CLIMATE RISK COUNTRY PROFILE

GEORGIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

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This profile is part of a series of Climate Risk Country Profiles that are jointly developed by the World Bank Group (WBG) and the Asian Development Bank (ADB). These profiles synthesize the most relevant data and information on climate change, disaster risk reduction, and adaptation actions and policies at the country level. The profile is designed as a quick reference source for development practitioners to better integrate climate resilience in development planning and policy making. This effort is co-led by Veronique Morin (Senior Climate Change Specialist, WBG), Ana E. Bucher (Senior Climate Change Specialist, WBG) and Arghya Sinha Roy (Senior Climate Change Specialist, ADB).

This profile was written by Alex Chapman (Consultant, ADB), William Davies (Consultant, ADB) and Ciaran Downey (Consultant). Technical review of the profiles was undertaken by Robert L. Wilby (Loughborough University). Additional support was provided by MacKenzie Dove (Senior Climate Change Consultant, WBG), Jason Johnston (Operations Analyst, WBG), Yunziyi Lang (Climate Change Analyst, WBG), Adele Casorla-Castillo (Consultant, ADB), and Charles Rodgers (Consultant, ADB). This profile also benefitted from inputs of WBG and ADB regional staff and country teams.

Climate and climate-related information is largely drawn from the Climate Change Knowledge Portal (CCKP), a WBG online platform with available global climate data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments and suggestions received from the sector, regional, and country development specialists, as well as climate research scientists and institutions for their advice and guidance on use of climate related datasets.

CONTENTS

FOREWORD

Climate change is a major risk to good development outcomes, and the World Bank Group is committed to playing an important role in helping countries integrate climate action into their core development agendas. The World Bank Group (WBG) and the Asian Development Bank (ADB) are committed to supporting client countries to invest in and build a low-carbon, climate-resilient future, helping them to be better prepared to adapt to current and future climate impacts.

Both institutions are investing in incorporating and systematically managing climate risks in development operations through their individual corporate commitments.

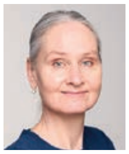
For the World Bank Group: a key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy planning, investment design, implementation and evaluation of development outcomes. For all International Development Association and International Bank for Reconstruction and Development operations, climate and disaster risk screening is one of the mandatory corporate climate commitments. This is supported by the World Bank Group's Climate and Disaster Risk Screening Tool which enables all Bank staff to assess short- and long-term climate and disaster risks in operations and national or sectoral planning processes. This screening tool draws up-to-date and relevant information from the World Bank's Climate Change Knowledge Portal, a comprehensive online 'one-stop shop' for global, regional, and country data related to climate change and development.

For the Asian Development Bank (ADB): its Strategy 2030 identified "tackling climate change, building climate and disaster resilience, and enhancing environmental sustainability" as one of its seven operational priorities. Its Climate Change Operational Framework 2017–2030 identified mainstreaming climate considerations into corporate strategies and policies, sector and thematic operational plans, country programming, and project design, implementation, monitoring, and evaluation of climate change considerations as the foremost institutional measure to deliver its commitments under Strategy 2030. ADB's climate risk management framework requires all projects to undergo climate risk screening at the concept stage and full climate risk and adaptation assessments for projects with medium to high risk.

Recognizing the value of consistent, easy-to-use technical resources for our common client countries as well as to support respective internal climate risk assessment and adaptation planning processes, the World Bank Group's Climate Change Group and ADB's Sustainable Development and Climate Change Department have worked together to develop this content. Standardizing and pooling expertise facilitates each institution in conducting initial assessments of climate risks and opportunities across sectors within a country, within institutional portfolios across regions, and acts as a global resource for development practitioners.

For common client countries, these profiles are intended to serve as public goods to facilitate upstream country diagnostics, policy dialogue, and strategic planning by providing comprehensive overviews of trends and projected changes in key climate parameters, sector-specific implications, relevant policies and programs, adaptation priorities and opportunities for further actions.

We hope that this combined effort from our institutions will spur deepening of long-term risk management in our client countries and support further cooperation at the operational level.



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KEY MESSAGES

- Average temperatures in Georgia have increased steadily since the 1960s and are projected to rise by more than the global average by the end of the 21st century.
- By the 2090s, the average temperature in Georgia is projected to increase between 1.4°C to 4.9°C above the 1986–2005 baseline, for emissions pathways RCP2.6 and RCP8.5, respectively
- The frequency of heat waves is projected to increase significantly by the 2090s under higher emissions pathways, representing major risks to human health, livelihoods, and biodiversity.
- Rapid retreat of glaciers is expected and is likely to shift the regional hydrological regime, increasing the risk of flooding and ultimately driving transitions in local ecosystems.
- The effects of rising temperatures on agricultural output could threaten an important source of income and employment in poorer rural areas and may consequently increase inequality and raise the risk of malnourishment.
- Projected long-term reductions in the flow rates of rivers in Georgia, rising average temperatures, and existing issues with energy distribution networks are expected to increase the risk of water shortages in the spring and summer months. As such, there is a need for more international cooperation in the management of transboundary rivers in the South Caucasus.
- River flow reductions during summer months, coinciding with peak energy demand for residential cooling, have important implications for Georgia's energy supply, which depends primarily on domestic hydropower sources.
- The capital city, Tbilisi, is subject to urban heat island effect, making its residents vulnerable to health risks as the frequency of extremely high temperatures increases over the coming decades.

COUNTRY OVERVIEW

Georgia is located in the South Caucasus Region, sharing land borders with Russia to the north, Turkey to the southwest, Armenia to the south and Azerbaijan to the east. With an area of 69,700 square kilometers, it lies between natural boundaries on three sides, in the form of the Greater Caucasus mountains in the north, the Lesser Caucasus mountains in the south, and a 320 km Black Sea coast in the west. The country has a population of approximately 3.72 million people (2019)[1] and has experienced negative population growth since independence from the Soviet Union in the early 1990s, primarily due to high levels of outward migration (**Table 1**). Over the past two decades, Georgia has experienced significant economic change, urbanization and displaced populations (due to conflict and disasters triggered by natural hazards). As of 2018, approximately 2.2 million people (58% of the population) live in urban areas, including in the capital Tbilisi (which has an estimated population of 1.1 million). Georgia's economy is reliant on the service sector (which accounts for 55%–60% of GDP), and the rise in prominence of services has been accompanied by a reduction in the importance of agriculture (which typically accounts for 7%–8% of GDP). Unemployment has remained high: Georgian unemployment rate of 13.9% was the lowest recorded since the early 2000s.

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[1] World Bank (2021). World Development Indicators – databank. [accessed 16 February, 2021]. URL: https://databank.worldbank.org/source/world-development-indicators

Georgia developed and submitted its Initial Nationally Determined Contribution to the UNFCCC in 2017.[2] Georgia submitted its Updated Nationally Determined Contribution in 2021, fully committing to an unconditional limiting target of 35 % below 1990 level of its domestic total greenhouse gas emissions by 2030 and to a target of 50%–57% of its total greenhouse gas emissions by 2030 compared to 1990, in case the global greenhouse gas emissions follow the 2 degrees or 1.5 degrees scenarios respectively.[3] Georgia is also in the process of finalizing its national climate change strategy and related action plan (2021–2030). Georgia completed and submitted its Fourth National Communication to the UNFCCC (NC4) in 2021. Agriculture, water resources, forestry, energy, waste, mineral resources, and health have been identified as highly vulnerable sectors to projected climate changes.[4] Adaptation priorities focus on the country's key sectors of agriculture, forestry, water resources, natural hazards, and energy sectors, with target areas including mountain ecosystems, water resources, forests and biodiversity, extreme weather, tourism, agriculture and public health. The country's mitigation focuses target key sectors, energy (generation), transport, buildings (energy efficiency), industry, agriculture, waste management and forestry. Adaptation and mitigation efforts are also paired with economic planning to support the country's development agenda and resilience to anticipated impacts.[5]

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[6]	8.2% (2017–2019)	FAO, 2020
National Poverty Rate[7]	20.1% (2018)	ADB, 2020
Share of Income Held by Bottom 20%[8]	6.5% (2018)	World Bank, 2019
Net Annual Migration Rate[9]	–0.25% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[10]	0.9% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[11]	0.4% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[12]	55 (2020)	UNDESA, 2019
Urban Population as % of Total Population[13]	59.5% (2020)	CIA, 2020
External Debt Ratio to GNI[14]	110.6% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP[15]	28.5% (2019)	ADB, 2020b

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[2] Ministry of Environment and Natural Resources Protection (2017). Georgia's Nationally Determined Contribution to the UNFCCC. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Georgia%20First/INDC_of_Georgia.pdf [accessed 12/10/2018]

[3] Georgia (2020). Georgia's Updated Nationally Determined Contribution. URL: https://mepa.gov.ge/En/PublicInformation/25717/

[4] Ministry of Environment and Natural Resources Protection (2021). Fourth National Communication of Georgia under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4%20Final%20Report%20-%20English%202020%2030.03_0.pdf

[5] Ministry of Environment and Natural Resources Protection (2017). Georgia's Nationally Determined Contribution to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4%20Final%20Report%20-%20English%202020%2030.03_0.pdf

[6] FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Transforming food systems for affordable healthy diets. FAO. Rome. URL: http://www.fao.org/documents/card/en/c/ca9692en/

[7] ADB (2020). Basic Statistics 2020. URL: https://www.adb.org/publications/basic-statistics-2020 [accessed 27/01/21]

[8] World Bank (2019). Income share held by lowest 20%. URL: https://data.worldbank.org/ [accessed 17/12/20]

[9] UNDESA (2019). World Population Prospects 2019: MIGR/1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

[10] UNDESA (2019). World Population Prospects 2019: MORT/1-1. URL https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

[11] UNDESA (2019). World Urbanization Prospects 2018: File 6. URL: https://population.un.org/wup/Download/ [accessed 17/12/20]

[12] UNDESA (2019). World Population Prospects 2019: POP/11-A. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

[13] CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

[14] ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: http://dx.doi.org/10.22617/FLS200250-3

[15] ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: http://dx.doi.org/10.22617/FLS200250-3

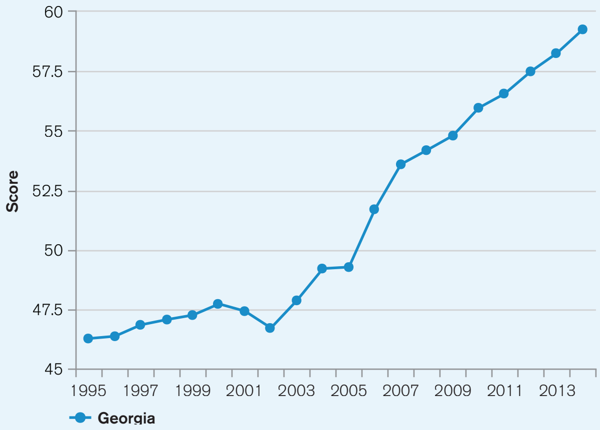
Green, Inclusive and Resilient Recovery

The coronavirus disease (COVID-19) pandemic has led to unprecedented adverse social and economic impacts. Further, the pandemic has demonstrated the compounding impacts of adding yet another shock on top of the multiple challenges that vulnerable populations already face in day-to-day life, with the potential to create devastating health, social, economic and environmental crises that can leave a deep, long-lasting mark. However, as governments take urgent action and lay the foundations for their financial, economic, and social recovery, they have a unique opportunity to create economies that are more sustainable, inclusive and resilient. Short and long-term recovery efforts should prioritize investments that boost jobs and economic activity; have positive impacts on human, social and natural capital; protect biodiversity and ecosystems services; boost resilience; and advance the decarbonization of economies.

This document aims to summarize the climate risks faced by Georgia. This includes short and long-term changes in key climate parameters, as well as impacts of these changes on communities, livelihoods and economies, many of which are already underway. This is a high-level synthesis of existing research and analyses, focusing on the geographic domain of Georgia, as such this profile potentially overlooks some localized impacts and transboundary flow dynamics. The core data presented is sourced from the database sitting behind the World Bank Group's Climate Change Knowledge Portal (CCKP). This document also aims to direct the reader to many useful sources of secondary data and research.

Due to a combination of political, geographic, and social factors, Georgia is recognized as vulnerable to climate change impacts, ranked 40th out of 181 countries in the 2020 ND-GAIN Index.[16] The ND-GAIN Index ranks 181 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. The more vulnerable a country is the lower their score, while the more ready a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st. **Figure 1** is a time-series plot of the ND-GAIN Index showing Georgia's progress

FIGURE 1. The ND-GAIN Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It aims to help businesses and the public sector better prioritize investments for a more efficient response to the immediate global challenges ahead



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[16] University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

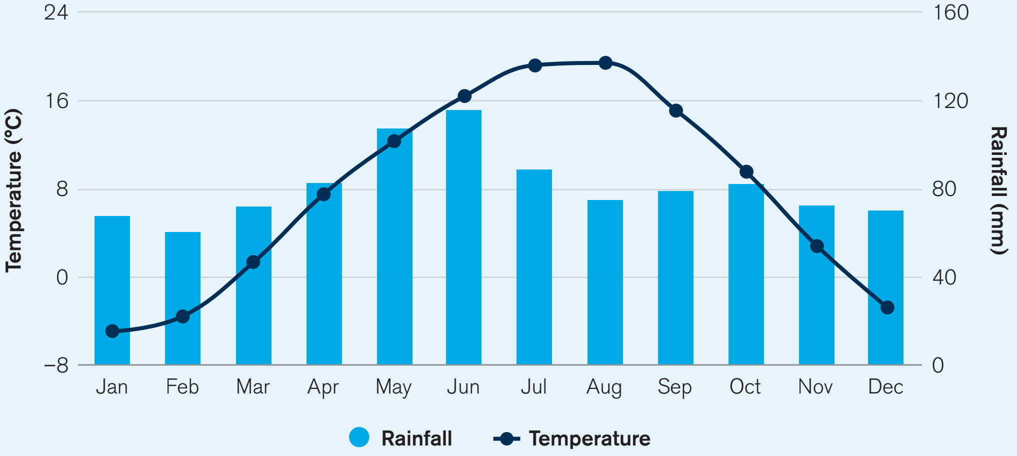
Climate Baseline

Overview

Georgia has a highly diverse physical geography, comprised of mountains, plateau, lowland-plains, glaciers, wetlands, arid areas (semi-deserts), lakes, and rivers. Approximately two-thirds of the country is mountainous and 20% of the country is located at 2,000 meters or more above sea level. Lower mountain areas include the country's inter-mountain plain, which is bounded to the north and south by the Greater and Lesser Caucus mountain ranges, respectively.[17] The Georgian climate is largely a function of distance from the Black Sea coast and altitude. The western parts of Georgia experience a milder climate due to the influence of the Black Sea with average winter temperatures well above freezing and relatively hot summers with higher humidity and higher average precipitation. Black Sea coastal areas average annual temperatures typically range from 9°C to 14°C, with 900–2,300 millimeters (mm) of precipitation per annum. Mountainous regions have a colder climate, with average annual temperatures of 2°C–10°C, very cold winter temperatures in some mountain towns and annual precipitation levels of 1,200–2,000 mm. In the eastern lowlands, the dry subtropical climate brings only 400–600 mm of rainfall per year and relatively high annual mean temperatures of 11°C–13°C.[18] Average temperatures in Georgia vary with the seasons, from sub-zero levels in winter months (December to February) to a relatively warm levels in the summer (averaging 18°C in July and August). Precipitation is relatively consistent throughout the year, although average precipitation totals are at their highest in late spring and early summer (**Figure 2**). **Figure 3** shows the spatial variation of observed temperature and precipitation in Georgia for the latest climatology, 1991–2020.

Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Georgia (1991–2020)[19]



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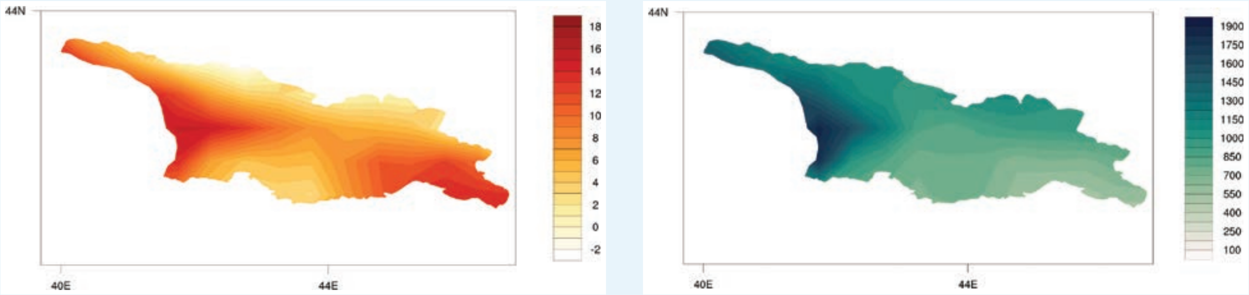
[17] Rukhadze, A., Vachiberidze, I., & Fandoeva, M. (2014). National Climate Vulnerability Assessment: Georgia. Climate Forum East and Georgia National Network on Climate Change. URL: https://climateforumeast.org/uploads/other/0/771.pdf [accessed 12/10/2018]

[18] USAID (2017). Climate Risk Profile – Georgia. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Change%20Risk%20Profile%20-%20Georgia.pdf [accessed 12/10/2018]

[19] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/georgia/climate-data-historical

Spatial Variation

FIGURE 3. (Left) Annual Mean Temperature (°C), and (Right) Annual Mean Precipitation (mm) in Georgia over the period 1991–2020.[20]



Key Trends

Temperature

The overall climate trend for Western Asia and the South Caucus sub-region shows a steady increase in average temperatures. Since the 1960s, Georgia has experienced increased temperatures of 0.3°C in western areas and 0.4–0.5°C in eastern areas. A marked increase in hot days has been observed, particularly in the lowlands, and in Tbilisi the number of days per year when the heat index reached dangerous levels increased by 14 in the period 1986–2010, relative to its 1961–19 85 baseline.[4] Heatwaves have been increasingly reported across the sub-region, particularly for urban areas.[21] Winter warming has been more pronounced in the eastern parts of Georgia between 1986 and 2010 (relative to a baseline period of 1961–1985), whereas central parts have seen little change in winter temperatures and some western areas experienced a decrease in average winter temperatures. Georgia has the largest glaciated area and greatest number of glaciers in the Caucasus region, many of which have retreated dramatically since 1974 as temperatures have risen.[22,23]

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[20] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/georgia/climate-data-projections

[21] ENVSEC (2016). Climate Change and Security in the South Caucasus: Republic of Armenia, Azerbaijan and Georgia- Regional Assessment. URL: https://www.osce.org/secretariat/331921?download=true [accessed 16/10/2018]

[22] Shahgedanova, M., Nosenko, G., Kutuzov, S., Rototaeva, O. and Khromova, T. (2014). Deglaciation of the Caucasus Mountains, Russia/Georgia, in the 21st century observed with ASTER satellite imagery and aerial photography. The Cryosphere, 8(6), pp. 2367–2379. URL: https://www.the-cryosphere.net/8/2367/2014/

[23] Tielidze, L.G. (2016). Glacier change over the last century, Caucasus Mountains, Georgia, observed from old topographical maps, Landsat and ASTER satellite imagery. The Cryosphere, 10(2), pp. 713–725. URL: https://www.the-cryosphere.net/10/713/2016/

Precipitation

Across the Western Asia and South Caucus sub-region, climate trends show a slight decrease in mean precipitation over the past decade, although an increase in heavy precipitation has been observed in certain areas. Total annual precipitation amounts generally increased in western Georgia between 1961–1985 and 1986–2010, although there were small areas within the west that witnessed decreases in precipitation. Some of the sharpest increases occurred in the western mountain areas of Svaneti and Adjara (up to 14% relative to the baseline period). There were increases in precipitation observed in many parts of the east, including the capital, Tbilisi. The far eastern part of the country (the eastern half of Kakheti region, near the border with Azerbaijan) experienced a fall in annual precipitation levels.[4]

A Precautionary Approach

Studies published since the last iteration of the IPCC's report (AR5), such as Gasser et al. (2018), have presented evidence which suggests a greater probability that earth will experience medium and high-end warming scenarios than previously estimated.[24] Climate change projections associated with the highest emissions pathway (RCP8.5) are presented here to facilitate decision making which is robust to these risks.

Climate Future

Overview

The main data source for the World Bank Group's Climate Change Knowledge Portal (CCKP) is the Coupled Model Inter-comparison Project Phase 5 (CMIP5) models, which are utilized within the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), providing estimates of future temperature and precipitation. Four Representative Concentration Pathways (i.e. RCP2.6, RCP4.5, RCP6.0, and RCP8.5) were selected and defined by their total radiative forcing (cumulative measure of GHG emissions from all sources) pathway and level by 2100. In this analysis RCP2.6 and RCP8.5, the extremes of low and high emissions pathways, are the primary focus RCP2.6 represents a very strong mitigation scenario, whereas RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database.

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[24] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience. URL: https://www.nature.com/articles/s41561-018-0227-0?WT.feed_name=subjects_climate-sciences

For Georgia, these models show a consistent trend of increasing temperatures across all emission scenarios. However, the projections in rainfall are less certain. Projected trends indicate no significant changes to current precipitation patterns; however, the intensity of heavy rainfall events is expected. **Tables 2** and **3** below, provide information on temperature projections and anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Georgia for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table is showing the median of the CCKP model ensemble and the 10–90th percentiles in brackets.[25]

	Average Daily Maximum Temperature		Average Daily Temperature		Average Daily Minimum Temperature	
Scenario	**2040–2059**	**2080–2099**	**2040–2059**	**2080–2099**	**2040–2059**	**2080–2099**
RCP2.6	1.5 (–0.8, 4.0)	1.5 (–0.9, 3.9)	1.4 (–0.4, 3.3)	1.4 (–0.6, 3.2)	1.3 (–0.5, 2.8)	1.3 (–0.5, 2.8)
RCP4.5	1.9 (–0.4, 4.1)	2.6 (0.4, 5.0)	1.7 –0.3, 3.6)	2.3 (0.6, 4.4)	1.6 (–0.3, 3.2)	2.3 (0.4, 4.2)
RCP6.0	1.7 (0.0, 3.7)	3.4 (1.2, 5.8)	1.5 (0.2, 3.1)	3.1 (1.3, 4.9)	1.5 (0.0, 2.8)	2.9 (1.0, 4.5)
RCP8.5	2.6 (0.4, 4.8)	5.4 (2.8, 7.8)	2.4 (0.5, 4.1)	4.9 (2.9, 7.0)	2.3 (0.4, 3.8)	4.7 (2.6, 6.6)

TABLE 3. Projections of average temperature anomaly (°C) in Georgia for different seasons (3-monthly time slices) over different time horizons and emissions pathways, showing the median estimates of the full CCKP model ensemble and the 10th and 90th percentiles in brackets.[22]

	2040–2059		2080–2099	
Scenario	**Jun–Aug**	**Dec–Feb**	**Jun–Aug**	**Dec–Feb**
RCP2.6	1.7 (–0.4, 4.6)	1.4 (–0.3, 2.6)	1.7 (–0.7, 4.6)	1.4 (–0.2, 2.6)
RCP4.5	2.1 (0.0, 5.3)	1.6 (–0.3, 2.7)	2.9 (0.9, 6.2)	2.1 (0.6, 3.5)
RCP6.0	1.9 (0.2, 4.0)	1.7 (0.3, 2.9)	3.8 (1.5, 6.4)	2.9 (1.4, 4.1)
RCP8.5	3.1 (0.9, 5.9)	2.0 (–0.2, 3.2)	6.1 (3.7, 9.3)	4.1 (2.5, 5.5)

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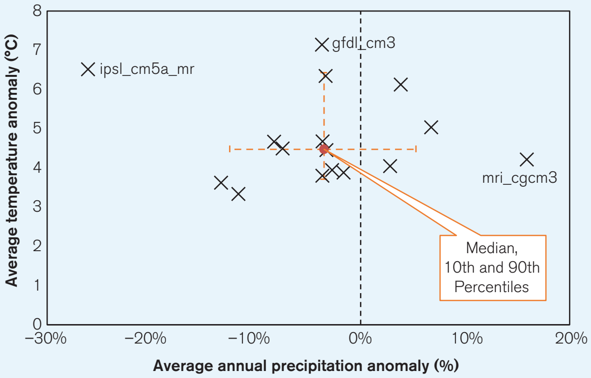
[25] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/georgia/climate-data-historical

Model Ensemble

Climate projections presented in this document are derived from datasets made available on the CCKP, unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) developed by climate research centers around the world and evaluated by the IPCC for quality assurance in the CMIP5 iteration of models (for further information see Flato et al., 2013).[26] Collectively, these different GCM simulations are referred to as the 'model ensemble'. Due to the differences in the way GCMs represent the key physical processes and interactions within the climate system, projections of future climate conditions can vary widely between different GCMs. This is particularly the case for rainfall related variables and at national and local scales. Exploring the spread of climate model outputs can assist in understanding uncertainties associated with climate models. The range of projections from 16 GCMs on the indicators of average temperature anomaly and annual precipitation anomaly for Georgia under RCP8.5 is shown in **Figure 4**. Spatial variation of future projections of annual temperature and precipitation for mid and late century under RCP8.5 are presented in **Figure 5**.

FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Georgia. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble that provide projections across all RCPs and therefore are most robust for comparison[22]. Three models are labelled.



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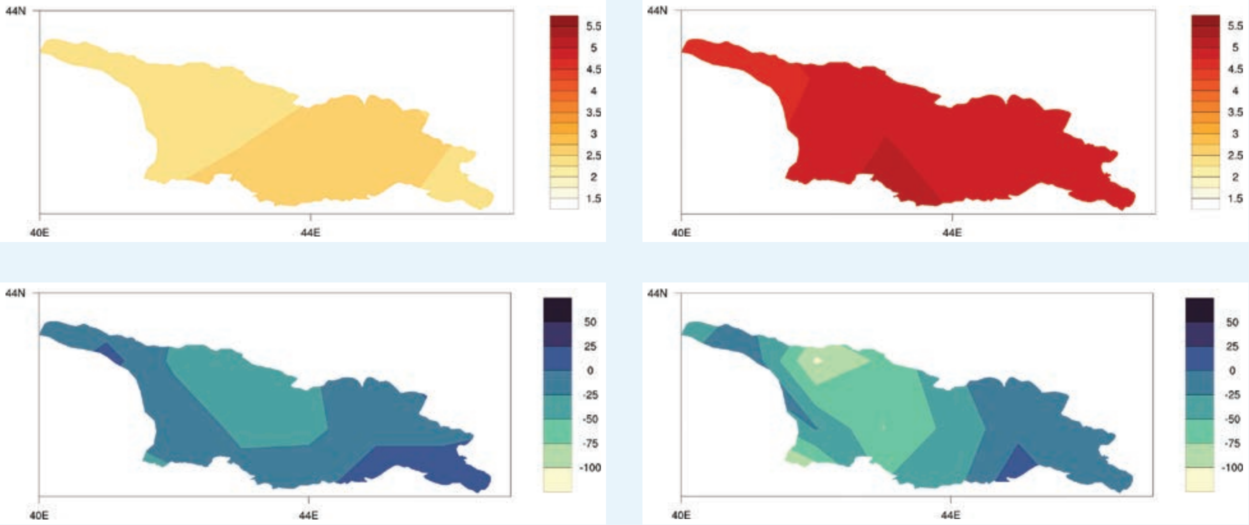
[26] Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W., . . . Rummukainen, M. (2013). Evaluation of Climate Models. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 741–866. URL: https://pubs.giss.nasa.gov/abs/ip06000g.html

Spatial Variation

FIGURE 5. CMIP5 ensemble projected change (32 GCMs) in annual temperature (top) and precipitation (bottom) by 2040–2059 (left) and by 2080–2090 (right) relative to 1986–2005 baseline under RCP8.5.[27]



Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes (anomalies) in daily maximum and daily minimum temperatures over the given time period, as well as changes in the average temperature. **Figures 6** and **7** display the annual and monthly average temperature projections. While similar, these three indicators can provide slightly different information. Monthly/annual average temperatures are most commonly used for general estimation of climate change, but the daily maximum and minimum can explain more about how daily life might change in a region, affecting key variables such as the viability of ecosystems, health impacts, productivity of labor, and the yield of crops, which are often disproportionately influenced by temperature extremes.

Temperature changes in Georgia are projected to increase significantly by the end of the 21st century under all four emissions pathways. These increases are expected to be greater than the global averages projected by the IPCC. Under the highest emissions pathway, RCP8.5, average temperatures in Georgia are projected to rise by 4.9°C by the 2090s, compared with a global average rise of 3.7°C. In Georgia, summer (May to September) is projected to see the largest rises in temperature, although this seasonality is less significant in the lowest emissions pathway, RCP2.6. The temperature increase of the last two decades of the 21st century projected under the highest emission pathway (RCP8.5) is 3.1°C greater than the rise projected under the lowest (RCP2.6) pathway, indicating the large difference in outcome for Georgia that could be achieved by controlling global emissions.

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[27] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/georgia/climate-data-projections

FIGURE 6. Historic and projected average annual temperature in Georgia under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.[28]

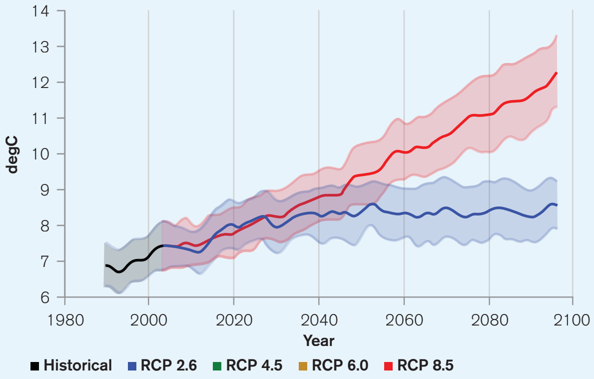
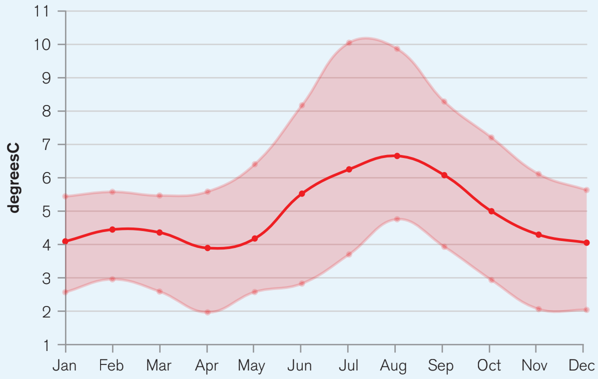


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Georgia for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles.[29]



Precipitation

While considerable uncertainty surrounds projections of local long-term future precipitation trends, some global trends are evident. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature. This finding is supported by evidence from different regions of Asia,[30] as well as from some observations within Georgia.[31] However, as this phenomenon is highly dependent on local geographical contexts, further research is required to constrain its impact in Georgia. Projections do indicate that western and northern areas of the country, especially areas along the Black Sea, are likely to experience a slight increase in days with rainfall greater than 20 mm, while eastern and southern areas are likely to experience a reduction in these days.

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[28] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/georgia/climate-data-projections

[29] WBG Climate Change Knowledge Portal (CCKP, 2020). Georgia. Agriculture Interactive Climate Indicator Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=GEO&period=2080-2099

[30] Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G., Roberts, N. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. Reviews of Geophysics, 52, 522–555. URL: https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2014RG000464

[31] Keggenhoff, I., Elizbarashvili, M., Amiri-Farahani, A. and King, L. (2014). Trends in daily temperature and precipitation extremes over Georgia, 1971–2010. Weather and Climate Extremes, 4, pp. 75–85. URL: https://www.sciencedirect.com/science/article/pii/S2212094714000334

CLIMATE RELATED NATURAL HAZARDS

Georgia faces significant disaster risk levels and is ranked 87th out of 191 countries by the 2019 Inform Risk Index[32] (**Table 4**). This ranking is driven strongly by the country's high exposure to hazard and very limited coping capacity. Earthquakes, droughts, and floods are significant physical hazards in Georgia. The section that follows analyses climate change influences on the exposure component of risk in Georgia. As seen in **Figure 1**, the ND-GAIN Index presents an overall picture of a country's vulnerability and capacity to improve its resilience. In contrast, the Inform Risk Index identifies specific risks across a country to support decisions on prevention, preparedness, response, and a country's overall risk management.

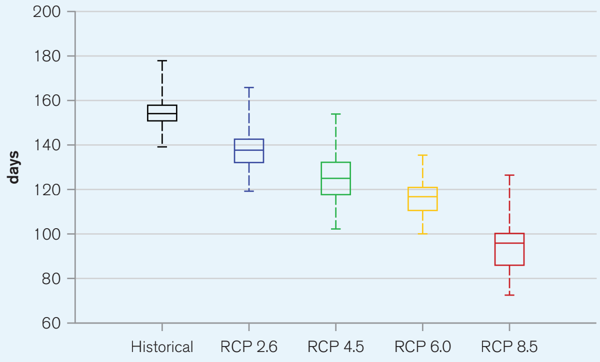
TABLE 4. Selected indicators from the INFORM 2019 Index for Risk Management for Georgia. For the sub-categories of risk (e.g. "Flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st. Global average scores are shown in brackets.

Flood (0–10)	Tropical Cyclone (0–10)	Drought (0–10)	Vulnerability (0–10)	Lack of Coping Capacity (0–10)	Overall Inform Risk Level (0–10)	Rank (1–191)
5.1	0	5.3	4.8	3.2	3.9	87

Heatwaves

Georgia can experience high maximum temperatures, with an average monthly maximum of only around 12°C but an average July maximum of 24°C. The current median probability of a heat wave (defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) is around 3%.[16] The model ensemble projects that under the higher emissions scenarios (RCP6.0 and RCP8.5), the annual probability of a heat wave could increase significantly in Georgia by the 2050s and continue rising over the remaining decades of the 21st century. Under the highest emissions pathway (RCP8.5), this implies an annual likelihood of observing a heat wave in Georgia of 1 in 5, by the 2090s. This high probability of observing a heat wave is projected to affect all regions of the country equally. These large projected rises are calculated against a baseline of 1986–2005 and should be seen in the context of continually rising temperatures. Further research is required to provide more information on the impact of climate change on temperature volatility. The country's increasing temperatures, both minimum and maximum temperatures as well as expanded heatwaves, impacts water resources and precipitation events. As shown in **Figure 8**, the number of frost days (Tmin<0°C) for Georgia is projected to decrease significantly by the 2090s, under RCP8.5.

FIGURE 8. Box Plot showing the reduction in number of Frost Days, or days with the minimum temperature above 0°C, across all emission scenarios.



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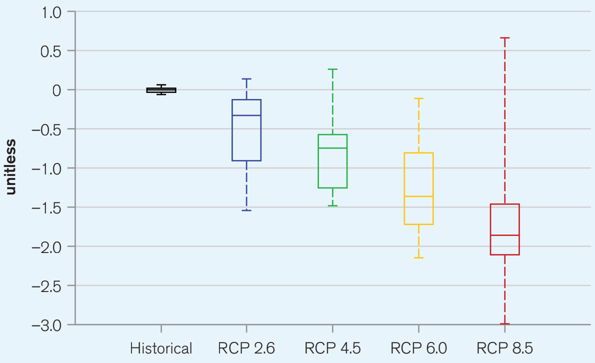
[32] European Commission (2019). INFORM Index for Risk Management. Georgia Country Profile. URL: https://drmkc.jrc.ec.europa.eu/inform-index/Countries/Country-Profile-Map

Drought

Two primary types of drought may affect Georgia, meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). Where hydrological dearth coincides with sub-optimal crop choices and land management practices there is also potential for agricultural drought. At present Georgia faces an annual median probability of severe meteorological drought of around 4%,[16] as defined by the Standardized Precipitation Evaporation Index (SPEI) of less than –2. Naumann et al. (2018), provide a global overview of changes in drought conditions under different warming scenarios.[33] They project large increases in the duration and magnitude of droughts in West Asia (i.e. the Caucasus region) by the end of the 21st century under global warming levels of 1.5°C, 2.0°C and 3.0°C. Droughts of a magnitude that are rarely seen at present, in West Asia, (returning once in 100-years) are projected to become 5 to 10 times more common under the same warming scenarios.

The CCKP model ensemble also projects very significant increases in the probability of drought. The highest emissions pathway, RCP8.5, projects an increase in annual severe drought probability to over 70% (**Figure 9**). Projections show considerable regional variation, with an annual probability of severe drought lower in the western parts of the country than the central and eastern regions.

FIGURE 9. Boxplots showing the annual probability of experiencing a 'severe drought' in Georgia (–2 SPEI index) in 2080–2099 under four emissions pathways.[34]



Flood and Landslide

The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of flood exposure.[35] As of 2010, assuming standards of protection up to a 1 in 25-year event, the population annually affected by riverine flooding in Georgia is estimated at 15,000 and the expected annual damages at $73 million. Socio-economic development and climate change are both expected to increase these figures. River flooding is also likely to increase sediment and affect dam management.

Georgia's population and economy are vulnerable to flooding and floods have occurred regularly in the past decades. In addition to episodes of flooding in 1995, 1997, 2004, 2005, 2011, 2012 and 2013, a particularly severe flood in Tbilisi in 2015 caused 19 fatalities and a combined $29 million in physical damage and financial losses.[36] More

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[33] Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., . . . Feyen, L. (2018). Global Changes in Drought Conditions Under Different Levels of Warming. Geophysical Research Letters, 45(7), 3285–3296. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL076521

[34] WBG Climate Change Knowledge Portal (CCKP 2020). Georgia. Water Sector Interactive Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=GEO&period=2080–2099

[35] WRI (2018) AQUEDUCT Gobal Flood Analyzer. Available at: https://floods.wri.org/# [Accessed: 22/11/2018]

[36] GFDRR (2015a). Tbilisi Disaster Needs Assessment 2015. URL: https://www.gfdrr.org/sites/default/files/publication/pda-2015-tbilisi.pdf [accessed 16/10/2018]

broadly, riverine and coastal floods with a 10-year return period can potentially affect 5% of Georgian GDP (and 10% of GDP in Tbilisi)[37] and floods are projected to continue creating an annual average loss to the economy of $45 million in future.[38] Flooding also has compounding effects in Georgia, via its impact on landslides and mudflows. The Georgian National Environmental Agency estimates that more than 70% of the country's territory lies in geological disaster risk zones[39] and there is potential for climate change to increase the hazard and exposure in these areas.[40] The model ensemble does not project significant increases in the average maximum 1-day precipitation level, nor are 10 and 25-year return levels of precipitation (over 1-day, 5-day or 1-month time horizons) projected to increase significantly. Nonetheless, recession of the country's glaciers is expected to lead to increased flooding in Georgia due to changes in the seasonality of flows and increases in peak flows.[14]

CLIMATE CHANGE IMPACTS

Natural Resources

Water

Georgia is rich in freshwater; however, these resources are unevenly distributed (heavily concentrated in western regions) and issues in the water supply system mean that people in rural areas rely on wells and boreholes for their water.[14] This increases their vulnerability to potential reductions in groundwater and drought periods. Rivers that are fed by glaciers and snow, such as the Khrami-Debed and Alazani, are projected to see reduced flow levels of between 30% and 55% by the end of the 21st century, posing a threat to an important source of water supply. This issue is projected to be more severe in spring and summer months and indeed will drive significant shifts in regional hydrological regimes. The negative impact of this reduction in river flow could be exacerbated by increases in average temperatures and heat wave probability, leading to higher agricultural demand for river-fed irrigation.[15] Over the short term, the ongoing glacial melt could lead to increases in runoff.[19]

Water-related climate change impacts may serve to aggravate political relations in the Caucasus region. This risk arises from the importance of water to both the agricultural and energy sectors in the countries of the region, increases in water demand due to higher temperatures in the region, and the presence of transboundary rivers such as the Alazani and Kura (Georgia and Azerbaijan) and the Debed (Georgia and Armenia). This is an area where policy development will be required; as of the end of 2020, no new water treaties have been developed between the countries.

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[37] GFDRR (2015b). GFDRR Europe and Central Asia Risk Profiles - Georgia. URL: https://www.gfdrr.org/sites/default/files/Georgia.pdf [accessed 16/10/2018]

[38] UNISDR (2015) Global Assessment Report on Disaster Risk Reduction 2015. URL: https://www.preventionweb.net/countries/geo/data/ [accessed 14/08/2018]

[39] Regional Environmental Centre for the Caucasus (2013). Views from the Frontline: Country Report: Georgia. URL: http://www.rec-caucasus.org/files/publications/pub_1393327902.pdf [accessed 12/10/2018]

[40] Stoffel, M. and Huggel, C. (2012). Effects of climate change on mass movements in mountain environments. Progress in Physical Geography, 36(3), pp. 421–439. URL: https://journals.sagepub.com/doi/abs/10.1177/0309133312441010

Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44–0.74 m by the end of the 21st century by the IPCC's Fifth Assessment Report[41] but some studies published more recently have highlighted the potential for more significant rises (**Table 5**).

Several medium-sized towns and cities are located along Georgia's Black Sea coastline, with the largest of these being Batumi in the south-west (with a population of approximately 153,000 in 2014). The level of the Black Sea rose by 0.7 m on the Georgian coast between 1956 and 2007, and the frequency of storms increased by more than 50% over the same period.[14] Coastal erosion and loss of coastline along the Black Sea has been of national concern, with mitigation efforts and investment aimed at reducing sea level rise impact for the country's coastal tourism.[42]

These changes are largely explained by pressure anomalies in atmospheric circulations, notably the North Atlantic Oscillation.[43] This sea-level rise threatens the port cities of Batumi and Poti, with the latter having experienced flooding caused by sea storms in recent years. An increased frequency of storms is also expected to have a negative effect on beach tourism along the Georgian coast.[4]

TABLE 5. Estimates of global mean sea-level rise by rate and total rise compared to 1986–2005 including likely range shown in brackets, data from Chapter 13 of the IPCC's Fifth Assessment Report with upper-end estimates based on higher levels of Antarctic ice-sheet loss from Le Bars et al. 2017.[44]

Scenario	Rate of Global Mean Sea-Level Rise in 2100	Global Mean Sea-Level Rise in 2100 Compared to 1986–2005
RCP2.6	4.4 mm/ yr (2.0–6.8)	0.44 m (0.28–0.61)
RCP4.5	6.1 mm/ yr (3.5–8.8)	0.53 m (0.36–0.71)
RCP6.0	7.4 mm/ yr (4.7–10.3)	0.55 m (0.38–0.73)
RCP8.5	11.2 mm/ yr (7.5–15.7)	0.74 m (0.52–0.98)
Estimate inclusive of high-end Antarctic ice-sheet loss		1.84 m (0.98–2.47)

Research by the UK Met Office (2014) projects that in the absence of adaptation measures, 29–33,000 people per year could experience flooding due to sea-level rise in Georgia by 2070–2100, with a similar number affected in less severe (RCP2.6) and more severe (RCP8.5) emissions pathways.[45] On the other hand, with proper adaptation it is estimated that almost none of these people would be exposed to flooding (**Table 6**).

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[41] Church, J. a., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., . . . Unnikrishnan, A. S. (2013). Sea level change. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1137–1216). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. URL: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

[42] Avsar, N. and Kutoglu, S. (2020). Recent Sea Level Change in the Black Sea form Satellite Altimetry and Tide Gauge Observations. International Journal of Geo-Information. 9(3), 185. DOI: https://doi.org/10.3390/ijgi9030185

[43] Tsimplis, M.N. and Josey, S.A. (2001). Forcing of the Mediterranean Sea by atmospheric oscillations over the North Atlantic. Geophysical Research Letters, 28(5), pp. 803–806. URL: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2000GL012098

[44] Le Bars, D., Drijhout, S., de Vries, H. (2017) A high-end sea level rise probabilistic projection including rapid Antarctic ice sheet mass loss. Environmental Research Letters: 12:4. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aa6512

[45] UK Met Office (2014). Human dynamics of climate change: Technical Report. Met Office, UK Government. URL: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/climate/human-dynamics-of-climate-change/hdcc_alternative_version.compressed.pdf

TABLE 6. The average number of people experiencing flooding per year in the coastal zone in the period 2070–2100 under different emissions pathways (assumed medium ice-melt scenario) and adaptation scenarios for Georgia.[42]

Scenario	Without Adaptation	With Adaptation
RCP2.6	29,310	20
RCP8.5	32,820	60

Land, Soil, and Biodiversity

Desertification as a result of both natural factors (e.g. increased temperatures and drought probability, strong winds) and economic factors (e.g. agricultural practices, irrigation, mining) is causing an expansion of semi-arid and arid areas in Georgia. This has reduced the quality of the soil, such as in the eastern Shiraki plain, where the humus content of black soil has fallen from 7.5% to 3.2% during the period 1983–2006.[14] The predicted increase in temperatures over coming decades is likely to compound the problem of desertification in Georgia.

Salinization is also an issue in the country, especially the eastern Kakheti region, where salinized soil constitutes 22% of the total area.[46] The increase in the probability of severe drought projected under all RCPs, which would have the greatest impact on eastern regions, could exacerbate the problem of soil salinization in Kakheti.[4] Disasters triggered by natural hazards have had a negative impact on soil quality. In the south-western region of Adjara, high levels of precipitation have hastened soil erosion and led to landslides and avalanches, resulting in a net reduction in agricultural land area of 7.4% between 1980 and 2010.[4] As land and soil go through climate change-driven transitions, ecotypes may shift in range or be lost. The implications of climate change for Georgia's rich ecosystems are generally poorly studied but the available evidence points to potentially significant reductions in habitats for many species.[47]

Forestry

Georgia has extensive forests, which cover approximately 39% of national territory and the country's forests display a rich biodiversity of over 800 different types of trees and bushes. Primary species include oriental beech (Fagus orientalis), oak (Quercus sp), Caucasian hornbeam (Carpinus caucasuca), alder (Alnus sp), birch (Betula sp), Caucasian fir (Abies nordmanniana), Oriental spruce (Picea orientalis), pine (Pinus sp.). Georgia's forests are important for soil and water protection and ecosystem services; however, projected climate impacts from increased temperatures, extreme rainfall events and changing precipitation patterns are resulting in new challenges for the sector. Increased temperature conditions are likely to particularly impact the distribution and growth of woody species. Additionally, forest ecosystem and the changes in current regimes of temperature and precipitation could also result in abiotic disorders from extreme events such as: fires, storms, floods, draughts; biotic disorders include changes in the frequency of activation of different pathogens and pests and geographic areas of their distribution. Forests on slopes, such as Borjomi and Bakuriani forests in central Georgia will be impacted by landslides. Increases in pests and diseases are expected.[48]

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[46] Regional Environmental Centre for the Caucasus. (2014). Second National Action Program to Combat Desertification. URL: http://www.rec-caucasus.org/files/publications/pub_1481807666.pdf [accessed 12/10/2018]

[47] Chaladze, G. (2012). Climate-based model of spatial pattern of the species richness of ants in Georgia. Journal of Insect Conservation, 16(5), pp. 791–800. URL: https://www.researchgate.net/publication/256088238_Climate-based_model_of_spatial_pattern_of_the_species_richness_of_ants_in_Georgia

[48] Ministry of Environment and Natural Resources Protection (2021). Fourth National Communication of Georgia under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4%20Final%20Report%20-%20English%202020%2030.03_0.pdf

Economic Sectors

Agriculture

Climate change is expected to impact food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation and temperatures. Indirect effects include through impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest profiles and the arrival of invasive species, as well as declines in arable areas due to the submergence of coastal lands. On an international level, these impacts are expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018) estimate 5% and 6% declines in global wheat and maize yields respectively even if the Paris Climate Agreement is met and warming is limited to 1.5°C.[49] Shifts in the optimal and viable spatial ranges of certain crops are also inevitable, though the extent and speed of those shifts remains dependent on the emissions pathway.

While the share of agriculture in overall employment in Georgia has fallen somewhat in the past decade, the sector still accounted for 41% of all jobs in 2017 and is especially important to employment in poorer and more rural parts of the country. Recent droughts (e.g. a severe event in 2000) caused wheat yields to drop by more than half.[15] Temperature rises in the coming decades, and particularly temperature extremes are expected to lead to lower crop yields in many parts of Georgia. An exception applies to higher altitude areas (such as in the east of the country) where warmer temperatures could extend the growing season and broaden the range of viable crops.[50] Subject to the availability of water resources, this may drive a relocation of production towards these mountainous regions, which could bring with it issues of deforestation and land degradation. Higher temperatures are also expected to hasten the spread of crop diseases, with the citrus sector at particular risk.[15]

Although Georgia has achieved a significant degree of self-sufficiency in many food groups, the country remains heavily dependent on imports for staple cereals, with 80%–90% of wheat consumed in Georgia imported.[51] The level of productivity in the Georgian agriculture sector is low in comparison with its neighbors in the Caucasus and other developing countries.[48] Although the Georgia government has made agricultural development a priority in recent years, the negative effects of climate change on crop yields could make it more difficult to improve agricultural productivity. Projected decreases in river flow during summer months may also affect irrigated agriculture, including along the Khrami-Debeda and Alazani rivers, where the main use of water is for irrigation.[14] In these contexts, pressure on agricultural infrastructure and its effective management will grow. A further, and perhaps lesser appreciated influence of climate change on agricultural production is through its impact on the health and productivity of the labor force. Work by Dunne et al. (2013) suggests that labor productivity during peak months has already dropped by 10% as a result of warming, and that a decline of up to 20% might be expected by the 2050s under the highest emissions pathway (RCP8.5).[52] In combination, it is highly likely that the above processes will have a considerable impact on national food consumption patterns both through direct impacts on internal agricultural operations, and through impacts on the global supply chain.

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[49] Tebaldi, C., & Lobell, D. (2018). Differences, or lack thereof, in wheat and maize yields under three low-warming scenarios. Environmental Research Letters: 13: 065001. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aaba48/meta

[50] Cola, G., Failla, O., Maghradze, D., Megrelidze, L. and Mariani, L., 2017. Grapevine phenology and climate change in Georgia. International Journal of Biometeorology, 61(4), pp. 761–773. URL: https://pubag.nal.usda.gov/catalog/5754446

[51] Oxfam (2017). Research on the Status of Food Security and Nutrition. URL: http://www.bridge.org.ge/en/publications/research/2017-09-12-research-on-the-status-of-food [accessed 11/10/2018]

[52] Dunne, J. P., Stouffer, R. J., & John, J. G. (2013). Reductions in labor capacity from heat stress under climate warming. Nature Climate Change, 3(6), 563–566. URL: http://www.precaution.org/lib/noaa_reductions_in_labour_capacity_2013.pdf

Increasing temperatures are likely to increase and prolong the presence of pests and diseases, as well as bring the potential to introduce new pathogens. For key agricultural production zones for staple foods such as potatoes and wheat, improved resistance to pests and diseases is necessary due to the projected increase in water and humidity; improvements to storage facilities and practices should also be improved.[53] Over the longer-term future, sustained temperature increases, and particularly daily, monthly and annual maximum temperatures are likely to drive a shift in the optimal growing ranges of current crops. However, the increase in other stressors may offset these gains. Specifically the risk that an increase in the frequency of very hot days (>35°C) (**Figure 10**) and potential water resource limitations may damage yields, as has been suggested at the global level.[54] There is, however, significant differences between emissions pathways, with higher emissions scenarios resulting in notably larger increases in daily maximum temperatures (**Figure 11**).

FIGURE 10. Increase in the annual average number of very hot days (>35°C) in Georgia under two emissions pathways. RCP2.6 (Blue) and RCP8.5 (Red)

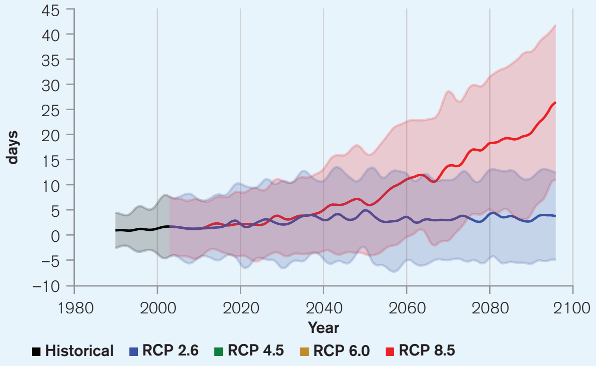
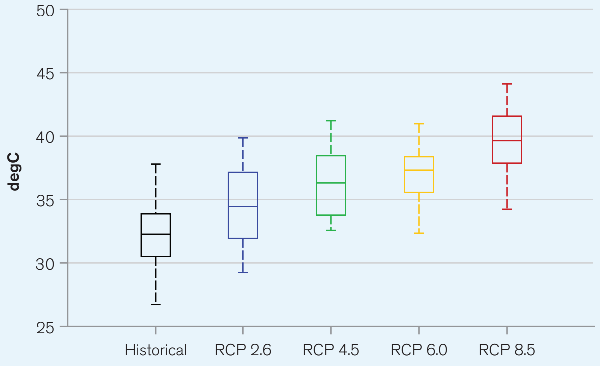


FIGURE 11. Average daily maximum temperature in Georgia under four emissions pathways over the period 2080–2099.



Urban and Energy

Research has established a reasonably well constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[55] In general terms, the impact of an increase in temperature on these indicators depends on whether the temperature rise moves the ambient temperature closer to, or further away from, the optimum temperature range. The optimum range can vary depending on local conditions and adaptations.

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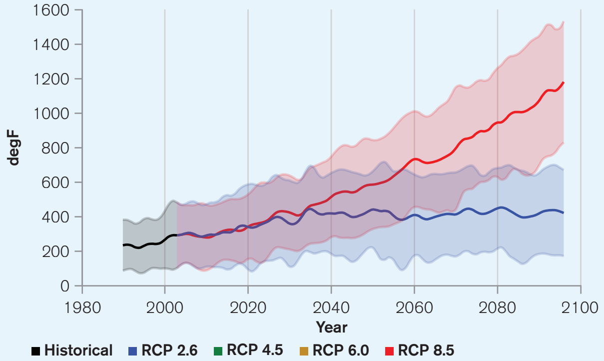
[53] Ministry of Environment and Natural Resources Protection (2021). Fourth National Communication of Georgia under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4%20Final%20Report%20-%20English%202020%2030.03_0.pdf

[54] Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D., [. . .] Wisser, D. (2014). Constraints and potentials of future irrigation water availability on agricultural production under climate change. Proceedings of the National Academy of Sciences: 111: 3239–3244. URL: https://www.pnas.org/content/111/9/3239

[55] Mani, M., Bandyopadhyay, S., Chonabayashi, S., Markandya, A., Mosier, T. (2018) South Asia's Hotspots: The Impact of Temperature and Precipitation changes on living standards. South Asian Development Matters. World Bank, Washington DC. URL: http://documents.worldbank.org/curated/en/201031531468051189/pdf/128323-PUB-PUBLIC-DOC-DATE-7-9-18.pdf

The effects of temperature rise and heat stress in urban areas are compounded by the phenomenon of the Urban Heat Island (UHI) effect. Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1–3°C in global mega-cities. Urban Heat Island effects have already been shown to amplify the effects of heatwaves in Tbilisi.[56] As well as impacting on human health (see Communities) the temperature peaks that could result from combined UHI and climate change, combined with future urban expansion, are likely to damage the productivity of the service sector economy, both through direct impacts on labor productivity, but also through the additional costs of adaptation. The model ensemble projects that, in the high emissions RCP8.5 scenario, the number of days per year on which cooling is required could increase significantly in Georgia by the latter decades of the 21st century (**Figure 12**). However, concurrently, the number of days during which heating is required may reduce considerably, likely resulting in a net reduction in the long-term burden on Georgia's energy supply.

FIGURE 12. Historic and projected annual cooling degree days in Georgia (cumulative degrees above 65°F) under RCP2.6 (Blue) and RCP8.5 (Red). The values shown represent the median of 30+ GCM model ensemble with the shaded areas showing the 10–90th percentiles[25]



A precautionary approach is nevertheless important. Research suggests that at higher temperatures a one degree increase in ambient temperature can result in a 0.5–8.5% increase in electricity demand.[57] Notably this serves business and residential air-cooling systems. This increase in demand during extreme climate events places strain on energy generation systems which can be compounded by the heat stress on the energy generation system itself, commonly due to its own cooling requirements, which can reduce its efficiency.

Other aspects of climate change could further exacerbate energy supply issues. Georgia's domestic electricity generation is heavily reliant on hydropower, which accounted for 78% of electricity generated in the country in 2015. River flows are expected to fall in the future during the summer months,[14] which would reduce potential power generation during the months of peak demand for air conditioning. At times of low generation from hydropower, imports of electricity could increase, with negative effects on Georgia's GDP and balance of payments. Additional risks may arise if climate changes increase the risk of landslides as these have been known to take place in the vicinity of key energy infrastructure.[58] Given the country's relatively modest industrial capacity, Georgia has focused

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[56] Keggenhoff, I., Elizbarashvili, M. and King, L. (2015). Heat wave events over Georgia since 1961: Climatology, changes and severity. Climate, 3(2), pp. 308–328. URL: https://www.mdpi.com/2225-1154/3/2/308/htm

[57] Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2015). On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. Energy and Buildings, 98, 119–124. URL: https://www.semanticscholar.org/paper/On-the-impact-of-urban-heat-island-and-global-on-of-Santamourisa-Cartalisb/17f86e9c161542a7a5acd0ad500f5da9f45a2871

[58] Tibaldi, A., Oppizzi, P., Gierke, J., Oommen, T., Tsereteli, N. and Gogoladze, Z. (2019). Landslides near Enguri dam (Caucasus, Georgia) and possible seismotectonic effects. Natural Hazards and Earth System Sciences, 19(1), pp. 71–91. URL: https://www.nat-hazards-earth-syst-sci.net/19/71/2019/nhess-19-71-2019.pdf

its climate change contributions for the energy sector into mitigation efforts such as increasing share of hydropower generation, increasing solar and wind generation in its energy mix, and beginning to embed energy efficiency into construction regulations and retrofitting public buildings. In order to meet recognized growing demand in the face of projected impacts from climate change to the country's power sector, Georgia has begun development of its long-term low-emission development strategy in order to support sustainable energy action plans.[59]

Tourism

The tourism sector in Georgia, is one of the country's fastest growing and most important economic sectors, contributing 23% to GDP. Climate change impacts are expected to hit Georgia's tourism sector particularly hard in both mountain regions and along the country's coastline and beaches of the Black Sea. Higher temperatures and declining snowpack will shorten winter seasons and affect major alpine resorts such as Bakuriani and Gudauri. Popular hiking and trekking destinations in the Upper Svaneti will more frequently experience avalanches due to intense rainfall, while Adjara, a popular beach destination, suffers from mudslides and landslides that disrupt transport and other service. Increase of sea surface temperature (as well as daily temperatures >30°C) has already resulted in a mass destruction of mollusks and other species inhabitants along the coastal strip, which has significantly impacted the diving attractions. Additional reports have also shown that the overheating of water recently caused dissatisfaction of tourists in Adjara coastal zone. An increased frequency of severe storms along the coastal zones are likely to further washout beaches and flood banks along the seashore. An increased risk of flash floods and mudflows in coastal zone, as a result of abundance of rainfall in summer, is especially dangerous for tourism sites located in mountain zone or settled along the riverbanks.[60]

Communities

Poverty and Inequality

Georgia's population has been vulnerable to the effects of regular flooding in recent years. Between 1995 and 2012, there were 202 recorded flooding and flash flooding events, which resulted in the deaths of 38 people.[36] The economic impact of flooding is also significant: in the capital, Tbilisi, floods affect 4% of GDP in an average year and flooding with a 10-year return period typically causes damage worth 10% of GDP.[34] Earthquakes, though relatively less frequent, pose a similar threat to Georgia's population and economy. A magnitude 7 earthquake in 1991, the worst such occurrence during the 20th century in Georgia, killed over 250 people and caused approximately $3 billion in damage, equivalent to nearly 50% of Georgia's GDP at the time.[34] Geological disasters, such as landslides and mudflows, affect more than 70% of the area of the country. The highest risk of landslides is in the north-west (Abkhazia), south-west (Adjara) and central (Imereti) regions, while the parts of the country most vulnerable to mudflows are the northern border with Russia and the central-eastern area north of Tbilisi.[36] Many of these risk zones are mountainous areas, meaning limited road access can complicate relief efforts following geological disaster events. Further work is required to understand and map potential increases in landslide exposure as a result of climate change, and its impact on precipitation extremes in particular.

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[59] NDC Partnership (2021). Georgia's leadership of LEDS. LEDS Global Partnership. URL: https://ledsgp.org/regions/georgia/?loclang=en_gb

[60] Ministry of Environment and Natural Resources Protection (2021). Fourth National Communication of Georgia under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4%20Final%20Report%20-%20English%202020%2030.03_0.pdf

Recent economic growth in Georgia has not always reached poorer residents. The World Bank Group found that although the economy grew by 5% per year on average during the 2000s, the income per person of the lowest 40% of Georgians fell by 1% per year.[61] Many of the climate changes projected are likely to disproportionately affect the poorest groups in society, who are more dependent on the economic sectors that are expected to be most affected. Rural communities in Georgia rely on agriculture as their main source of income, with 45% of income on average coming from this source in 2011 (compared with 28% from social grants and pensions and 27% from salaried work). Subsistence agriculture also makes up 73% of employment in rural areas.[58] Higher temperatures and the associated lower crop yields could lead to lower incomes in rural areas, which in turn would worsen inequality at the national level and drive further outward migration from these areas.

Climate change in Georgia is also likely to affect regional disparities in living standards. Research covering the period 2013–2016[62] found a higher prevalence of undernourishment among communities in mountainous areas of Georgia (9–13%), relative to the national average (7.4%). Households in mountainous areas were also found to spend a higher proportion of their income on food and were reliant on purchases of food from other parts of the country for most food groups. Temperature increases due to climate change may have a positive impact on incomes and food security in mountainous areas, allowing a broader range of crops to be grown and lengthening the growing season. This is expected to lead to higher yields in crops such as corn, tomatoes and wheat in mountainous areas of eastern Georgia.[15] Additionally, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[63] Poorer businesses are least able to afford air conditioning - an increasing need given the projected increase in cooling days. Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation.

Gender

An increasing body of research has shown that climate-related disasters have impacted human populations in many areas including agricultural production, food security, water management and public health. The level of impacts and coping strategies of populations depends heavily on their socio-economic status, socio-cultural norms, access to resources, poverty as well as gender. Research has also provided more evidence that the effects are not gender neutral, as women and children are among the highest risk groups. Key factors that account for the differences between women's and men's vulnerability to climate change risks include: gender-based differences in time use; access to assets and credit, treatment by formal institutions, which can constrain women's opportunities, limited access to policy discussions and decision making, and a lack of sex-disaggregated data for policy change.[64]

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[61] World Bank Group (2014). Project Information Document: Irrigation and Land Market Development Project. Available at: http://documents.worldbank.org/curated/en/852611468274176891/pdf/PID-Appraisal-Print-P133828-02-11-2014-1392133352923.pdf [accessed 12/10/2018]

[62] Oxfam (2016). Food Security and Nutrition Challenges in the High Mountains of Georgia. URL: http://www.bridge.org.ge/en/publications/research/2017-09-11-food-security-and-nutrition-challenges [accessed 11/10/2018]

[63] Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., Hyatt, O. (2016) Heat, human performance, and occupational health: A key issue for the assessment of global climate change impacts. Annual Review of Public Health: 37: 97–112. URL: https://www.ncbi.nlm.nih.gov/pubmed/26989826

[64] World Bank Group (2016). Gender Equality, Poverty Reduction, and Inclusive Growth. URL: http://documents1.worldbank.org/curated/en/820851467992505410/pdf/102114-REVISED-PUBLIC-WBG-Gender-Strategy.pdf

Human Health

Nutrition

The World Food Program estimate that without adaptation the risk of hunger and child malnutrition on a global scale could increase by 20% respectively by 2050.[65] Work by Springmann et al. (2016) has assessed the potential for excess, climate-related deaths associated with malnutrition.[66] The authors identify two key risk factors that are expected to be the primary drivers: a lack of fruit and vegetables in diets, and health complications caused by increasing prevalence of people underweight. The authors' projections suggest there could be approximately 32.36 climate-related deaths per million population linked to lack of food availability in Georgia by the 2050s, under RCP8.5.

The prevalence of undernourishment in Georgia has fallen sharply in the past three decades, from 56.5% of the population in 1990 to 7.4% in 2014.[6] Now the main nutritional issue facing the Georgian population is malnourishment, rather than undernourishment.[48] A 2015 survey found that poorer households had a lack of meat and fruit in their diets due to affordability concerns.[67] Food expenditure made up 65% of all monthly expenditure for Georgians in the lowest third of the income distribution, compared with 35% of monthly expenditure for those in the top third of the income distribution, and 60% of Georgian households reported buying some of their food on credit.[63] These findings suggest that food consumption among poorer Georgians could be strongly affected by volatility in their incomes.

Heat-Related Mortality

Research has placed a threshold of 35°C (wet bulb ambient air temperature) on the human body's ability to regulate temperature, beyond which even a very short period of exposure can present risk of serious ill-health and death.[68] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change will push global temperatures closer to this temperature 'danger zone' both through slow onset warming and intensified heat waves.

Honda et al. (2014), utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0) to estimate that without adaptation, annual heat-related deaths in the Central Asian region, could increase 139% by 2030 and 301% by 2050.[69] The potential reduction in heat-related deaths achievable by pursuing lower emissions

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[65] WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Program. URL: https://docs.wfp.org/api/documents/WFP-0000009143/download/

[66] Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., . . . Scarborough, P. (2016). Global and regional health effects of future food production under climate change: a modelling study. The Lancet: 387: 1937–1946. URL: https://www.ncbi.nlm.nih.gov/pubmed/26947322

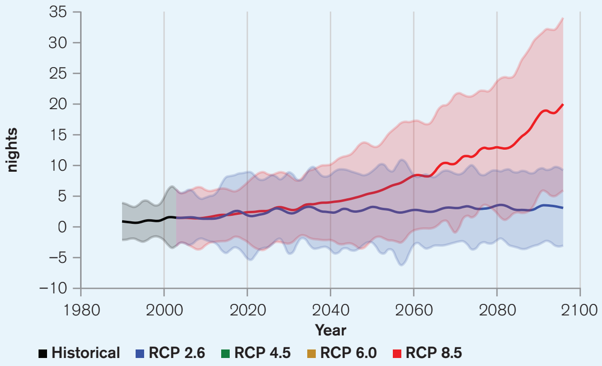
[67] Manjavidze, T. (2015). National Nutrition Research in Georgia. URL: http://www.bridge.org.ge/en/publications/research/2017-09-11-national-nutrition-research-in-georgia [accessed 11/10/2018]

[68] Im, E. S., Pal, J. S., & Eltahir, E. A. B. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Science Advances, 3(8), 1–8. URL: https://advances.sciencemag.org/content/3/8/e1603322

[69] Honda, Y., Kondo, M., McGregor, G., Kim, H., Guo, Y-L, Hijioka, Y., Yoshikawa, M., Oka, K., Takano, S., Hales, S., Sari Kovats, R. (2014). Heat-related mortality risk model for climate change impact projection. Environmental Health and Preventive Medicine 19: 56–63. URL: https://www.ncbi.nlm.nih.gov/pubmed/23928946

pathways is significant, as demonstrated by Mitchell et al. (2018).[70] However, Georgia is expected to have significant adverse health effects caused by increasing incidence of high temperatures and more intense heat waves. Heat wave effects are anticipated to be more severe in highly populated urban areas and are likely to significantly affect the country's vulnerable populations. Keggenhoff et al. (2015) found that increases in the occurrence, intensity and duration of heat waves from 1961 to 2010 were more pronounced in Tbilisi than in the rest of Georgia, which they attributed to an urban heat island effect.[53] Relatively more severe heat waves, a relatively higher population density and an ageing population will thus put the capital at a higher risk of heat-related mortality in future decades. **Figure 13** shows the change in night temperatures (above 20°C) are also increasing for Georgia, resulting in decreased opportunity for natural cooling. Increased health threats can be projected and monitored through the frequency of tropical nights. Tropical Nights represents the projected increase in tropical nights for different emission scenarios to demonstrate the difference in expected numbers of tropical nights.

FIGURE 13. The historical and projected number of Tropical Nights (Tmin >20°C) through the end of the century



Disease

For Georgia, the annual distribution of days with a high heat index provides insight into the health hazard of heat. While high temperature alone can be compensated for by evaporative cooling from perspiration, if the air is nearly saturated with moisture (humidity), then cooling potential is reduced and apparent temperature increases. Climate change could also affect the health of the Georgian population, in particular those who suffer from cardiovascular and respiratory diseases. These conditions are already on the increase in the country, with cases of cardiovascular disease having more than doubled from 2000 to 2011 and incidence of respiratory diseases increasing fourfold over the same period.[14] These conditions are expected to be exacerbated by the increased frequency of extremely high temperatures and heatwaves.[15] Higher temperatures are also projected to drive a higher incidence of vector- and water-borne diseases such as malaria.[15]

Increases in flooding, which may occur as a result of glacial melting or more intense rainfall, could also have detrimental effects on human health in Georgia. Flooding in Adjara in the south-west has been associated with outbreaks of malaria[36] and increased incidence of diarrheal diseases.[15] Furthermore, flood-related damage to the water supply system has the potential to hasten the spread of infectious diseases in the aftermath of such natural disasters.[14]

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[70] Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://www.ncbi.nlm.nih.gov/pubmed/30319715

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 7. Key national adaptation policies, strategies, and plans

Policy/Strategy/Plan	Status	Document Access
Climate Change National Adaptation Plan (NAP) for Georgia's Agriculture Sector	Enacted	2017
Nationally Determined Contribution (NDC) to Paris Climate Agreement	Submitted	May, 2017
National Disaster Risk Reduction Strategy 2017–2020	Enacted	January, 2017
National Communications to the UNFCCC	Four submitted	Latest: April, 2021
Technology Needs Assessment (TNA)	Completed	September, 2012
Climate Change National Adaptation Plan for Georgia's Agriculture Sector	Enacted	2017

Climate Change Priorities of ADB and the WBG

ADB Country Partnership Strategy

Georgia's 2019–2023 Country Partnership Strategy (CPS) with ADB seeks to expand trade, create more jobs, and combat poverty through development of economic corridors. . Climate change is a cross-cutting theme across its four focus areas but is highlighted in the third focus area of "Urban development around and along the way". Under this priority, ADB will support the integrated development of resilient urban area clusters with proximities to transport networks, turning transport corridors into economic corridors. Development of these clusters will be based on a solid understanding of climate change and disaster risk to support inclusive growth and local economic development.

Generally, ADB's support for infrastructure development in Georgia will also promote improvements in climate change and disaster resilience. As part of investment operations for infrastructure development, ABD will help Georgia meet its NDC commitments to (i) reduce its annual greenhouse gas emissions in 2030 by up to 25% compared with business as usual, particularly in the sectors of agriculture, energy, trade and industry, and forestry; and (ii) strengthen the resilience of infrastructure and agriculture to climate change and disaster impacts. Opportunities for the preservation of water resources in connection with hydropower, agriculture, and drinking water will be explored as well.

WBG Country Partnership Framework

The WBG and Georgia established the 2019–2022 Country Partnership Framework (CPF). Climate change is a cross-cutting theme cited throughout the CPF. In particular, ongoing and planned operations that address natural resource management aim to build resilience to climate shocks, decouple economic growth and carbon emissions, and improve the sustainability of the country's natural resources. Infrastructure activities are designed to promote both climate change adaptation and mitigation.

CLIMATE RISK COUNTRY PROFILE

GEORGIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK