvili and Poti in western Georgia.
Low impact: Kazbegi, Tianeti, Kareli, Aspindza and Adigeni in eastern Georgia; Tkibuli, Zestaponi, Kharagauli, Terjola, Bagdati, Sachkhere, Oni, Ambrolauri, Tsageri, Lentekhi and Mestia in western Georgia.

According to the prognosis, adaptive measures to extreme temperatures and heat waves should be taken in Kvemo Kartli and in the municipalities that border the coastal zone in Adjara, Guria and Samagrelo by 2070 and beyond.

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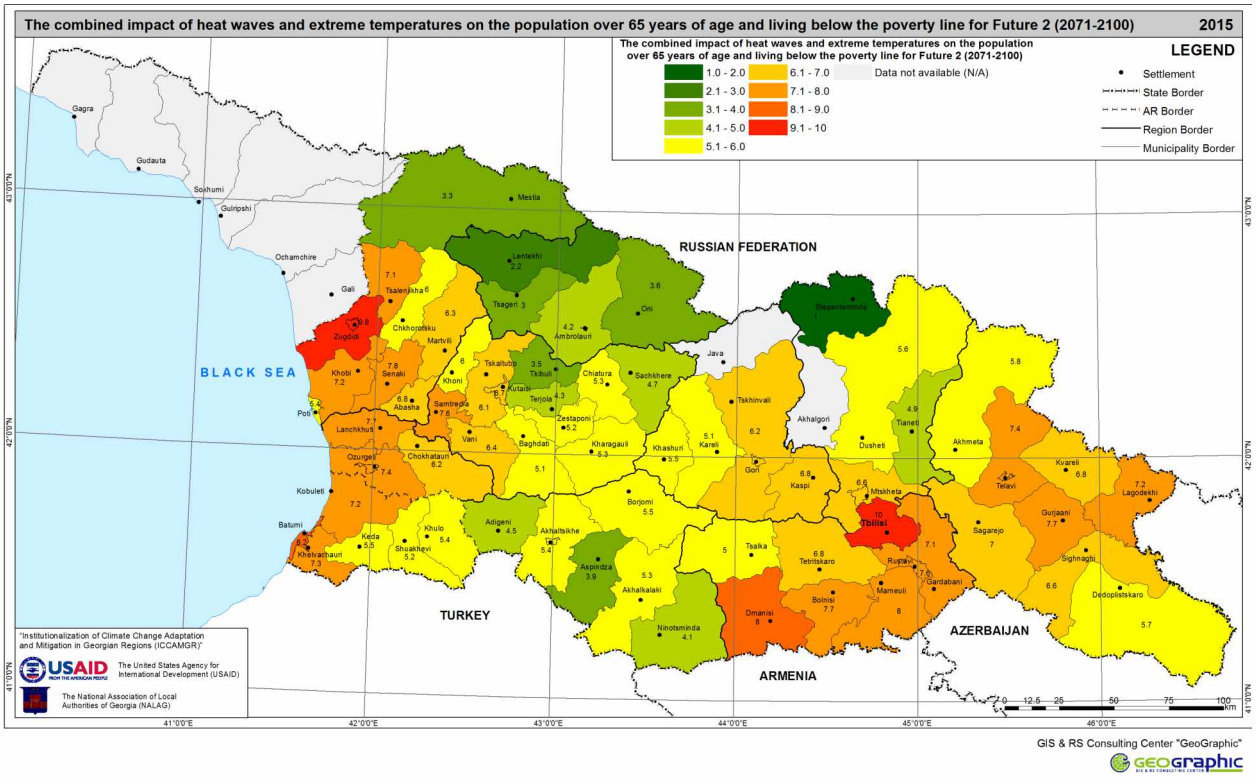
230 The urban population is very sensitive to extreme temperatures and heat waves of the "heat island effect" in densely populated areas or urbanized territories, in which "white-hot" asphalt and buildings heat the air further.

231 Climate change exposure indicators are combined by a weighing method that combines changes in absolute maximum temperatures and average annual numbers of hot days by 2021-2050.



Map 92. The combined impact of heat waves and extreme temperatures on the population over 65 years of age and living below the poverty line for Future 2 (2071-2100)

To calculate the impact of heat waves for Future 2 (2071-2100) on two separate socio-demographic groups, a combined sensitivity index for the indicators (a) over 65 years of age and (b) below the poverty line population density[232] was correlated with the aggregated climate exposure index[233]. To better understand the climate change impact on these groups, municipalities were grouped according to impact levels.

Thus, by 2071-2100, due to change in absolute maximum temperatures and the annual average numbers of hot days, acute deterioration is projected in the following high-impact municipalities: Tbilisi, Rustavi, Dmanisi, Rustavi, Marneuli, Gardabani, Bolnisi, Telavi, Gurjaani and Lagodekhi in eastern Georgia; and Zugdidi, Batumi, Khobi, Senaki, Samtredia, Tsalenjikha, Lanchkhuti, Ozurgeti and Kobuleti in western Georgia.

Above medium impact:
- Eastern Georgia - Mtskheta, Kaspi, Tetritskaro, Gori, Sagarejo, Kvareli and Signagi;
- Western Georgia - Vani, Chokhatauri, Tskaltubo, Martvili and Abasha.

Medium impact:
- Eastern Georgia - Dedoplistskaro, Akhmeta, Dusheti, Tsalka, Akhalkalaki, Akhaltsikhe, Borjomi, Khashuri and Kareli;
- Western Georgia - Keda, Shuakhevi, Khulo, Bagdati, Zestaponi, Kharagauli, Chiatura, Khoni, Chkhorotsku and Poti.

Low impact:
- Eastern Georgia - Stepantsminda, Tianeti, Ninotsminda, Aspindza and Adigeni;
- Western Georgia - Tkibuli, Terjola, Sachkhere, Oni, Ambrolauri, Tsageri, Lentekhi and Mestia.

According to the prognosis, presumably by 2070 and beyond, adaptive measures to extreme temperatures and heat waves should also be taken in Kvemo Kartli and in the municipalities that border the coastal zone in Adjara, Guria and Samagrelo.

[232] The urban is very sensitive to extreme temperatures and heat waves of the "heat island effect" in densely populated areas or urbanized territories population, in which "white-hot" asphalt and buildings heat the air further.

[233] Climate change exposure indicators are combined by a weighing method that combines changes in absolute maximum temperatures and average annual numbers of hot days by 2021-2050.

5. RECOMMENDATIONS & ACTIONS FOR OVERCOMING SOCIO-ECONOMIC RISKS ASSOCIATED WITH CLIMATE CHANGE

5.1.2 Recommendations to be implemented at the national level

Tourism is one of the main sources of Georgia's income, currently contributing 6 percent of GDP[234]. In the country's regions, many municipalities possess sufficient natural beauty, geographic diversity and valued cultural heritage for the further development of tourist and recreational activities. One of Georgia's main competitive advantages in terms of tourism is its climate. The favorable climate conditions include the current temperature ranges, natural settings, health spas and recreational properties and diverse landscapes. However, climate change poses clear potential hazards that, if disregarded, will damage both the country's tourism industry and its underlying potential tourist resources in terms of cultural heritage and natural resources. This report assesses the impact of climate change on Georgian tourism, including cultural heritage sites and protected areas, and provides recommendations on measures to prevent or mitigate its negative effects.

TOURISM DEVELOPMENT:

- National authorities should develop a uniform approach to the sustainable development of tourism, including the elaboration of a long-term plan that would take into account the impact of climate change on tourism.
- The restoration of the climate observation system in the regions; the facilitation of applied research; and learning from the experience of the authorities in more developed countries should be assured in order to provide continuous monitoring and regular, inter-disciplinary scientific research, including climatology, bio-geography, hydrology, geomorphology and tourism geography since climate change and its potential negative impact on tourism need to be monitored.
- A system for non-climactic data collection needs to be arranged, including the collection of spatial data. The existence of uniform, climate change information in historical time series that could be easily assessed would facilitate more effective analysis and planning.
- The general infrastructure (roads, transport, road service objects, energy and water supply networks among others) needs to be built and improved to be of optimal use for tourism. This is in addition to the activities carried out by the National Tourist Administration and other government organizations, (such as the promotion of tourism in Georgia and the encouragement of individual projects, among others. This work should be performed with due regard for climate change trends and the probable natural hazards they will cause.
- The development of international tourism also requires the essential introduction of state-of-the-art technologies (for example, to preserve or prolong the winter tourism season) and the promotion of competitiveness. However, it is also necessary to encourage tourism among Georgian nationals in order to maximize the local tourism and recreational resources and develop small and medium tourist enterprises, irrespective of low profitability caused by the population's low purchasing power. The projected constant temperature increase in Georgia as a result of climate change should also be taken into account, since, the microclimate and environmental state in Georgian towns, especially in large cities, will further deteriorate in the future. Consequently, the local demand for summer cottages, resorts and holiday tourism is likely to increase significantly.
- Alternatives should be taken into account when developing and planning the tourism industry since winter tourism is particularly vulnerable to climate change. Where possible, this should include sharing of relevant international experience, such as in the Alps[235].

[234] Georgian National Tourism Administration
[235] "Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management", 2007.

CULTURAL HERITAGE PRESERVATION:

Any assessment of the impact of climate change on cultural heritage sites and planning of appropriate conservation and restoration measures, as mentioned, cannot be limited to the results of this study. The risks already identified by existing studies, including those given in the Third National Communication, should be taken into consideration by decision-makers.

The potential impacts of climate change exposure risks on cultural heritage can be divided into two types:

1) Climate change exposure such as to temperature changes, humidity variations, abundant precipitation and regime change, wind speed and direction change among others, that threaten monuments with gradual damage, such as erosion, comparative change of humidity in monument structures, decay, corrosion of steel constructions, etc., including change of the storage microclimate of the exhibits kept in some museums[236] and;
2) Climate change-conditioned natural hazards that directly threaten museums or monuments with damage, destruction and flooding among others.

Systematic research is needed on both types of risks. The risks related to natural hazards have been better investigated and conservation and restoration work in this direction is either under way, or has already been completed, (e.g. in Uplistsikhe and Vardzia among other areas). Moreover, the methodology and approaches of studying the risks of the second group above resemble the methodology used for studying the vulnerability of other infrastructure (see Sections 3.5 and 4.5 on natural disasters).

However, studies on the first type of risks defined above are very few. An exact assessment of this type of risk on cultural heritage will require the introduction of new approaches, study and application of international best practices and standards, sharing of international experiences, and training of specialists and corresponding job opportunities for these specialists in Georgia.

Presumably, in order to assess the impact of these exposure risks on cultural heritage it is desirable to classify the monuments according to building material and structure, to categorize them by region; and to group them in line with the climate change impact exposures that exist in those regions. It would also be desirable to classify the monuments according to their importance, and thus prioritize any subsequent work that is to be done. The application of different modeling and spatial analysis methods would be important as well. All this would make it possible to identify and determine a list of climate change related risks and indicators for Georgian monuments, which will, in turn, help to define the appropriate conservation and restoration technologies and plan further work.

It is also desirable that climate change risks should be appropriately considered in respective action and strategic documents related to conservation and restoration.

PROTECTED AREAS:

As protected areas aim to retain and preserve the status quo of natural processes and conserve these areas in the long term, climate change will have an unconditional impact on the habitats of species and their migration processes. As already mentioned, the assessment approach used here was developed specifically for this study and will not serve as a complete assessment of the vulnerability of all protected areas to climate change. The impact of climate change on particular ecosystems or species conserved in each protected area should be assessed individually and fully.

[236] Of special importance are ethnographic museums, where the national government, for different reasons, fails to create appropriate conditions.

Recommendations on the conservation of biological species in the protected areas, and prevention of the negative impact of climate change on them are included in the National Biodiversity Strategy of Georgia for 2014-2020[237]. The strategy defines issues that require additional research in order to adapt Georgia's biodiversity to climate change. However, none of the follow-up studies defines the best standards, modeling and principles to assess the impact of climate change. Presumably, in order to cope with the existing challenges and based on the issue's complexity, an ecosystem-based assessment methodology should be applied that is both a comprehensive study and is tailored to the complexity of planned adaptation measures.

Similar to other sectors, it is also desirable that comprehensive information and historical/time series should be established for protected areas that track indicators for analysis, and that the observation network be widened to improve the climate data series.

The potential impacts of climate change on biodiversity and the sustainability of ecosystems should be reduced by developing a respective environmental policy and introducing adequate activities in line with the Aichi Biodiversity Targets from the Convention on Biodiversity[238]. Continuous monitoring of protected areas that are free from anthropogenic impacts should be carried out to assess the impacts of climate change on land degradation and the endemic species of flora and fauna.

It is also important to develop and enhance the system of protected areas so that the amount of CO_2 absorption is increased[239]. It is also desirable to determine the amount of carbon in other terrestrial and non-terrestrial ecosystems within protected areas[240].

Climate change issues should be reflected in the management plans for protected areas. In addition, awareness-raising workshops should be conducted at both the national and local levels so that adaptive and effective management within the protected areas is enhanced and facilitated.

5.1.2. Recommendations to be implemented at the municipal level

Tourism has developed over time in Georgia and the sector continues to develop, leading to corresponding growth in the number of tourists and revenues from tourism. While there are negative factors, such as a weak economic base, a low level of tourism and the lack of hospitality management skills and services, the country has serious potential for tourism growth based on its diverse natural resources, historic and cultural heritage, local traditions and livelihoods and traditional culture among others. However, tourism faces certain risks caused by climate change. Measures for preventing such risks and adapting tourism to new conditions should include the participation of both national and local authorities.

The purpose of our recommendations to local self-government is to raise the importance of tourism in the municipalities as well as the critical need for adaptation to the challenges posed by climate change. As evidenced by the study's results, tourism plays a significant role in a number of self-governing units (municipalities), particularly Kobuleti, Khelvachauri, Borjomi, Kazbegi, Mestia, Akhmeta, Telavi, Kvareli, Tskaltubo and Batumi. In addition, there are a number of municipalities where the development of tourism is in an early stage.

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237 Resolution of the Government of Georgia #343 "On the Approval of the National Biodiversity Strategy and Action Plan of Georgia 2014-2020", 2014 https://matsne.gov.ge/ka/document/view/2342057 (accessed March 19, 2016)

238 Aichi Biodiversity Targets include 20 targets to achieve five strategic goals in the improvement of risks of biodiversity loss. https://www.cbd.int/sp/targets/ (accessed March 19, 2016).

239 A total of 143,000 tons of carbon are stored within the Mtirala National Park. The study conducted by V. Gulisashvili Forest Institute shows that pine forests (6,983 ha) in Borjomi State Reserve store 767,250 tons of carbon (about 110t/ha). The annual absorption of CO2 in these forests amounts to 8 ton CO2/ha, or 50,976 tons of CO2. According to the WWF Caucasus, 9.1 tons of CO2/ha, or 771,000 ton of CO2 are stored in the Borrjomi-Kharagauli National Park, which includes 85,000 ha of spruce forests. biodiversity loss. https://www.cbd.int/sp/targets/ (accessed March 19, 2016).

240 "The Role of Protected Areas in Regard to Climate Change, Scoping Study", Georgia, IUCN, 2012.

Municipalities vary in terms of the impact of climate change and the types, structure and development level of tourism. As a result, the recommended measures for adapting to climate change also differ. In some tourist areas, in particular in Kobuleti, Lanchkhuti, Ozurgeti, Mestia and Kazbegi municipalities, an expected increase in precipitation in spring and in autumn for Future 1 will negatively affect summer tourism. An increase in peak summer tourism season temperatures is also expected. The local governments should respond by preparing for a prolonged summer tourism season, supporting the development of tourism directions other than sea resorts, such as ecological, urban and event tourism, and arranging of alternative tourist services with neighboring municipalities.

Highland areas such as Akhmeta, Dusheti, Kazbegi and Mestia municipalities are projected to experience temperature increases and a decline of precipitation in the summer. This should have a positive impact on tourism, as it means the summer tourism season could be prolonged. On the other hand, the lack of snow is obviously a negative factor for winter tourist centers in Borjomi (Bakuriani), Kazbegi (Gudauri), Mestia (Hatsvali, Tetnuldi) and Akhalkalaki (Aragva) municipalities. These processes, according to a projection for Future 1 , will have less negative effects in Khulo municipality (Goderdzi), where snow cover is regularly high – although, the projection for Future 2 indicates that the impact of climate change will be distinctly negative there as well. In response to this problem, municipal governments should provide assistance to tourist companies and hotels to participate in the summer tourism season, offer alternative tourist services and develop respective services, and learn from the experience of self-governing units in European highland regions in coping with similar problems.

Climate change in the Kakheti region is characterized by reduced precipitation in all seasons of the year and increased temperatures. The impact is negative for the active summer tourism period, but is positive for other seasons of the year, except the winter period.

Climate change will have a distinctly negative impact on protected areas, their ecosystems and individual biological species – particularly in the arid and semi-arid landscapes in Dedoplistskaro municipality (Vashlovani State Reserve and National Park, Chachuna Managed Reserve, natural monuments of Alazani flood plain, Takhti-Tepa and Artsivi Valley), where desertification may lead to the loss of valuable biological species. It will be important to constantly monitor the landscape changes there in an area where local authorities clearly support scientists and managers of protected areas.

The self-governing Cities of Batumi, Kutaisi, Zugdidi, Telavi and Mtskheta possess comparatively greater adaptive capacities against climate change. Future efforts to develop tourism in self-governing cities should reflect their urban identity, by focusing on cultural, urban, event, business, festival, sport, and gastronomic tourism.

Local authorities should also be concerned with the preservation of cultural heritage and biodiversity, including their protection from the negative impact of climate change. These issues, however, are within the special central jurisdiction, except in Adjara, which is autonomous. The key central government agencies are: the National Agency for Cultural Heritage Preservation of Georgia, the Cultural Heritage Preservation Agency of Adjara and the Agency of Protected Areas of Georgia. All local government activity should be coordinated with these agencies.

In littoral and plains areas, temperature increases during peak tourist season are likely to result in a decline in the number of tourists. In such cases, it is recommended to compensate for the loss by prolonging the season into spring, early summer and autumn.

For winter tourist centers, such as Gudauri, Bakuriani, and Mestia, where climate change forecasts predict a lack of snow days, it is recommended to use the summer tourist season more actively, as well as learning from modern technologies and experience. For good reason, as the additional demand for energy and water resources and the existing winter tourism adaptation facilities (snow guns among other technologies) are costly and frequently ineffective. Therefore, in the long term, priority should be given to the development of alternative tourist services, including in wintertime.

Municipal governments should also support the initiation of various mass events, such as congresses, festivals, conferences, sport competitions in large cities and tourist centers, such as Batumi, Kutaisi, Borjomi, Tskaltubo and Sairme, to prolong the tourist season in autumn and spring and attract more tourists.

In order to relieve the discomfort caused by bad weather, especially frequent autumn rains, it would be important to offer a range of different tourist services across the country. This would be particularly relevant for Adjara, which has seaside tourist centers and highland regions. For example, short-term seashore holiday tours could be organized in neighboring municipalities to see various sights (e.g. Mtirala and Machakhela National Parks) and to take part in different events (e.g. traditional horse races in Bakhmaro, traditional Georgian folk festivals Shuamtoba held in Shuakhevi and Namepfaroba held in Keda) or stay in mountain resorts (e.g. Beshumi, Bakhmaro, Gumista).

Local authorities should prioritize the implementation of measures to protect tourist attractions in the zones exposed to natural hazards. They should also assist individuals engaged in tourist companies and tourism to prevent potential negative effects and reduce the damage caused by climate change. In this respect, it would be important to do the following:

- Ensure the functioning of early warning and security systems;
- Inform entrepreneurs about the importance and means of insurance against disasters; and
- Restrict the construction of tourist and recreational attractions in areas prone to natural hazards and account for such places when planning tourist routes.

5.2. Recommendations for overcoming socio-economic risks in the agricultural and forestry sectors

5.2.1 Recommendations to be implemented at the national and municipal levels in the agricultural sector:

The agricultural sector is unconditionally vulnerable to climate change. The recommendations given below, elaborated in accordance with the document "Strategy for Agricultural Development in Georgia"[241], are aimed at increasing the adaptive capacities of the agriculture sector and mitigating the climate change impact. Implementation of these recommendations will help to increase the country's food security and improve its economic position and environmental protection, both in the short term and the long term.

Even though in the short-term outlook (within five years), climate change should not have a significant impact on agriculture, timely implementation of the recommendations below could reduce the sensitivity of the primary sector to climate change and help to gain economic profit. The said recommendations will also help municipalities to be prepared for climate change impacts on the sector in the long-term perspective (beyond five years).

The recommendations are as follows:

- Improve data management and availability, to perform more in-depth research in the future and to make a comprehensive analysis, it is necessary to enhance hydrometeorology services and build up indicator-based historical rows for the non-climactic data at the national level.
- Perfect geo-information databases and perform relevant analytical work, e.g. Application of geo-information technologies (GIS) for establishing optimal configuration of contours of relief and gravity irrigation canals and identifying the negative relief forms optimal[242].
- The development of the hydrometorological service and network is also necessary for taking other measures, for example, planning seasonal agricultural activities or perfecting the agriculture insurance portfolio and, most importantly, perfecting climate change-related projections.
- It is desirable that a cadaster of ameliorated land areas be prepared and that monitoring thereof is ensured.
- For rational utilization of soils and development of agriculture with due regard for climate change, analyses, inventory of the state of soils under agricultural crops, as well as planning and implementing the rehabilitation activities based on the produced results is of great importance.
- To improve soil fertility, specific agrotechnical measures and programs need to be implemented. Accordingly, field and laboratory analyses of the soil under individual agricultural crops need to be made, which will contribute to their efficient use. Soil estimation also plays an important part in the planning and implementing of land consolidation projects.
- In 2021–2050, based on the climatic conditions of Georgia, it is necessary that land amelioration and the construction of irrigation and drainage systems be accelerated. The maintenance and management of such systems represent a significant sphere, which should ensure creation in the country of the conditions necessary for intensive and efficient agricultural production. The construction of such systems shall be implemented through application of state-of-the art effective technologies.
- The relatively arid climate of eastern Georgia requires wide application of irrigation, while many regions of western Georgia need to remove excess water through drainage systems. The measures to be taken in this respect imply construction and rehabilitation of water reservoirs through irrigation designation as well as the rehabilitation of drainage systems.

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[241] Resolution of the GoG #167 "On the Approval of the Strategy for Agricultural Development in Georgia for 2015-2020", 2015. www.moa.gov.ge

[242] The Ministry of Environmental Protection of Georgia. "Climate Change and Technology Needs assessment and Technology Action Plans for Climate Change Adaptation", Tbilisi, 2012, op. cit.

- A task for the near future is to complete the reclamation of agricultural lands. Attention should be given to the incomplete loading of the systems operating in the irrigation zone as, in reality, the irrigated land areas are less prevalent in the water-supplied areas.
- The implementation of comprehensive studies of modern technologies and management approaches for the efficient use of irrigation water[243] and facilitation of the process of introduction of drip and/or artificial sprinkling irrigation systems are required. The latter is advantageous compared with gravity irrigation. It can be applied under conditions of a complicated relief, covering 80% of an irrigated land area unit. As a result, costs are minimized, irrigation water rates per hectare decrease by 200-300 m^3, soil water erosion and the risk of its salinization are reduced, soil structure is improved, and water filtration and evaporation losses are reduced[244].
- Finally, the purpose of the modernization of land-reclamation systems is the improvement of water-supply to irrigated land areas, removal of excess water from the water-logged areas, the widening of the range of amelioration services and the creation in the soil of the air-and-water conditions necessary for growth and development of a plant, which, in parallel with the employment of modern agricultural practices, shall ensure a secure and high crop yield.

Regarding soil protection from erosion, the issue of restoring windbreaks is of special interest. Hence, in coordination with the Ministry of Environmental and Natural Resources Protection, a document regulating the windbreaks-related issues should be drafted, wherein the competences and management-related responsibilities of the competent authorities will be designated. In Georgia, among the recommended erosion-resistant trees, priority is given to a new fast growing and widely used tree, the Paulownia, which is of Chinese origin. It has a sparse crown and a deep, widely distributed root system and high adaptability, and is suitable for use in agroforestry and afforestation. It rather successfully protects soil from erosion. Its height reaches 12-15 meters in five years. This is of commercial significance. Within four or five years of planting it can be subjected to commercial logging, after which it should be regenerated.

An inventory of the topsoil of Georgia requires the existence of a sufficient number of necessary laboratory and human resources. Accordingly, the creation of a new scientific base with a modern high technological laboratory is essential. Soil fertility improvement will require the introduction of safe, progressive technologies and the perfection of a relevant legislative framework.

In the utilization of degraded soils (saline, acidic, damaged and polluted in the course of mineral extraction) special attention should be given to their investigation and the development of science-based activities for the restoration of their fertility and their overall improvement, their promotion in farm households and other undertakings using special-purpose state programs, and their introduction on the base of an agricultural research center.

Great attention should be paid to climate change and its impact on soil degradation and desertification processes. Special research in the development of measures aimed at analyzing changes in the fertility of said soils and their improvement should be carried out.

Perfection and optimization of the cost-effective and fair sharing of water resources, including a tariff system, are required, as well as involvement of water user groups and other stakeholders in the process of rehabilitation and maintenance of farm-irrigation systems.

In parallel with drafting and implementing rural development and spatial planning programs, consolidation of fragmented privately owned agricultural land parcels through purchases and/or organizing and institutional unification of farmers is necessary for productive and technological development of agriculture.

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[243] Gavardashvili G.V., "Drip irrigation efficiency taking into account fertigation (Technical guidelines)," Tbilisi, 1999.
[244] The Ministry of Environmental Protection of Georgia, "Climate Change and Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation", Tbilisi, 2012. op. cit.

Agricultural extension services capable of sharing the relevant knowledge and experience on innovative agricultural technologies with farmers should be developed. For this purpose, regular retraining programs of the personnel engaged in these services should be planned and implemented under the auspices of the existing scientific research institutes with concurrent strengthening of these institutes. This would lead to the improvement of their material and technical basis, and human resources development.

To implement the above-mentioned recommendations, the municipal authorities shall, within their competence, become involved in the implementation and advocacy/lobbying of the mentioned activities.

5.2.2 Recommendations to be implemented at the national level in the forestry sector and for ecosystems protection

The National Forest Concept of Georgia[245] and the Biodiversity Strategy[246], policy documents that explicitly recognize climate change as such, outline specific actions in response to the challenges posed by climate change. The Biodiversity Strategy also names forest ecosystems as the most vulnerable to climate change.

The National Forest Concept underlines that a delayed response to climate change will endanger forest areas with catastrophic degradation and cause a dramatic quantitative and qualitative reduction of forest resources and useful functions, on which a significant part of the population depends. Based on this Concept and the research conducted, the following important actions should be carried out:

- Commissioning a national report on the state of Georgian forests and the benefits received therefrom; the impacts of expected climate change on forests and forest goods and services; and potential mitigation and adaptation strategies, using the best available information from national and international sources;
- Categorizing forest stands according to forest composition and vulnerability to climate change; preparing and implementing mitigation and adaptation plans for forest stands that are vulnerable to climate change;
- Elaborating and adopting sustainable management guidelines, including guidance on mitigation and adaptation measures, for each forest type;
- Reforestation including forest planting, greening urban areas, forest plantations, planting trees in general, including orchards, which can also be done on unused agricultural lands;
- Provide forest management bodies and forest users with the best methods for carrying out vulnerability assessments and information about the environmental characteristics of species and provenances; implementing research programs, specifically on the impacts of expected climate change on forests and the goods and services provided by forests, and ways of mitigating and adapting to the impacts of climate change.

In addition, it would be desirable to implement the following actions:

- Introduce climate-smart forest tenure practices, an important component of the forestry development strategy and action plan;
- Assess the climate change impact of forestry and forest ecosystems; create a database on the negative impact due to climate change and natural disasters; develop a system of agro-climate monitoring, analysis, outcomes and other information communication that should become customary;
- Develop and approve indices of forest resource vulnerability to climate change, according to which historical series on non-climatic data will be collected to be applied during analysis, including geo-information analysis;
- Establish, through Emergency Management and Forest Services, a coordinated and efficient forest fire satellite observation in situ validation system, including clear-cut collation of satellite observation data with in situ observations with strict categorization of fire incidents, ensuring the generation of historical series of quality and reliable observation data by operational production of temporally and spatially distributed data;

[245] Enactment of the Parliament of Georgia #1742 "On the Approval of National Forest Concept for Georgia".
[246] Resolution of the Government of Georgia #343 "On the Approval of the Biodiversity Strategy and Action Plan for 2014-2020".

- Develop, in coordination with the Ministry of Environment and Natural Resources Protection, a forest-fire action plan, where the competences of agencies will be differentiated and the necessary fire prevention activities will be detailed;
- Undertake comprehensive follow-up research on the above-mentioned issues (This can be regarded as the main recommendation). A single package of future forest adaptation and mitigation actions will facilitate a decrease of the risks caused by climate change;
- Develop and approve guiding principles and measures for mitigating climate change impact on Georgian forests and adapting Georgian forests to climate change;
- Specify the degraded forest areas, and identify the areas to be restored and developed; plan and implement appropriate measures;
- Set up modern nurseries with an orientation towards climate change-resistant species;
- Enhance forest areas and productivity, including the arrangement of windbreaks;
- Elaborate a wildfire prevention plan, strengthening fire control monitoring and prevention;
- Elaborate an integrated plan of fire prevention on agricultural lands with the participation of the agricultural, environmental protection, forestry sectors, other stakeholders and local governments; strengthen fire-control monitoring and prevention; introduce alternative agricultural production methodologies; composting and recycling the biomass accumulated on cropland and pastures instead of burning it.

5.2.3. Recommendations to be implemented at the municipal level in the forestry sector and for ecosystems protection

The actions subject to mandatory implementation at a municipality level can include:

- Promoting an inventory of forest areas and implementing forest management plans developed on its basis;
- Promoting the setting up of a nursery for the purpose of extension of forest areas;
- Protecting forests, seeking out accessible alternatives for firewood as well as for cattle grazing on forest lands;
- Cooperating with the central authorities in delimitation of forest and municipal areas;
- Promoting implementation of the National Forest Concept's principle "All forests are local";
- Enhancing the capacities of municipalities to exercise their legitimate right to manage local forests;
- Planting on unused municipal areas of fast-growing tree species to ensure the reduction of pressure on natural forests and provide the forest-dependent community with firewood.

The recommendations detailed below are tailored to the Georgian municipalities as well as national governmental agencies. These recommendations are based on available information. The recommendations address the following issues:

- Different types of measures;
- Development of programs and instructions;
- Introduction of definite regulations;
- Necessary information gathering and processing; and
- Data processing and grouping as well as increased cooperation between different structures.

5.3.1. Recommendations to be implemented at the national level

- To carry out more advanced studies, the collected information and data should be processed and evaluated by the relevant national government bodies in a more thorough way. In the event statistical information is available for a fee, the charge should be minimized or complete or partial exemption from payment should be practiced, as such types of studies ensure the sustainability of the national industrial sector;
- Given the fact that there is a lack of data on municipal based enterprises, it is difficult to evaluate the exact climate change impacts on these industries and the relevant municipal populations. It is recommended that both the national and municipal governments maintain the following data sets, sub-categorized by enterprise type:
    - o Number of individuals employed in the above-mentioned industrial sectors per municipality,
    - o Registration of employed individuals, sub-divided by age groups, for all municipalities,
    - o Locations of existing large and small enterprises, and
    - o The type of enterprise should also be indicated.
- International donors and national government agencies should invest in science for developing agriculture, industry and construction and finding and introducing technological innovations;
- Information about enterprises should be collected and processed per municipality;
- For the promotion of the agricultural sector, it is recommended to develop programs within the framework of which local entrepreneurs will be familiarized with climate-proofed agricultural crops and climate-friendly innovative technologies;
- To measure the industrial damage caused by natural disasters, which directly impact the income of a company and production prices, industrial infrastructure should be recorded and assessed in detail. For example, those industries located in riverbeds and or within a landslide prone zones are at risk; and
- It is also recommended that the national government publicize the exact locations of industries, inclusive of GIS coordinates, per municipality, for external parties. This information would help researchers evaluate potential risks to industries, their employers and employees.

- Representatives from municipalities, the private sector, NGOs and national government should cooperate in the following activities:
  - o Creation, maintenance and monitoring of safety standards in industries while introducing relevant financial or other intellectual protection mechanisms; and
  - o Dissemination of information on climate change risks in the industrial sector among enterprises. The information should include preventative measures aimed to mitigate potential risks and damages;
- Local public awareness-raising campaigns should be carried out in the municipalities;
- Guidelines/instructions addressing potential climate changes and associated risks should be drafted for both industry owners and their employees;
- Academia should be involved in relevant research studies to build capacity and technical skills;
- For diminishing and preventing the financial risks resulting from natural disasters, it is important that the industry insurance sector be further developed to create necessary social welfare packages and safety regulations. A study on agricultural insurance schemes developed by the European Commission in 2006[247] provides several practical guidelines. While there have been several initiatives in the areas of agricultural insurance in Georgia, insurance for other industrial sectors is underdeveloped;
- Finally, it is recommended that the industrial sector introduce energy-saving and cleaner production processes to increase efficiency and reduce expenditures.

[247] European Commission, Agriculture and Rural Development, "Agricultural insurance schemes", 2006. http://ec.europa.eu/agriculture/analysis/external/insurance/ (accessed March 24, 2016)

5.4 Recommendations for overcoming potential socio-economic risks in the

The energy sector is one of the key sectors contributing to climate change. In Georgia's renewable energy sector, capacity might be significantly affected by different climate change impacts such as change of rivers' hydrology regimes, amount of precipitation and the level of solar radiation or wind speed. The recommendations detailed below aim to reduce the potential impacts of climate change on energy supply and demand as well as support the capacity of the energy sector to either mitigate or adapt to climate changes. The implementation of these recommendations will help improve Georgia's energy security and economic conditions and promote immediate and long-term environmental protection.

5.4.1 Recommendations to be implemented at the national level

- Enhance risk management and long-term strategic planning of the energy sector, both of which are essential on the national level. The Ministry of Energy follows the long-term planning model for the energy sector called MARKAL, through which different climate change mitigation scenarios could be modeled. In addition, elaboration and analysis of climate change mitigation scenarios is being done by the USAID-funded Low Emissions Development Strategy (LEDS) project, the results of which may be used in corresponding policy development.
- Analyze how potential natural disasters impact the safety of critical energy infrastructure. The strategy should be developed to aim to protect critical infrastructure installations during a natural disaster while also considering the increased risks of potential natural disasters while constructing infrastructure. The open availability of precise spatial data of existing critical infrastructure installations is necessary for such a study.
- Develop emergency action plans in the event critical infrastructure is impacted by natural disasters.
- Study the potential for renewable energy resources, taking into consideration climate change. This may include projections of solar radiation as well as wind and hydrology changes. In addition, the relevant national governmental agency should prepare a forecast of annual and seasonal runoff as well as water flows for main rivers. This data would support a comprehensive analysis of the potential climate change impacts on the energy supply.
- Encourage energy-efficient buildings and consumption technologies and their implementation in the medium and long term, thus necessitating the usage of best practices of energy-efficient construction regulations. Energy-efficient construction is critical to decreasing the potential increased demand for cooling such as proper roof insulation significantly decreases energy consumption needed for cooling. It is necessary to monitor these new constructions and develop support mechanisms for insulation of roofs and walls of existing buildings as well. In this regard, cooperation with the Ministry of Economy and Sustainable Development, in particular with the Spatial Planning and Construction Policy Department is essential. It is possible to get financial support from different climate funds, such as Green Climate Fund, Global Environment Facility among others. In addition, researchers recommend implementing demand-side management[248] to use existing resources more effectively.
- Maintain regular surveys of the impacts of climate change on the energy sector in the future. This requires support from respective research institutes to ensure the systematic research of climate change issues and planning of necessary mitigation and adaptation measures.
- Take into consideration climate change impacts while constructing critical infrastructure energy installations and preparing environmental impact assessments (EIA).

[248] Demand-side management means influencing energy consumption by different methods including financial incentives and education. Basically, the goal of demand side management is motivating the customer to use less energy in peak hours or transfer consumption to other periods of time during the day and night. Such behavior does not necessarily mean decreasing the total energy consumption, but rather making the load curve smoother, resulting in less needed investment in peak capacity. Demand-side management also includes stimulation of energy efficiency.

5.4.2 Recommendations to be implemented at the municipal level

The recommendations listed below will support the municipalities included in Group 2 (see Section 4.4), however, fulfillment of the recommendations is desirable for Group 1 municipalities as well, since they will have greater reductions of energy consumption and get economic, environmental and social benefits.

Despite the fact that in the short term, climate change should not impact energy consumption, sensitivity towards climate change can be reduced and economic benefit can be ensured with the help of the recommendations given below that will also help the municipalities to prepare for climate change.

- Analyze the structure and dynamics of energy consumption. In order to comprehensively analyze this sector, relevant statistical and descriptive data such as: the type of housing built in the municipalities; the level of energy efficiency in housing; types of technologies used by the residential sector and commercial sector for cooling and heating; heating sources for the residential sector and how much and what energy types are used. It is recommended that municipalities collaborate with the National Statistics Office of Georgia and the Ministry of Energy to develop methodology for statistical data collection and analysis. Collected data shall be in compliance with national energy statistics. This data is necessary for the elaboration of a targeted energy efficiency policy. In addition, detailed statistical data on the municipal or regional level will improve the quality of quantitative surveys (for example, it will allow assessment of the percentage change in energy consumption in case of a one-degree increase in temperature) and will facilitate making effective decisions with respect to planning climate change adaptation measures and solving socio-economic problems among the population;
- Promote energy efficiency, especially in the residential sector. This will help to improve living standards and reduce the sector's sensitivity to climate change. It is necessary to implement the projects to demonstrate the benefit of energy-efficient activities. Additionally, information campaigns are needed to raise awareness about energy efficiency. Mechanisms for co-financing the thermal insulation of houses and inexpensive credit lines, among others, could be elaborated for the establishment of financial incentives for the promotion of energy efficiency. In order to raise donor aid, it is advisable to cooperate with both the Ministry of Energy and the Covenant of Mayors (CoM) initiatives, among others;
- Promote the use of renewable energy technologies for cooling, which is necessary in the residential sector. For this purpose, respective support mechanisms shall be elaborated and studies on similar technologies shall be carried out. In addition, financial mechanisms should be introduced for the development of a market for similar technologies, which will promote technological progress and stimulate local economic activity. In addition, green roofs and zero energy buildings could serve as a demonstration of reduction in the demand for cooling and the resulting energy consumption. Such actions will be effective and useful in spite of many uncertainties in the long term – 100-year forecasts, for example – regarding the extent of climate change impact, types of consumption technologies, and rates of economic development, since these measures can bring benefits already in the short and medium term.

5.5.1 Recommendations to be implemented at the national level

DEVELOPMENT OF GUIDELINES

Extreme activation of natural hazardous phenomena during recent years in Georgia has affected nearly all fields of human activity, thereby revealing the need for this issue to be a state priority with a high importance placed on the development of a long-term prevention strategy.

STUDY AND MONITORING

Without knowledge on how to resist natural hazards, it is impossible to avoid the consequences of degradation of agricultural lands, to maintain safe operation of infrastructure, to develop mountain tourism and in general, to maintain the living space. There should be appropriate knowledge on types, locations and scales of expected hazardous processes and threats that they would impose on the population, infrastructure and the environment as a whole, at the country scale, as well as at the regional and municipal levels. This type of research and development can lead to the creation of relevant specialized geodynamic maps that will serve as the basis for the establishment of a reliable system of early notification and the development of adaptation technologies.

The most effective preventive measures for avoiding or mitigating the negative impact of natural hazards is to provide well-organized geo-monitoring research at the regional level and to establish regime-stationary polygons at the most relevant and strategically important sites. They would meet the requirements for conducting a whole cycle of continuous observation of changes in the geological environment, starting from control parameters to prognoses and management.

The geological monitoring conducted by the National Environmental Agency of the Ministry of Environment and Natural Resources Protection throughout the territory of Georgia should be extended to include some additional activities. In particular, all settlements and infrastructure within each municipality should be assessed for their risk of natural hazards and disasters. Geological monitoring should be conducted twice annually, each spring and autumn.

INFORMATION AVAILABILITY

Information bulletins with special maps, showing threat risks (on a scale) as well as relevant preventive measures developed based on the study should be sent to all interested institutions and regional authorities. Special authorities in areas of high anthropogenic pressure (for instance, Adjara region, Lentekhi and Tsageri municipalities, etc.) should conduct geological monitoring. If such pressure and the corresponding impact is confirmed, the relevant information should be submitted to the municipal authorities in a timely manner and reflected in the annual information bulletin. At the same time, it is necessary to raise awareness among the local population.

MAIN ADAPTATION TECHNOLOGIES FOR MITIGATION OF NATURAL HAZARDS

The scale and the recurrence of the development and re-activation of natural hazards in most of the regions of Georgia show that they are in a phase of geo-ecological crisis, beyond which irreversible cataclysms could take place, when it would be impossible to provide safe environments for the population and safe operation of infrastructure.

The general situation created during recent years has been extremely complicated with the background of global climate change, high anthropogenic pressure and global background of activation of earthquakes. Adjara, Svaneti, Racha-Lechkhumi, Imereti, the mountainous area of Guria, the Samegrelo foothills and Mtskheta-Mtianeti are the most vulnerable to these factors.

To neutralize the critical situation created by natural hazards it is necessary to develop complex scenarios of adaptation through technological measures.

It was proved that, in practice, some expensive major infrastructure projects conducted in the areas of large-scale natural hazards, or in the areas where there is a threat of their development, have not been effective and have not often had the desirable result. These kinds of measures are mainly carried out in case of protection of the most significant infrastructure.

Taking into account that landslides, mudflows and erosion cause the main impact among natural hazards in Georgia, emphasis should be placed on adaptation technologies to minimize their impact. However, in addition, up to 60-70% of mudflow transformations are related to the activation of landslide processes, while the process of erosion of riverbanks, in turn, significantly contributes to the activation of landslide processes. In other words, we are concerned with significant interaction of the mentioned processes. On the positive side, this means that one type of measure to deal with one kind of process would also be beneficial for mitigation of other associated processes.

The scale of natural hazards in the country is so significant currently that it would, however, be very hard to overcome the financial and technical barriers to their mitigation. Hence, the priority for this stage should be given to those preventive measures that could be implemented by local municipalities with their own available capacity. Local populations may also be involved, which in turn could naturally contribute to information and awareness raising on natural hazard threats and risks. Such measures could include regulation of surface and ground waters, arrangement of mountain drainage facilities, catchment and drainage of springs, and filling and packing landslide fissures. If the area affected by the hazardous geological process is no longer suitable for agricultural purposes, the planting of fast-growing and deep-rooted trees could be undertaken. The trees should be preferably planted in staggered rows, and can include, for instance, Paulownia trees, the wood of which in addition is multi-purpose and therefore a definite market value.

It should also be noted that phyto-engineering regulates not only surface flows, but also prevents infiltration of rain and melting snow waters, protects the soil from erosion and prevents the development of gullies. It also contributes to drying of humid ground through transpiration and improves the quality of vulnerable ground.

As regards fundamental measures in landslide prevention, they should be conducted in certain areas to protect infrastructure of particular significance after relevant engineering and geo-dynamic studies are conducted in accordance with the developed project.

To protect riverbanks from erosion, and at the same time protect adjacent areas from development of riverbank landslides, the most optimal option, in our opinion, is to arrange stone gabions with wire fences and to fortify the banks with lump stones.

Conditions for the development of mudflow processes, including the dynamics and rheological nature of streams, fully depend on the geological environment where mudflow transformations take place. Hence, while selecting measures to prevent mudflows, we should take into consideration the rheological character of mudflow streams and their structural nature. In this regard, mudflow frequency reduction and stream-detaining iron/concrete engineering constructions (dams), reservoirs (with sediment-retarding basins), weirs, stream- and mudflow directing earthen riverside levees (stream passage construction) should be used. Riverbeds must be periodically cleaned up and fast-growing plants with deeper root systems should be planted in mudflow hearth areas.

Concerning protection of soil against water erosion, the efficient technologies are transverse-contour modeling, arrangement of water-collecting grooves and buffer lines, terracing and phyto-reclamation.

MINIMIZATION OF FINANCIAL RISKS

It is advisable to establish an insurance system to minimize the possible financial risks associated with natural hazards, at both national and municipal levels and in the private sector. Insurance should cover private property that is especially valuable. For these purposes, it is necessary: (a) to develop cooperation between the state and private sectors; (b) to share international experience; and (c) to develop and introduce insurance products adjusted to the socio-economic needs of Georgia.

5.5.2 Recommendations to be implemented at the municipal level

As it is already known, among the various and most dangerous natural hazards in Georgia that present a special threat to populations and infrastructure, the most significant are landslides, mudflows, floods and the associated riverbank erosion, as well as avalanches. Below is the list of regions and municipalities grouped according to the mentioned processes. Also indicated are measures to be conducted. It should be taken into consideration that most of these processes are mutually dependent, provoking one another, and that consequently, preventive measures can be similar and have a broad effect. Quite often, one type of measure allows the avoidance of the activation of another negative phenomena.

LANDSLIDE-PRONE AREAS AND PREVENTIVE MEASURES
Landslides dominate in following regions (with municipalities in parentheses): Adjara (Khulo, Shuakhevi, Keda, Khelvachauri, Kobuleti), Mtskheta-Mtianeti (Dusheti, Tianeti, Mtskheta), Racha-Lechkumi (Ambrolauri, Oni, Tsageri), Imereti (Kharagauli, Chiatura, Sachkhere, Vani, Bagdadi, Tskaltubo, Khoni), Guria (Chokhatauri, Lanchkhuti, Ozurgeti), Samegrelo (Zugdidi, Tsalenjikha, Chkhorotsku, Martvili), Shida Kartli (Gori, Khashuri, Kareli), Samtskhe-Javakheti (Adigeni, Borjomi, Aspindza, Akhaltsikhe), Kvemo Kartli (Tetri Tskaro).

Preventive measures to be taken: regulation of surface and ground waters; arrangement of drainage systems; capturing and draining of springs; filling and packing landslide fissures; arranging supporting walls; phyto-reclamation (bio-engineering) in areas that can no longer be used for agricultural purposes; planting of plants with deep root systems; terracing of slopes. Fortifying with supportive facilities can be also carried out through changing of topography of the landslide relief, phyto-reclamation. Areas prone to landslides, such as highways or cut slopes envisaged for construction of houses exposed to high risk, should be reinforced by supporting constructions. In places where the activation of landslide processes arises from riverbank erosion, the situation can be improved by fortifying with gabions and stones. If these measures turn out to be ineffective, fundamental, major capital measures should be taken (construction of supporting walls, wire nets and dams, cementing of fissures, bituminization, changing of landslide-prone ground through arranging Terramesh, installing of piles). In case of deeper and complex landslides, which can threaten engineering constructions, it will be necessary to select technologies based on detailed engineering studies and create specially developed projects.

MUDFLOW-PRONE AREAS AND PREVENTIVE MEASURES
Mudflow processes are especially significant for Kazbegi and Dusheti municipalities, in Kakheti region (Sagarejo, Gurjaani, Telavi, Akhmeta, Kvareli, Lagodekhi), Adjara region, and Svaneti.

Preventive measures to be conducted: periodic cleaning up of riverbeds; construction of stream-directing dams, water containment barriers and structural basins; planting within the riverbeds, leveling of riverbeds; construction of mudflow passing channels; construction of coastal dams; construction of stream-directing and stream-catching facilities.

FLOODS (INCLUDING FLASHFLOOD)-PRONE AREAS AND EROSION-PREVENTION MEASURES
Preventive measures against erosion and floods: flashfloods should be conducted first of all to protect lowland rivers in the Shida Kartli (Khashuri, Kareli, Gori and Kaspi municipalities) Kvemo Kartli (Tetritskaro, Marneuli, Gardabani, Tsalka, Dmanisi and Bolnisi municipalities), and Samegrelo regions (Samtredia, Tsqaltubo, Tsageri, Lentekhi, Ambrolauri, and Ozurgeti municipalities).

Protective measures to be conducted: gabions, stream-directing coastal earth fills, fortifying of riverbanks with deeply rooted plants, and construction of protective walls.

COASTAL EROSION-PRONE AREAS AND PROTECTIVE MEASURES

Coastal erosion can be observed in all coastal municipalities to a certain extent. An especially serious situation can be found in Kobuleti, Lanchkhuti and Batumi municipalities.

Protective measures to be conducted: introduction of relevant material to the coastal line. The material can be taken from places of excessive natural accumulation (Batumi cape), and transported to other areas. In separate cases, it may become necessary to build solid constructions (wave breakers, seawalls, etc.).

AVALANCHE-PRONE AREAS AND PROTECTIVE MEASURES

Avalanches can be observed in Mtskheta-Mtianeti (Kazbegi, Dusheti), Adjara (Khulo) and Svaneti (Mestia, Lentekhi) regions.

Protective measures to be conducted: It is necessary to arrange avalanche-passing galleries and install a complex system for their artificial activation.

Decision-makers should pay attention to the following three critical issues facing the social sector:

- Sensitivity of populations in densely settled areas, particularly in cities, towards extreme temperatures. Socially unprotected and elderly populations are even more sensitive. Therefore, much more attention should be paid to the population's social adaptation in those municipalities where the socially vulnerable population is dense, such as in urban areas, in order to reduce the negative impacts of climate change.
- Determination of the exact numbers of socially vulnerable populations in the municipalities, in order to ensure that decision-makers have accurate information about the scope of the problem. In addition to the cities, the number of the population above 65 years of age and below the poverty line is high in other municipalities as well. In order to support adaptation, decision-makers should pay more attention to these municipalities as well, not only concerning extreme temperatures and heat waves.
- Women make up the majority of people sensitive towards high temperatures, heat waves and natural disasters (with the sole exception of the Dmanisi municipality, where the number of men over 65 exceeds the number of women). Thus, it is necessary for decision-makers to pay particular attention to women's adaptation to climate change.

5.6.1 Recommendations to be implemented on the national level

General recommendations must be taken into account mainly by national level decision-makers. Although local government representatives, particularly in high-impact municipalities, can advocate for issues concerning their municipalities, decisions will be made at the national level. For example, in line with the present responsibilities of self-governance, the kinds of changes in the healthcare system that would help the country cope with climate change, such as improvement of the medical infrastructure and training of medical personnel, are the responsibility of national governments. The same is true for the facilitation of social initiatives, such as increase of the TSA (Targeted Social Assistance) and increase to pensions among others.

RECOMMENDATIONS TO COPE DIRECTLY WITH THE IMPACTS OF CLIMATE CHANGE:

- Raise public awareness about climate change by informing vulnerable groups about climate change and different adaptation methods. For example, how to behave in the event of natural disasters and heat waves.
- Plan protective measures that can be adjusted to help vulnerable groups in municipalities where extremely high temperatures are an acute problem, or where the problem is aggravated by the urban heat island effect such as Zugdidi, Rustavi, Kutaisi, Batumi, Samtredia and Senaki. At present, an Action Plan against Heat Waves for Tbilisi[249] is being developed, which includes a stepwise action plan for health care specialists, managers of social institutions, such as retirement homes and children's homes, and employers. In addition, it includes full information and recommendations for the wider population and other vulnerable groups. Tbilisi Municipality can share its experience and knowledge with other municipalities.
- More attention should be paid to gender issues when planning and carrying out adaptation measures to climate change as the study revealed that the number of women among the population above 65 and below the poverty line is higher than the number of men. In addition, children, aged people and persons with chronic diseases are also vulnerable to climate change and, therefore, should receive more attention.

RECOMMENDATIONS FOR THE ADAPTATION OF THE HEALTH CARE SYSTEM AND OTHER RELATED BRANCHES TO CLIMATE CHANGE:

- Provide information to medical personnel about the management of climate-dependent diseases through training and workshops;

- Improve the health care system so that socially vulnerable groups, particularly those with climate-dependent diseases, such as cardiovascular, respiratory system pathologies and infectious diseases, as well as elderly people, persons with chronic diseases, small children, and socially unprotected groups are better protected. For example, one step could be to include climate-related diseases in the insurance package, both private and state, and access to particular advantages for vulnerable groups of the population.
- Improve the functioning of relevant municipal or state services, such as first aid and emergency care, hospitals, social service agency and trauma service among others, which will help to facilitate better preparation and adaptation to climate change challenges. This, in the first place, can be achieved by providing them with information about these challenges, retraining and carrying out workshops. Special groups equipped with relevant knowledge of particular negative manifestations of climate change, such as heat waves and natural disasters among others, could provide timely and adequate aid to affected population groups, for example, by moving them to a safe place, rendering medical assistance, and engaging in the post-traumatic rehabilitation process.

RECOMMENDED IMPROVEMENTS IN THE SOCIO-ECONOMIC SITUATION TO BUILD CLIMATE-RESILIENT AND SUSTAINABLE COMMUNITIES:

- Implement several social and economic measures, such as increasing TSA and creating work places to reduce the number of people below the poverty line and other groups that are vulnerable to climate change. Decision-makers should also work on developing different types of social protection mechanisms, such as private, state or municipal mechanisms, such as insurance and pensions.
- Work with the insurance sector to raise their awareness about climate-dependent diseases and other climate change challenges. In particular, developing evidence-based insurance models would facilitate better planning and increase the cost-effectiveness of the insurance program. More generally, it is important to improve and further develop the insurance system, particularly in terms of property and life insurance packages for socially unprotected population groups.
- Take into account gender balance when planning and carrying out economic and social measures. This could include creating more work places for women and increasing women's engagement in decision-making processes.
- Facilitate and advocate healthy lifestyles, which in turn will facilitate the improvement of health. It is clear that healthy populations will cope better with climate change challenges.

5.6.2 Recommendations to be implemented on the municipal level

Recommendations that were developed for specific municipalities are primarily intended for local government implementation. Although decisions about the adaptation of the social sector to climate change may be made at the national level, local government should advocate for the problem by all means available and initiate discussions on these issues with the central authorities.

Thus, on the municipal level it is recommended to:

- Raise the awareness of urban populations about climate change and its manifestations, including heat waves and how to adapt to them. Particular attention should be paid to vulnerable populations, such as the elderly, children, the poor and people with chronic diseases. Amongst other things, this involves the provision of practical information to help the population during heat waves: for example, information about emergency care, including practical advice, medical details, and the contact details of first aid services. Priority cities are Tbilisi, Rustavi, Kutaisi, Zugdidi, Samtredia, Senaki, and Batumi.
- Organize municipal infrastructure in such a way that the population can more easily cope with heat waves and extreme temperatures.

[249] The National Plan against Heat Waves for Tbilisi is being developed in the framework of a joint ADA, AutRC project: "Formation of Safe and Stable Communities in South Caucasus".

- In case of necessity, develop Heat Wave Action Plans for specific cities, which is a priority adaptation measure. An Action Plan has already been developed for Tbilisi, and a National Action Plan is also planned, which will pay attention to other cities as well, including Rustavi, Kutaisi, Batumi and Zugdidi.
- Develop and implement pilot adaptation projects for both urban and rural populations, particularly for groups sensitive to climate change. For example, mobilize first aid personnel during heat waves to ensure better monitoring of people over the age of 65 who suffer from chronic diseases. In this case, priority should be given to remote regions, where the medical personnel should be adequately trained in climate-dependent disease management and health monitoring of vulnerable populations.
- In cooperation with non-governmental organizations, raise the awareness of local communities about climate change. Relevant information will help the local population to become engaged in the decision-making process.
- Provide information to the population about behavior during natural disasters. Also, carry out measures to prevent natural disasters to enhance the protection of the population, including socially vulnerable groups (see Section 5.5 on natural disaster recommendations).

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