CLIMATE RISK COUNTRY PROFILE

TURKMENISTAN

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).

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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.

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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 are projected to rise by 5.1°C in Turkmenistan by the 2090s, relative to the 1986–2005 baseline under the highest emissions pathway (RCP8.5), with the pace of warming significantly exceeding the global average.
- There is a significant 3.3°C difference between the temperature rise projected by the 2090s under the highest emissions pathway (RCP8.5) and the rise expected under the lowest emissions pathway (RCP2.6), indicating the benefit of controlling global emissions.
- Daily maximum and minimum temperatures are expected to warm slightly faster than average temperatures, a trend which may amplify impacts on human health, livelihoods, and ecosystems.
- The annual probability of experiencing a severe drought is projected to increase very significantly over the 21st century. Indeed, under higher emissions pathways the majority of Turkmenistan's surface is projected to convert to 'hyper-arid' land cover.
- Increased temperatures and more rapid melting of glaciers elsewhere in the region may lead to severe water shortages along Turkmenistan's most important river, the Amu Darya, by the 2040s and 2050s.
- Temperature rises, increases in drought frequency and water shortages that are projected to occur in Turkmenistan are expected to reduce the yields of the country's major crops. Without adaptation significant falls in agricultural revenue, and food shortages, may result.
- Barriers to adaptation and elevated hazard exposure mean Turkmenistan's lower income group communities are likely to be disproportionately impacted by climate changes. Further research and analysis are urgently required to better understand the poverty and inequality outlook under increased temperatures.

COUNTRY OVERVIEW

Turkmenistan is in the southwestern part of Central Asia, covering an area of 488,100 kilometers square (km^2). The country is bordered to the north by Uzbekistan and Kazakhstan, to the southeast by Afghanistan and to the south by Iran, with the 1,748 km Caspian Sea coastline forming a natural boundary to its west. Turkmenistan's climate is extremely dry and a large proportion of the territory is desert. Consequently, the country has a very low population density of just 12.5 people per square kilometer (and total population of 5.9 million in 2019) (**Table 1**).[1]

Turkmenistan's economy has seen a very high rate of growth, with GDP increasing by 12.3% on average between 1998 and 2016[2] due to a significant expansion in the export of natural gas, oil and related products, which accounted for the bulk of its exports over this period.[2] Although the economy remains dependent on hydrocarbons, cotton is the country's next most important export, accounting for the bulk of textile exports, which in turn constituted 6.2% of all exports in 2017.[3] The nation has a similar position on the Human Development Index to its Central

[1] WBG (2021). World Development Indicators. [accessed 5 February, 2021]. URL: https://databank.worldbank.org/source/world-development-indicators
[2] ADB. (2017). *Country Partnership Strategy*. Available at: https://www.adb.org/documents/turkmenistan-country-partnership-strategy-2017-2021 [accessed 13/11/18]
[3] OEC. (2019). Turkmenistan (TKM) Exports, Imports and Trade Partners. Available at: https://atlas.media.mit.edu/en/profile/country/uzb/ [accessed 08/03/2019]

Asian neighbors, ranked 108th. However, inequality in income and opportunity are believed to be higher than most countries with a comparable rank.[4] These social issues, combined with the climate extremes experienced, mean that Turkmenistan has significant vulnerability to climate change.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[5]	4.0% (2017–2019)	FAO, 2020
Proportion of Employed Population Living Below $1.90 PPP a Day[6]	7.6% (2019)	ADB, 2020
Share of Income Held by Bottom 20%[7]	unknown	World Bank, 2019
Net Annual Migration Rate[8]	–0.09% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[9]	4.3% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[10]	2.46% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[11]	55 (2020)	UNDESA, 2019
Urban Population as % of Total Population[12]	52.5% (2020)	CIA, 2020
External Debt Ratio to GNI[13]	2.3% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP[14]	13.3% (2019)	ADB, 2020b

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.

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4 UNDP (2018). Human Development Indices and Indicators: 2018 Statistical Update: Turkmenistan. United Nations Development Programme. URL: http://hdr.undp.org/en/content/human-development-indices-indicators-2018-statistical-update

5 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/

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

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

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

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

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

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

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

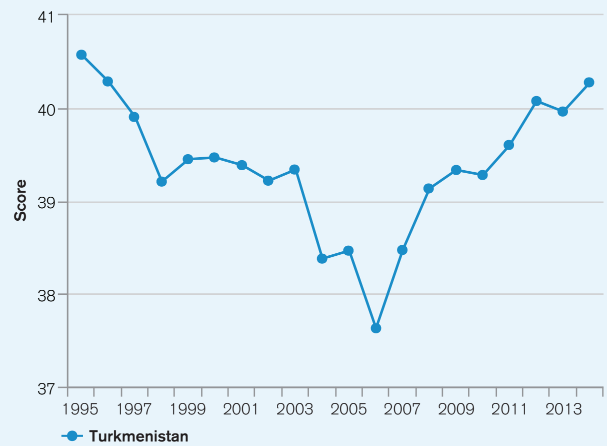
13 ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020

14 ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020

This document aims to succinctly summarize the climate risks faced by Turkmenistan. This includes rapid onset 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 Turkmenistan, therefore potentially excluding some international influences and localized impacts. The core data presented is sourced from the database sitting behind the World Bank Group's Climate Change Knowledge Portal (CCKP), incorporating climate projections from the Coupled Model Inter-comparison Project Phase 5 (CMIP5). This document is primarily meant for WBG and ADB staff to inform their climate actions. The document also aims and to direct the reader to many useful sources of secondary data and research.

Due to a combination of political, geographic, and social factors, Turkmenistan is recognized as vulnerable to climate change impacts, ranked 124th out of 181 countries in the 2020 ND-GAIN Index due.[15] 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. The higher the score, the higher the rank. Norway has the highest score and is ranked 1st. **Figure 1** is a time-series plot of the ND-GAIN Index showing Turkmenistan's progress.

FIGURE 1. The ND-GAIN Index score (out of 100) 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



CLIMATOLOGY

Climate Baseline

Overview

Turkmenistan's area falls under the cold desert and cold semi-arid climate classifications, with the Karakum desert being the dominant feature of its topography. Its continental location means that summers are hot, dry and long, with average temperatures of 27°–29°C between June and August (**Figure 2**) and maximum temperatures

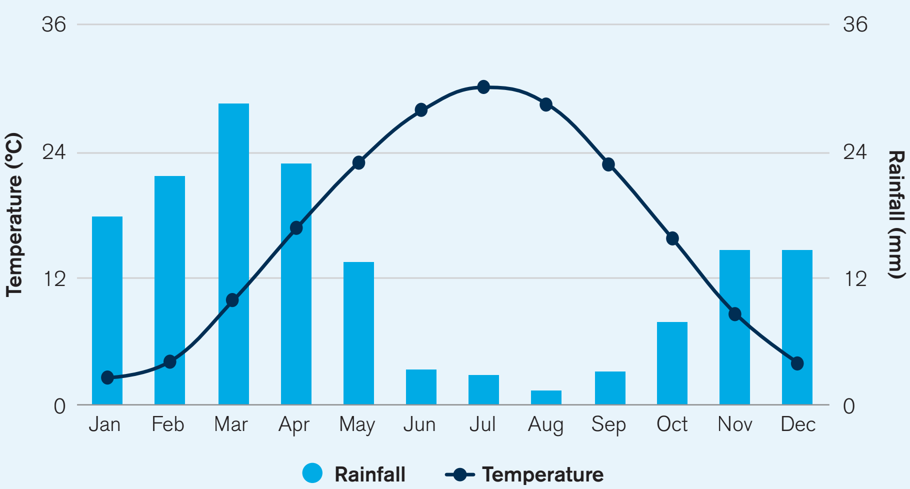
[15] University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

occasionally approaching 50°C in the hottest parts of the country.[16] While overall annual precipitation levels are low throughout Turkmenistan, there is a consistent seasonal trend. The bulk of the rain each year falls in the four months from January to April, whereas many parts of the country receive little or no rain during the months from June to September. The country's predominantly flat terrain allows for regular and strong winds which are favorable for the generation of dust storms.

Northern areas of Turkmenistan experience longer, colder winters and more snow, as well as shorter, relatively milder summer weather. On the other hand, southern regions experience milder winters, with average temperatures well above freezing point, and hotter summers. Areas on the Caspian Sea coast receive slightly milder summer temperatures than the interior.[17] Precipitation levels vary somewhat by region, although they are generally very low. The exception is in mountainous areas of the country, such as the Kopet Dag range on the southern border with Iran, where precipitation is higher (albeit still in the range of 300–400mm per year) and more constant throughout the year.[17] **Figure 3** shows observed spatial variation for temperature and precipitation across Turkmenistan.

Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Turkmenistan, 1991–2020[18]



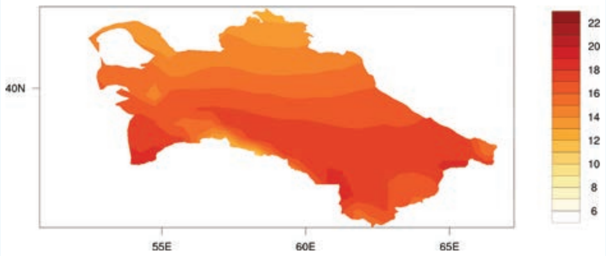
[16] Novikov, V. & Kelly, C. (2017). *Climate Change and Security in Central Asia*. Geneva: ENVSEC. URL: https://www.osce.org/files/f/documents/b/7/355471.pdf

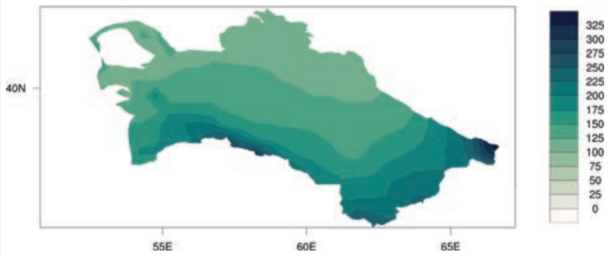
[17] Ministry of Nature Protection of Turkmenistan. (2016). *Third National Communication of Turkmenistan under the UN Framework Convention on Climate Change*. Ashgabat: Ministry of Nature Protection of Turkmenistan. URL: https://unfccc.int/sites/default/files/resource/Tkmnc3.pdf

[18] WBG Climate Change Knowledge Portal (CCKP, 2020). Climate Data: Projections. URL: https://climateknowledgeportalworldbank.org/country/turkmenistan/climate-data-projections

Spatial Variation

FIGURE 3. Annual Mean Temperature (°C) (left), and Annual Mean Rainfall (mm) (right) in Turkmenistan over the period 1991–2019





Key Trends

Temperature

A warming trend has been observed in all regions of Turkmenistan in recent decades. The average temperature across the country rose by approximately 2°C between 1950 and 2010, equivalent to warming of approximately 0.3°C per decade.[19] The extent of this warming was subject to considerable regional variation, however. In general, warming has been more pronounced in central and eastern areas of the country, and temperature rises have been slightly less on the Caspian Sea coast. The rise in average temperature between 1950 and 2010 ranged from 1.1°C in Birata in the centre of the northern border, to 1.45°C in Balkanabat in the west, 2.05°C in Bayramali in the southeast, and 2.4°C in Kerki in the far east. Daily fluctuations in temperature have also increased in Turkmenistan in recent years, and temperature extremes have risen sharply, particularly daily minimum temperatures.[20,21]

[19] Ministry of Nature Protection of Turkmenistan. (2016). *Third National Communication of Turkmenistan under the UN Framework Convention on Climate Change*. Ashgabat: Ministry of Nature Protection of Turkmenistan. URL: https://unfccc.int/sites/default/files/resource/Tkmnc3.pdf

[20] Government of Turkmenistan. (2012). *National Climate Change Strategy of Turkmenistan*. Available at: http://www4.unfccc.int/nap/Documents%20NAP/Turkmenistan's%20National%20Climate%20Change%20Strategy.pdf [accessed 08/03/2019]

[21] Feng, R., Yu, R., Zheng, H. and Gan, M. (2018). Spatial and temporal variations in extreme temperature in Central Asia. *International Journal of Climatology*, *38*, pp.e388–e400. DOI: https://doi.org/10.1002/joc.5379

Precipitation

Historical changes in levels of precipitation for Turkmenistan are far less clear than for temperature.[22] Average annual precipitation in the country has risen slightly during the period 1901–2015, albeit without a statistically significant increase.[23,24] However, as a result of other climatic shifts, notably evapotranspiration trends, drought indices have increased in Turkmenistan.[25] Inter-annual variability in precipitation is also influenced by El Niño Southern Oscillation (ENSO).[26]

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.[27] 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 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.

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. In subsequent analysis RCP2.6 and RCP8.5, the extremes of low and high emissions pathways, are the primary focus. RCP2.6 assumes rapid and systemic global action, achieving emissions reduction throughout the 21st century enough to reach net zero global emissions by around 2080. RCP8.5 assumes annual global emissions will continue to increase throughout the 21st century. Climate changes under each emissions pathway are presented against a reference period of 1986–2005 for all indicators.

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22 Xenarios, S. et al. (2018). Climate change and adaptation of mountain societies in Central Asia: uncertainties, knowledge gaps, and data constraints. Regional Environmental Change. URL: https://link.springer.com/article/10.1007%2Fs10113-018-1384-9

23 Ministry of Nature Protection of Turkmenistan. (2016). *Third National Communication of Turkmenistan under the UN Framework Convention on Climate Change*. Ashgabat: Ministry of Nature Protection of Turkmenistan. URL: https://unfccc.int/sites/default/files/resource/Tkmnc3.pdf

24 Reyer, C. et al. (2017). Climate change impacts in Central Asia and their implications for development. Regional Environmental Change. 17:1639 – 1650. URL: https://link.springer.com/article/10.1007/s10113-015-0893-z

25 Hu, Z., Chen, X., Chen, D., Li, J., Wang, S., Zhou, Q., Yin, G. and Guo, M. (2019). "Dry gets drier, wet gets wetter": A case study over the arid regions of central Asia. International Journal of Climatology, 39(2), pp.1072–1091. URL: https://www.deepdyve.com/lp/wiley/dry-gets-drier-wet-gets-wetter-a-case-study-over-the-arid-regions-of-qR4noywkEp

26 Gerlitz, L., Steirou, E., Schneider, C., Moron, V., Vorogushyn, S. and Merz, B. (2019). Variability of the cold season climate in Central Asia–Part II: Hydro-climatic Predictability. Journal of Climate, (2019). URL: https://journals.ametsoc.org/view/journals/clim/31/18/jcli-d-17-0715.1.xml

27 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, 11, 830–835. URL: https://www.nature.com/articles/s41561-018-0227-0?WT.feed_name=subjects_climate-sciences

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Turkmenistan for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table shows the median of the CCKP model ensemble and the 10th–90th percentiles in brackets.[28]

Scenario	Average Daily Maximum Temperature		Average Daily Temperature		Average Daily Minimum Temperature	
	2040–2059	2080–2099	2040–2059	2080–2099	2040–2059	2080–2099
RCP2.6	1.4 (–0.6, 4.1)	1.4 (–0.6, 3.6)	1.4 (–0.2, 3.5)	1.3 (–0.3, 3.3)	1.4 (–0.4, 3.3)	1.2 (–0.5, 3.2)
RCP4.5	1.9 (–0.1, 4.1)	2.6 (0.6, 5.0)	1.8 (0.1, 3.7)	2.4 (0.7, 4.7)	1.8 (–0.1, 3.7)	2.4 (0.3, 4.6)
RCP6.0	1.7 (0.1, 3.9)	3.3 (1.2, 5.7)	1.6 (0.0, 3.5)	3.1 (1.4, 5.2)	1.5 (0.3, 3.4)	3.0 (1.0, 5.1)
RCP8.5	2.4 (0.3, 4.8)	5.2 (3.0, 7.7)	2.4 (0.6, 4.5)	5.1 (3.2, 7.3)	2.4 (0.5, 4.4)	5.1 (3.0, 7.3)

TABLE 3. Projections of average temperature anomaly (°C) in Turkmenistan 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.[28]

Scenario	2040–2059		2080–2099	
	Jun–Aug	Dec–Feb	Jun–Aug	Dec–Feb
RCP2.6	1.6 (0.2, 3.7)	1.4 (0.3, 4.0)	1.5 (0.5, 3.5)	1.3 (0.4, 3.7)
RCP4.5	2.1 (0.2, 4.3)	1.6 (0.2, 3.8)	2.9 (0.9, 5.4)	2.3 (0.6, 4.6)
RCP6.0	1.8 (0.0, 3.6)	1.7 (0.2, 4.0)	4.0 (1.6, 5.7)	3.6 (1.2, 5.3)
RCP8.5	2.8 (0.9, 5.0)	2.0 (0.0, 4.2)	5.9 (3.8, 8.6)	4.4 (2.5, 6.7)

Model Ensemble

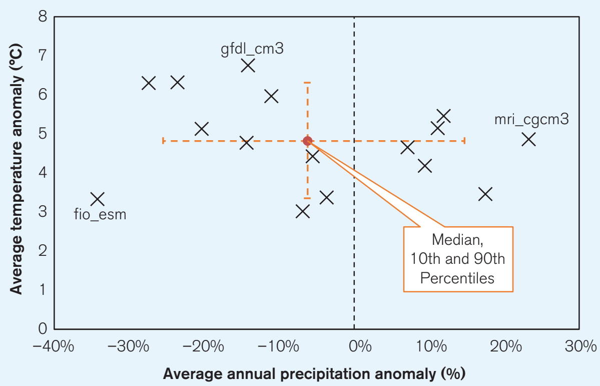
Climate projections presented in this document are derived from datasets available through the CCKP, unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) (for further information see Flato et al., 2013).[29] Collectively, 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

[28] WBG Climate Change Knowledge Portal (CCKP 2020). Turkmenistan. Climate Data. Projections. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=TKM&period=2080-2099

[29] 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: http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

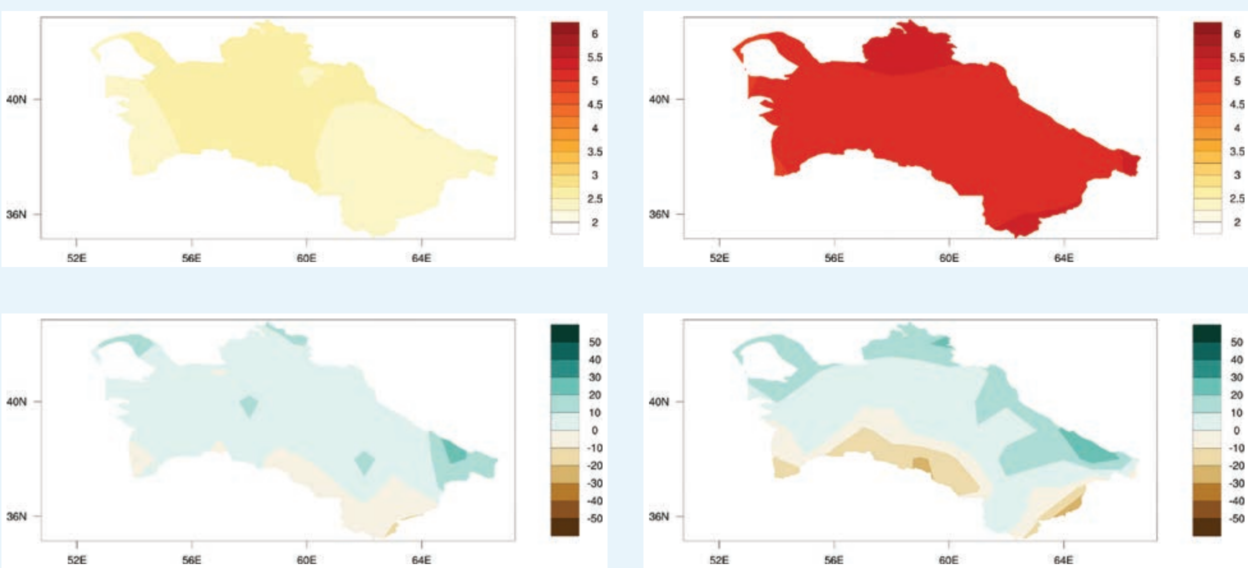
widely between different GCMs, this is particularly the case for rainfall related variables and at national and local scales. The range of projections from 16 GCMs for annual average temperature change and annual precipitation change in Turkmenistan under RCP8.5 is shown in **Figure 4**. Spatial representation 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 Turkmenistan. 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 which provide projections across all RCPs and therefore are most robust for comparison.[28] Three models are labelled.



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[30]



[30] WBG Climate Change Knowledge Portal (CCKP 2020). Turkmenistan. Climate Data. Projections. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=TKM&period=2080-2099

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 temperature projections. Although similar, these three indicators can provide slightly different information. Monthly and 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.

The model ensemble projects that annual average temperatures in Turkmenistan could increase significantly by the 2090s relative to their 1986–2005 baseline. This statistically significant increase is present under all four emissions pathways and the rate of warming for Turkmenistan is expected to outstrip the global average temperature rise. This equates to a rise in annual average temperature of between 1.3°C (in the lowest emissions pathway, RCP2.6) and 5.1°C (in the highest emissions pathway, RCP8.5) by the 2090s. Both maximum and minimum temperatures are projected to rise quickly with daily mean temperatures, with respective increases of 5.2°C and 5.1°C expected by the 2090s under RCP8.5. The temperature rise by the last two decades of the 21st century projected under the most severe warming scenario (RCP8.5) is 3.3°C greater than the rise projected under the most benign (RCP2.6) pathway, indicating the potentially beneficial outcome for Turkmenistan that could be achieved by controlling global emissions.

FIGURE 6. Historic and projected average annual temperature in Turkmenistan under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble[31]

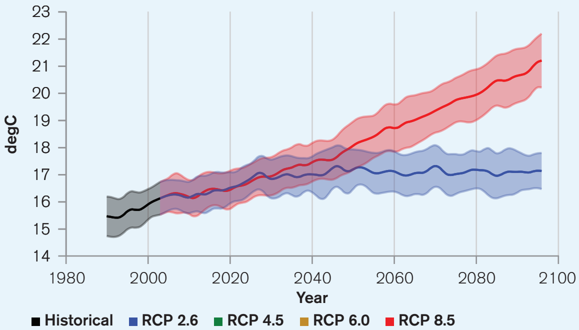
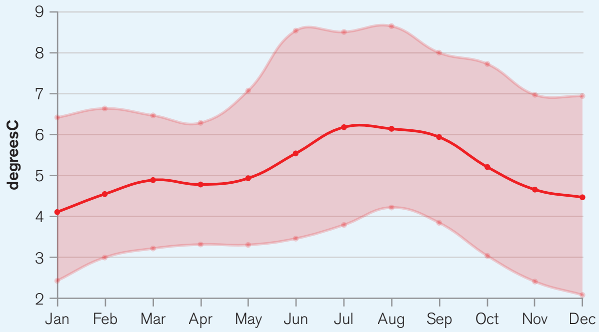


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Turkmenistan for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles[31]



[31] WBG Climate Change Knowledge Portal (CCKP 2020). Turkmenistan. Climate Data. Projections. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=TKM&period=2080-2099.

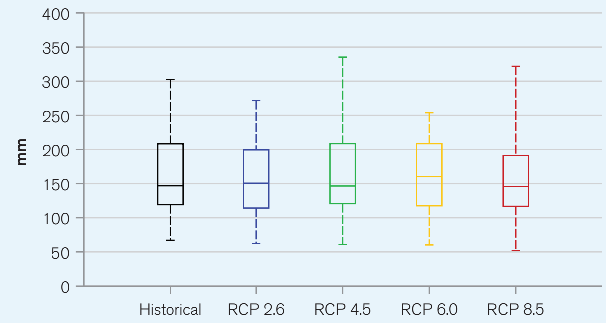
The temperature increases projected by the model ensemble are highest during the summer months (July to September), for which the median estimate is an average temperature increase of approximately 6°C by the end of the 21st century under the RCP8.5 pathway. Given that average daily maxima between June and August can already exceed 35°C in many parts of Turkmenistan, warming of this magnitude is likely to have a severe socio-economic impact on the country as summer temperatures reach hazardous levels.

Increases in average temperatures are expected to be greater in eastern parts of Turkmenistan, with somewhat less warming projected along the Caspian Sea coast in the west. Under the RCP8.5 emissions pathway, the coastal city of Turkmenbashi is projected to experience a rise of 5.5°C, while the temperature increases projected for the interior and east are between 6.1°C and 6.5°C.[28]

Precipitation

The model ensemble does not project any significant change in average annual precipitation for Turkmenistan in future. This lack of a significant change is evident across all four emissions pathways (see **Figure 8**, below). 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, a finding supported by evidence from different regions of Asia.[32] This change is broadly backed by the ensemble projection that future 5-day extreme rainfall events could increase by up to 15% by the 2090s under RCP6.0 and RCP8.5 emissions pathways. However, this projection is highly uncertain and dependent on local geographical contexts; further research is required to constrain its impact in Turkmenistan's sub-regions and to build on the limited number of downscaling studies.[33] Climate modelling in Turkmenistan must also contend with unique atmosphere-ocean interactions with the Caspian Sea.[34]

FIGURE 8. Projected average annual precipitation for Turkmenistan in the period 2080–2099.[31]



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[32] 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. DOI: https://doi.org/10.1002/2014RG000464

[33] Mannig, B., Müller, M., Starke, E., Merkenschlager, C., Mao, W., Zhi, X., Podzun, R., Jacob, D. and Paeth, H. (2013). Dynamical downscaling of climate change in Central Asia. Global and planetary change, 110, pp.26–39. DOI: https://doi.org/10.1016/j.gloplacha.2013.05.008

[34] Turuncoglu, U.U., Giuliani, G., Elguindi, N. and Giorgi, F. (2013). Modelling the Caspian Sea and its catchment area using a coupled regional atmosphere-ocean model (RegCM4-ROMS): model design and preliminary results. Geoscientific Model Development, 6(2), pp.283–299. URL: https://gmd.copernicus.org/articles/6/283/2013/

Moderate levels of disaster risk are experienced in Turkmenistan, leading to a ranking of 101st on the INFORM 2019 Risk Index. This risk is driven by above average levels of flood and drought exposure, and by a lack of coping capacity (**Table 4**). On other indicators, such as social vulnerability, Turkmenistan performs notably better than average. The following section explores climate influences on key aspects of hazard and exposure. The section which follows, analyses climate change influences on the exposure component of risk in Turkmenistan. 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 Turkmenistan. For the sub-categories of risk (e.g. "Flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st. Global averages 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)
6.4 [4.5]	0.0 [1.7]	4.6 [3.2]	1.9 [3.6]	6.3 [4.5]	3.4 [3.8]	101

Heatwaves

Turkmenistan regularly experiences high maximum temperatures, with an average monthly maximum of around 21.5°C and an average July maximum of 36.4°C. The country has experienced several record-breaking high temperatures in recent years. In June 2015, the temperature in Ashgabat reached 47.2°C, its highest ever recorded level,[35] while in 2018 temperatures exceeded 40°C in March for the first time ever in the desert city of Tejen. 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 2%.[18] The Government of Turkmenistan has stated that heat stroke and cardiovascular disease are likely to increase as warming occurs.[36]

The model ensemble projects that the daily probability of a heat wave could increase significantly by the 2030s under the RCP2.6, RCP6.0 and RCP8.5 pathways. Under the higher emissions pathways (RCP6.0 and RCP8.5), this likelihood could continue to rise steadily during the 21st century, and under the most adverse RCP8.5

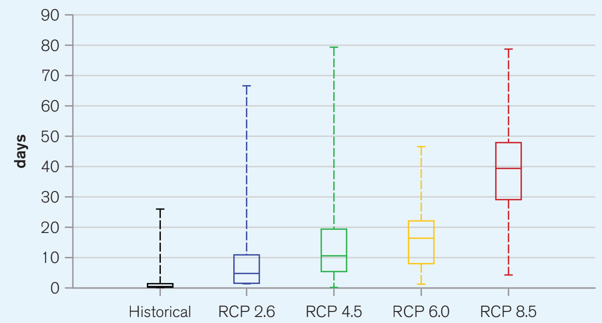
[35] Climate Council of Australia. (2016). *The Hottest Year on Record (Again)*. URL: https://www.climatecouncil.org.au/uploads/d8ed2731739da328fe6149ca1e17f9a9.pdf [Accessed 07/01/2019]

[36] Ministry of Nature Protection of Turkmenistan. (2016). *Third National Communication of Turkmenistan under the UN Framework Convention on Climate Change*. Ashgabat: Ministry of Nature Protection of Turkmenistan. URL: https://unfccc.int/sites/default/files/resource/Tkmnc3.pdf

pathway the ensemble median estimate suggests that the daily probability of a heatwave could reach 20%. This projection reflects the constant shift of temperatures away from the baseline against which heatwave is measured (1986–2005).

Considering the high average and maximum temperatures at present, even the lower emissions pathways suggest that temperatures that are hazardous to public health could become more common in Turkmenistan in the near future. As shown in **Figure 9**, under all emissions pathways the Heat Index (a function of both temperature and humidity) could begin passing 35°C on a regular basis.

FIGURE 9. Historical (1986–2005) and projected (2080–2099) average annual frequency of days surpassing 35°C Heat Index in Turkmenistan.[28]



Drought

Two primary types of drought may affect Turkmenistan, 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). These may interact with land and crop management practices to result in agricultural drought. At present Turkmenistan faces an annual median probability of severe meteorological drought of around 5%,[18] as defined by a standardized precipitation evaporation index (SPEI) of less than –2.

As outlined in Turkmenistan's Third National Communication under the UNFCCC,[17] drought poses a greater risk to the country than any other extreme weather phenomenon. Droughts are a frequent occurrence in Turkmenistan, negatively affecting the country's water supply and reducing the availability of pasture for livestock. The severe drought events of 2000–01 reduced the available pasture by between 40% and 70% in those years.[17]

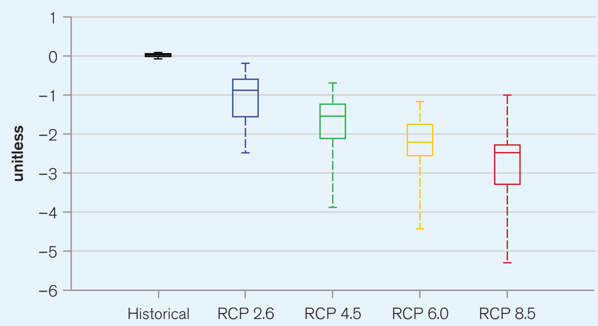
Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[37] They project large increases in the duration and magnitude of droughts in Central Asia by the end of the 21st century under global warming levels of 1.5°C, 2.0°C and 3.0°C. Droughts of a magnitude that is extremely rare at present in Central Asia (100-year droughts) are projected to become 4 to 10 times more common under the same warming scenarios.[38]

[37] 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

[38] White, C., Tanton, T., and Rycroft, D. (2014). The Impact of Climate Change on the Water Resources of the Amu Darya Basin in Central Asia. Water Resource Management. 28: 5267–5281. URL: https://link.springer.com/article/10.1007/s11269-014-0716-x

The model ensemble suggests that the annual probability of experiencing a severe drought in Turkmenistan could increase significantly by the 2090s, relative to its baseline level (1986–2005). The magnitude of this projected increase varies between emissions pathways. Severe drought is expected in two out of every five years by the 2090s in the lowest emissions pathway (RCP2.6), whereas under the most severe pathway (RCP8.5) severe drought is projected to occur in nine of every ten years (**Figure 10**). This projected increase in the probability of severe drought applies equally to most regions of Turkmenistan, albeit the projected probability is slightly higher in the interior and slightly lower in the northern part of the Caspian Sea coast. Effectively these projections represent a transition in many regions to chronically drought affected (i.e. considerably more arid) environments.

FIGURE 10. Annual probability of experiencing a 'severe drought' in Turkmenistan (–2 SPEI index) in 2080–2099 under four emissions pathways.[31]



Flood

Multiple forms of flooding affect Turkmenistan, particularly river flooding and flash (pluvial) flooding. Analysis for the period 1986–1995 indicates an increase in the occurrence of flash flooding, mudflows and heavy rainfall in Turkmenistan.[20] There were 30 instances of substantial economic losses caused by flash flooding and mudflows in the decade between 1996 and 2005.[20] One flood in 1993, the most severe incident since Turkmenistan's independence, caused damages equivalent to approximately $200 million.[39]

The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of river flood exposure. As of 2010, assuming protection for up to a 1-in-25-year event, the population annually affected by flooding in Turkmenistan is estimated to be 14,000 people with an expected annual impact on GDP of $90 million (approximately 0.4%). Development and climate change are both likely to affect these figures. The climate change component can be isolated but its impact by 2030 is expected to be very limited, marginally decreasing the annually affected population by around 2,000 people with no change in the GDP impact (AQUEDUCT Scenario B)[40].

[39] GFDRR. (2017). *Disaster Risk Profile: Turkmenistan.* URL: https://www.gfdrr.org/sites/default/files/Turkmenistan.pdf [accessed 10/01/2019]

[40] WRI (2018). AQUEDUCT Global Flood Analyzer. URL: https://floods.wri.org/# [Accessed: 22/11/2018]

Climate change impacts are more significant on extreme floods and flash flooding. Willner et al.[41] estimate that the number of people potentially affected by an extreme flood (at the 90th percentile in terms of magnitude) could reach 100,864 in Turkmenistan by 2035–44, an increase in affected population of 60% relative to the period 1971–2004 (see **Table 5**, below). The eastern Lebap region is currently most economically vulnerable to flooding, with an estimated 7% of its GDP potentially affected by a flood with a 10-year return period, compared with 4% of GDP affected by a 10-year flood in the southern half of the country.[39,42] It should be noted that all projections of flood extent, particularly at the localized level, will be strongly influenced by other human drivers of land degradation and use change.[43]

TABLE 5. Estimated number of people in Turkmenistan affected by an extreme river flood (extreme flood is defined as being in the 90th percentile in terms of numbers of people affected) in the historic period 1971–2004 and the future period 2035–2044. Figures represent an average of all four RCPs and assume present day population distributions.[44]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	37,771	64,513	26,742
Median	63,056	100,864	37,808
83.3 Percentile	104,780	131,230	26,450

Longer-term projections for flood risk in Turkmenistan are more uncertain. Hydrological projections for the Amu Darya river and the glaciers that feed it[45] suggest that there may be a reduced risk of summer flooding, with a mean runoff reduction of 25% expected during July and August, whereas a projected increase in spring runoff levels may increase flood risk at that time of year. Other models project severe water shortages on the Amu Darya by 2050,[46] leading to virtually zero risk of flooding thereafter. Longer-term models for similar glaciers in the Central Asian region (e.g. Sorg et al (2014)[47] for the Tien Shan mountains) suggest that in the latter half of the 21st century there may be a sharp decrease in runoff as glacial mass becomes critically low, which might also point to a significant reduction in flood risk.

[41] Willner, S., Levermann, A., Zhao, F., Frieler, K. (2018). Adaptation required to preserve future high-end river flood risk at present levels. Science Advances: 4:1. URL: https://pubmed.ncbi.nlm.nih.gov/29326981/

[42] GFDRR. (2017). *Disaster Risk Profile: Turkmenistan.* URL: https://www.gfdrr.org/sites/default/files/Turkmenistan.pdf [accessed 10/01/2019]

[43] Kaplan, S., Blumberg, D.G., Mamedov, E. and Orlovsky, L. (2014). Journal of Arid Environments, 103, pp.96–106. DOI: 10.1016/j.jaridenv.2013.12.004

[44] Willner, S., Levermann, A., Zhao, F., Frieler, K. (2018). Adaptation required to preserve future high-end river flood risk at present levels. Science Advances: 4:1. URL: https://pubmed.ncbi.nlm.nih.gov/29326981/

[45] Hagg, Wilfried & Hoelzle, Martin & Wagner, Stephan & Mayr, Elisabeth & Klose, Zbynek. (2013). Glacier and runoff changes in the Rukhk catchment, upper Amu-Darya basin until 2050. Global and Planetary Change. DOI: https://doi.org/10.1016/j.gloplacha.2013.05.005

[46] Punkari, Mikko; Droogers, Peter; Immerzeel, Walter; Korhonen, Natalia; Lutz, Arthur; Venäläinen, Ari. (2014). Climate Change and Sustainable Water Management in Central Asia. Asian Development Bank. DOI: http://hdl.handle.net/11540/1296

[47] Sorg, A., Huss, M., Rohrer, M. & Stoffel, M. (2014). The days of plenty might soon be over in glacierized Central Asian catchments. *Environmental Research Letters, 9, 104018.* URL: https://iopscience.iop.org/article/10.1088/1748-9326/9/10/104018

Natural Resources

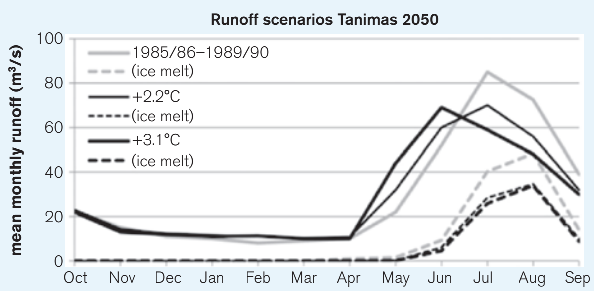
Water

Some of the most severe climate change impacts projected to affect Turkmenistan in the coming decades relate to the country's water supply. The current level of water stress in Turkmenistan indicates that providing a sustainable water supply could be challenging in the coming years and may impinge on the country's economic development.[48] Turkmenistan continues to have a high level of water stress, which has continued to increase over recent decades.[49] Agriculture, and particularly pasture operations, rely on groundwater resources to make up for limited surface flows.[50]

Hagg et al (2013)[51] use hydrological models to project the effect of climate change on the glaciers that feed the main tributary of the Amu Darya river, using an earlier ensemble of General Circulation Models (CMIP3). They project that temperature rises of between 2.2 and 3.1°C by 2050 in mountainous areas would lead to a loss in glacial mass of 36–45% relative to present levels. This leads to only a slight reduction in river flow by 2050, as the smaller glacial mass and increased evapotranspiration are partly offset by a faster glacial melt rate.[51]

As glaciers in the region recede, a change in the seasonal patterns of river flow is expected, with peak flow shifting from the summer to the spring in line with broader climate change impacts across central Asia.[52] Hagg et al project a mean runoff reduction of 25% during July and August for the main tributary of the Amu Darya (**Figure 11**, above), which would cause major water supply issues for both agriculture – cotton and wheat growth is heavily dependent on irrigation – and drinking water in Turkmenistan.[45,53]

FIGURE 11. Baseline and future scenarios for the Tanimas river. Total runoff (solid lines) and ice melt (dashed lines) at the basin outlet (Rukhk hydrological post) are displayed.[51]



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[48] WBG (2015). Assessment of the role of glaciers in stream flow from the Pamir and Tien Shan Mountains. GWADR – Europe and Central Asia. URL: http://documents1.worldbank.org/curated/en/663361468283187700/pdf/AralBasinGlaciers-FinalReport-May-2015.pdf

[49] FAO (2016). AQUASTAT Main Database, Food and Agriculture Organization of the United Nations (FAO). Website accessed on [03/01/2019 10:41]. URL: http://www.fao.org/aquastat/en/

[50] Rakhmatullaev, S., Huneau, F., Kazbekov, J., Le Coustumer, P., Jumanov, J., El Oifi, B., Motelica-Heino, M. and Hrkal, Z. (2010). Groundwater resources use and management in the Amu Darya river basin (Central Asia). Environmental Earth Sciences, 59(6), p.1183. URL: https://link.springer.com/article/10.2478/s13533-011-0062-y

[51] Hagg, W., Hoelzle, M., Wagner, S., Mayr, E., and Klose, Z. (2013). Glacier and runoff changes in the Rukhk catchment, upper Amu-Darya basin until 2050. Global and Planetary Change. DOI: https://doi.org/10.1016/j.gloplacha.2013.05.005

[52] USAID. (2018). *Climate Risk Profile – Central Asia.* URL: https://www.climatelinks.org/sites/default/files/asset/document/2018-April-30_USAID_CadmusCISF_Climate-Risk-Profile-Central-Asia.pdf [accessed 10/02/2019]

[53] Luo, Y. at al. (2018). Contrasting streamflow regime induced by melting glaciers across the Tien Shan – Pamir – North Karakoram. Nature – Scientific Reports. (2018) 8:16470. URL: https://www.nature.com/articles/s41598-018-34829-2

Punkari et al (2014) also use CMIP3 models to project the impact of climate change on the Amu Darya river and related water supply by 2050.[54] They project that inflow into the downstream areas of the river could decline by 26–35% by 2050, even as water demand rises in order to allow continued irrigation in the face of higher evaporation rates. This projection implies that by 2050 there could be a severe water shortage in the Amu Darya basin, with approximately 50% of demand being unmet.[54]

Although further research is needed to project the change in runoff in the Amu Darya beyond 2050, models for similar glaciers in the Central Asian region (e.g. Sorg et al (2014)[55] for the Tien Shan mountains) suggest that in the latter half of the 21st century there may be a sharp decrease in runoff as glacial mass becomes critically low. This accelerated glacial melt in the latter decades of the 21st century would pose a threat to the river that is currently Turkmenistan's only major water source.[56] However, the true impact will depend to a great extent on water management practices in upstream reaches which, in the case of the Amu Darya, cross multiple international borders.

Approximately 90% of Turkmenistan's water resources are derived from the Amu Darya river, which flows through the north-east of the country and forms part of the border with Uzbekistan.[20] The water resources offered by the Amu Darya are projected to diminish and become more variable during the second half of the 21st century. Lower river flow is also likely to be accompanied by water quality issues such as high mineral content, as has been the case during recent low-water years.[16]

As of 2014, 97% of Turkmenistan's water supply came from resources originating outside its borders.[57] This makes the country vulnerable to increased water use upstream by other countries, and the situation may worsen as climate change affects the patterns of precipitation and snow melting. The management of water resources in the Amu Darya basin in particular could be complicated by potential increased demand in Afghanistan and other neighboring countries.[16]

The Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. Although Turkmenistan is landlocked, the country's westernmost regions may still be affected by the impact of climate change on the level of the Caspian Sea. The Caspian Sea level fell by an average of 6.7 centimeter (cm) per year between 1996 and 2015, with recent research finding that evaporation played a dominant role in this sea-level reduction.[58] As average temperatures in the region increase in the coming decades, this decrease in the level of the Caspian Sea is expected to continue, unless offset by corresponding increases in inflows from rivers such as the Volga. Research is suggesting that climate changes may drive ecosystem shifts in the Caspian Sea which are as-yet poorly understood.[59]

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[54] Punkari, Mikko; Droogers, Peter; Immerzeel, Walter; Korhonen, Natalia; Lutz, Arthur; Venäläinen, Ari. (2014). Climate Change and Sustainable Water Management in Central Asia. Asian Development Bank. DOI: http://hdl.handle.net/11540/1296

[55] Sorg, A., Huss, M., Rohrer, M. & Stoffel, M. (2014). The days of plenty might soon be over in glacierized Central Asian catchments. *Environmental Research Letters, 9, 104018*. URL: https://iopscience.iop.org/article/10.1088/1748-9326/9/10/104018

[56] Luo, Y. at al. (2018). Contrasting streamflow regime induced by melting glaciers across the Tien Shan – Pamir – North Karakoram. Nature – Scientific Reports. (2018) 8:16470. URL: https://www.nature.com/articles/s41598-018-34829-2

[57] FAO. (2012). *Turkmenistan*. URL: http://www.fao.org/nr/water/aquastat/countries_regions/TKM/ [Accessed 08/03/2019]

[58] Chen, J., Pekker, T., Wilson, C., Tapley, B., Kostianoy, A., Cretaux, J.-F. & Safarov, E. (2017). Long-term Caspian Sea level change. *Geophys. Res. Lett., 44, 6993–7001*. URL: https://www.lcps.org/cms/lib4/VA01000195/Centricity/Domain/12871/Journal%20article.pdf

[59] Kashkooli, O.B., Gröger, J. and Núñez-Riboni, I. (2017). Qualitative assessment of climate-driven ecological shifts in the Caspian Sea. PloS one, 12(5), p.e0176892. URL: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176892

Land and Soil

Turkmenistan's soils are already affected by significant salinization, with more than 60% of the country's agricultural land being salinized.[60] This is a consequence of the inefficient irrigation systems in many areas. Despite ongoing official efforts to improve this technology, increased temperatures and the resulting increased demand for irrigation water caused by climate change may contribute to increased evaporation, accelerating the process of soil salinization. Crop yields in recent years, which have fallen by 20%–30% due to soil salinity and waterlogging,[60] illustrate the severity of the potential economic impact of climate change in this sector.

Arid land cover spans 80% of the area of Turkmenistan[60] and consequently large parts of the country are subject to desertification. An estimated 16% of the country is subject to moderate desertification, while 6% of its area is susceptible to high desertification.[60] These trends are likely enhanced by local land management practices, and these may have exacerbated issues with dust storms, but research is limited.[61] The significant increase in drought probability projected by the model ensemble under all emissions pathways is likely to hasten the process of desertification in the absence of mitigation efforts. This trend is captured in recent publications, which suggest a transition of much of Turkmenistan's land surface to hyper-arid cover by 2041–2071 under RCP8.5.[62] This shift is likely to have fundamental impacts on the biodiversity and ecology of the region, reducing productivity and viable species ranges of desirable species.[63] Land degradation and aridity have also been shown to be driving range extension of less desirable species such as the locust, with knock-on effects for agricultural production.[64]

Economic Sectors

Agriculture

Climate change could influence 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 and disease profiles, the arrival of invasive species, and decline in arable areas due to the salinization of coastal lands and desertification. On an international level, these impacts are expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018)[65] 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. 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.

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60 UNECE. (2012). *Environmental Performance Reviews: Turkmenistan – First Review*. New York and Geneva: United Nations. URL: https://unece.org/press/environmental-performance-review-turkmenistan-reveals-soil-salinity-waterlogging-land

61 Hamidov, A., Helming, K. and Balla, D. (2016). Impact of agricultural land use in Central Asia: a review. Agronomy for sustainable development, 36(1), p.6. URL: https://link.springer.com/article/10.1007/s13593-015-0337-7

62 Huang, J., Yu, H., Guan, X., Wang, G., & Guo, R. (2016). Accelerated dryland expansion under climate change. Nature Climate Change, 6(2), 166–171. URL: https://www.nature.com/articles/nclimate2837

63 Wang, X., Hua, T., Lang, L., & Ma, W. (2017). Spatial differences of aeolian desertification responses to climate in arid Asia. Global and Planetary Change, 148, 22–28. DOI: https://doi.org/10.1016/j.gloplacha.2016.11.008

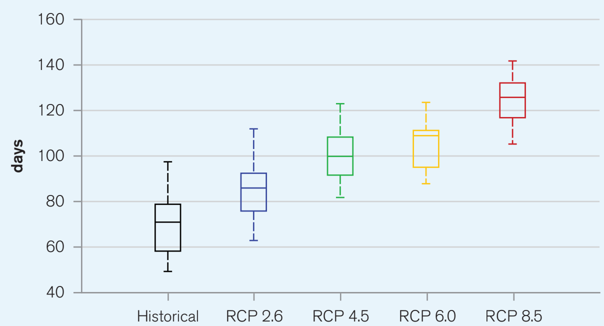
64 Kokanova, E.O. (2017). Natural foci of the Moroccan locust (Dociostaurus maroccanus, Orthoptera, Acrididae) in Turkmenistan and their current state. Entomological Review, 97(5), pp.584–593. URL: https://link.springer.com/article/10.1134/S0013873817050049

65 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

Although the sector has declined in prominence in recent years, agriculture contributed approximately 9% to Turkmenistan's GDP in 2015[66] and accounted for an estimated 8% of employment in 2018.[67] With its dry climate and high average summer temperatures, Turkmenistan is heavily reliant on irrigation to sustain agricultural output.[16] As a result, the country's agricultural sector is highly exposed to any climate change impacts that may affect the water supply of the Amu Darya river.[20,68] Rising temperatures in the region are expected to accelerate the rate of melting in the glaciers feeding the Amu Darya, while also driving higher demand for irrigation through impacts on evapotranspiration. The net result of these developments is a projection of severe water shortages along the Amu Darya by 2050, with an estimated 50% of demand going unmet.[46] These water shortages are likely to severely affect crop productivity in major crops such as cotton and wheat, with the affect being amplified by projected seasonal shifts towards lower water availability in the Amu Darya Basin during the hotter summer months.[45] Cotton is the country's most important agricultural export, accounting for the bulk of textile exports, which in turn constituted 6.2% of all exports in 2017.[3]

The climate model ensemble projects that the number of days per year with a maximum temperature above 35°C could increase in Turkmenistan by 2080–99 (**Figure 12**), with a statistically significant increase to almost double the 1986–2005 baseline projection in the highest emissions pathway (RCP8.5). The median estimate in all but the lowest emissions pathway suggests over 100 such days per year in Turkmenistan by the latter decades of the century. An increased frequency of very high temperatures is likely to reduce crop productivity via evaporation and lower soil moisture. In combination, and without adaptation, the above changes are projected to reduce the revenue generated by irrigated agriculture.[69] However, with adaptation, one study has suggested that it is still possible to achieve significant gains in productivity and revenue across the major crops produced in Turkmenistan.[69]

FIGURE 12. Ensemble estimate of the annual number of very hot (Tmax >35°C) days in 2080–2099 under four emissions pathways in Turkmenistan.[31]



More frequent extreme heat may also affect livestock farming both directly (via heat stress on the animals)[52] and indirectly (via lower productivity of pasture). The expected increase in the annual probability of drought may also have severe effects on the availability of pasture for the livestock subsector, as seen during the severe drought events of 2000–01, which reduced the available pasture by between 40% and 70% in those years.[17]

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66 World Bank. (2019a). Agriculture, forestry, and fishing, value added (% of GDP) URL: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=TM [accessed 08/03/2019]

67 World Bank. (2019b). Employment in agriculture (% of total employment) (modelled ILO estimate). URL: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS [accessed 08/03/2019]

68 Unger-Shayesteh, K. et al. (2013). What do we know about past changes in the water cycle of Central Asian headwaters? A review. Global and Planetary Change. 110:4–25. DOI: http://dx.doi.org/10.1016/j.gloplacha.2013.02.004

69 Duan, W., Chen, Y., Zou, S., & Nover, D. (2019). Managing the water-climate- food nexus for sustainable development in Turkmenistan. Journal of Cleaner Production, 220, 212–224. URL: https://agris.fao.org/agris-search/search.do?recordID=US201900207724

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. Dunne et al. (2013)[70] suggest that global 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 2050 under the highest emissions pathway (RCP8.5). In combination, it is highly likely that the above processes could 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.

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.[71] Generally, 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.

The effects of regional temperature increases and heat stress in urban areas are compounded by the phenomenon of Urban Heat Island (UHI). Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[72] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C–3°C in global mega-cities.[73] This process is poorly understood in Turkmenistan, but has been recognized by the UNDP and the former Ministry of Nature Protection as a key focus area for urban adaptation activity in the capital Ashgabat.[74] Turkmenistan faces challenges delivering 'greening' of urban areas to enable cooling and health benefits, in the context of a pressing need to carefully manage water shortages.[75] As well as impacting on human health (see Communities) the temperature peaks that could result from combined UHI and climate change (frequently breaching 40°C), as well as future urban expansion (**Table 1**), 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.

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70 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

71 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: https://openknowledge.worldbank.org/handle/10986/28723

72 Cao, C., Lee, X., Liu, S., Schultz, N., Xiao, W., Zhang, M., & Zhao, L. (2016). Urban heat islands in China enhanced by haze pollution. Nature Communications, 7, 1–7. URL: https://www.nature.com/articles/ncomms12509

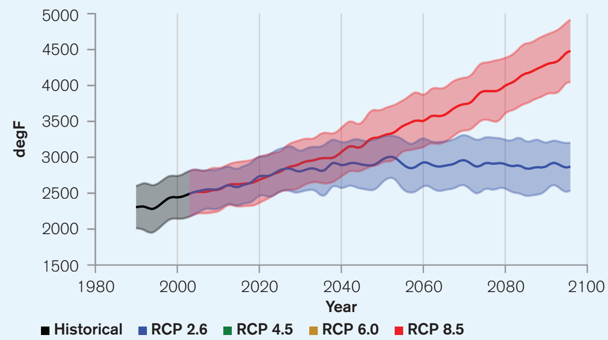
73 Zhou, D., Zhao, S., Liu, S., Zhang, L., & Zhu, C. (2014). Surface urban heat island in China's 32 major cities: Spatial patterns and drivers. Remote Sensing of Environment, 152, 51–61. DOI: 10.1016/j.rse.2014.05.017

74 UNDP (2015). Sustainable Cities in Turkmenistan: Integrated Green Urban Development in Ashgabat and Awaza. Project Identification Form; Application to the Global Environment Facility. Ministry of Nature Protection Government of Turkmenistan. URL: https://www.tm.undp.org/content/turkmenistan/en/home/projects/sustainable-cities.html

75 Koch, N. (2015). The violence of spectacle: Statist schemes to green the desert and constructing Astana and Ashgabat as urban oases. Social & Cultural Geography, 16(6), pp.675–697. DOI: https://doi.org/10.1080/14649365.2014.1001431

Research suggests that on average a one degree increase in ambient temperature can result in a 0.5%–8.5% increase in electricity demand.[76] Notably this serves business and residential air-cooling systems. This increase in demand places strain on energy generation systems which is compounded by the heat stress on the energy generation system itself, due to cooling requirements which can reduce efficiency.[77] The number of cooling degree days (when such cooling systems would be required) is projected to increase significantly by the 2090s in the higher emissions (RCP6.0 and RCP8.5) pathways (**Figure 13**). Under the highest emission pathway (RCP8.5), the median projection could see the number of cooling degree days increase by 84% relative to the country's 1986–2005 baseline, implying a sharp increase in electricity demand for air conditioning. This increase in demand should also be seen in the context of potential declines in the productivity of hydropower as an energy source in Turkmenistan due to hydrological climate changes.[78]

FIGURE 13. Historic and projected annual cooling degree days in Turkmenistan (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.[31]



Communities

Welfare, Inequality, and Vulnerability to Climate-Related Disaster

Many of the climate changes projected could disproportionately affect the poorest groups in society. For instance, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[79] 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.[69] There is an urgent need for data gathering and further research into the intersection between welfare, inequality and climate change in Turkmenistan.

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[76] 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. DOI: https://doi.org/10.1016/j.enbuild.2014.09.052

[77] ADB (2017). Climate Change Profile of Pakistan. Asian Development Bank. URL: https://www.adb.org/publications/climate-change-profile-pakistan

[78] Reyer, C. P. O., Otto, I. M., Adams, S., Albrecht, T., Baarsch, F., Cartsburg, M., . . . Stagl, J. (2017). Climate change impacts in Central Asia and their implications for development. Regional Environmental Change, 17(6), 1639–1650. DOI: https://doi.org/10.1007/s10113-015-0893-z

[79] 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. DOI: 10.1146/annurev-publhealth-032315-021740

Natural hazards pose a threat in Turkmenistan and their impacts are likely to be unequally distributed. As outlined in Turkmenistan's Third National Communication under the UNFCCC,[17] drought poses a greater risk to the country than any other extreme weather phenomenon. Droughts are a frequent occurrence in Turkmenistan, negatively affecting the country's water supply (both for drinking and irrigation of crops) and reducing the supply of pasture required by livestock farmers. The severe drought events of 2000–01 reduced the available pasture by between 40 and 70% in those years.[17]

Flooding, which typically occurs during spring and summer months, also poses a risk to the population and the economy.[17] There were 30 instances of substantial economic losses caused by flash flooding and mudflows in the decade between 1996 and 2005. Mudflows are a frequent occurrence in mountainous parts of the country, such as the Kopetdag, Koytendag and Balhan ranges, typically occurring between April and August following periods of heavy rainfall.[17] There is a lack of data available on the effects of mudflows on the population and economy of these mountainous regions, but the severity of the mudflows recently experienced suggests the potential for loss of life and extensive damage to physical infrastructure.

A further threat in the northern regions of Turkmenistan comes from dust storms, which spread salt and agricultural pesticides from the drying Aral Sea.[80] These storms can cause respiratory illness in the local population[81] and damage the productive potential of surrounding agricultural land. Löw et al (2013) analyze this phenomenon, finding that the source area for salt storms in the Aral Sea grew in area by 36% between 2000 and 2008.[82] They project that the risk of dust and salt storms could increase as the desiccation of the Aral Sea continues.

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.[83]

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80 O'Hara, S.L., Wiggs, G.F., Mamedov, B., Davidson, G. and Hubbard, R.B., 2000. Exposure to airborne dust contaminated with pesticide in the Aral Sea region. The Lancet, 355(9204), pp.627–628. DOI: 10.1016/S0140-6736(99)04753-4

81 UNICEF. (2007). Brining water, bringing life to people in the most remote areas of Turkmenistan. URL: https://www.unicef.org/turkmenistan/reallives_7182.html [Accessed 08/03/2019]

82 Löw, F & Navratil, Peter & Kotte, Karsten & Schöler, Heinz & Bubenzer, Olaf. (2013). Remote-sensing-based analysis of landscape change in the desiccated seabed of the Aral Sea - A potential tool for assessing the hazard degree of dust and salt storms. Environmental monitoring and assessment. 185(10). URL: https://pubmed.ncbi.nlm.nih.gov/23564411/

83 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 Programme estimate that without adaptation the risk of hunger and child malnutrition on a global scale could increase by 20% respectively by 2050.[84] Springmann et al. assessed the potential for excess, climate-related deaths associated with malnutrition.[85] 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 47.7 climate-related deaths per million population linked to lack of food availability in Turkmenistan by the year 2050 under RCP8.5.

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.[86] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change could push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves.

Turkmenistan regularly experiences high maximum temperatures, with an average July maximum of 36.4°C. The country has experienced several record-breaking high temperatures in recent years. In June 2015, the temperature in Ashgabat reached 47.2°C, its highest ever recorded level, while in 2018 temperatures exceeded 40°C in March for the first time ever in the desert city of Tejen.[87] Although humidity is relatively low in the summer months, further warming to the extent projected for even lower-end estimates of the model ensemble could pose a serious risk of heat-related mortality to the population of Turkmenistan by the middle and latter parts of the 21st century.

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.[88] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[89]

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84 WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Programme. URL: https://www.wfp.org/publications/two-minutes-climate-change-and-hunger

85 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. DOI: 10.1016/S0140-6736(15)01156-3

86 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

87 Ministry of Nature Protection of Turkmenistan. (2016). *Third National Communication of Turkmenistan under the UN Framework Convention on Climate Change*. Ashgabat: Ministry of Nature Protection of Turkmenistan. URL: https://unfccc.int/sites/default/files/resource/Tkmnc3.pdf

88 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://pubmed.ncbi.nlm.nih.gov/23928946/

89 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://pubmed.ncbi.nlm.nih.gov/30319715/

Disease

Deterioration in the water quality of the Amu Darya river poses a threat to public health in Turkmenistan, and this issue may be exacerbated by the impacts of climate change over the coming decades. Poor quality drinking water in the lower parts of the Amu Darya has been linked to increases in kidney, thyroid and liver diseases and anemia.[90] Although there is a lack of available evidence for Turkmenistan on the relation between heat, water quality and disease, parts of the country may see similar impacts as in neighboring Uzbekistan, where acute intestinal infections are positively correlated with air temperature and the incidence of bacterial dysentery is three times higher during summer months than at other times of the year.

Discharges of water from agriculture (including in neighboring countries) has raised salinity in the river to levels that pose a health risk to the population of the northern Dashoguz region.[57] Pollution along the Amu Darya has also introduced pesticides and other chemicals into the water supply. Higher temperatures caused by climate change could contribute to increased evaporation, exacerbating soil salinization and water salinity in the Amu Darya. An expected reduction in the river's runoff in the coming decades,[45] especially in summer months when demand for irrigation is highest, may also drive elevated salinity levels upwards.

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 6. Key national adaptation policies, plans and agreements

Policy/Strategy/Plan	Status	Document Access
Nationally Determined Contribution to Paris Climate Agreement	Submitted	October, 2016
National Communications to the UNFCCC	Three submitted	Latest: January, 2016
National Climate Change Strategy of Turkmenistan	Enacted	June, 2012
National Strategy on the Development of Renewable Energy in Turkmenistan until 2030[91]	Adopted	December, 2020

[90] UNEP, GRID Arendal and Zoi Environmental Network. (2011). *Environment and Security in the Amu Darya Basin.* URL: http://www.grida.no/publications/202 [Accessed 08/03/2019]

[91] Ministry of Foreign Affairs of Turkmenistan (2021). Resolution of the President of Turkmenistan. URL: https://www.mfa.gov.tm/en/articles/487

Climate Change Priorities of ADB and the WBG

ADB – Country Partnership Strategy

The Asian Development Bank agreed a Country Partnership Strategy (CPS) with the Government of Turkmenistan covering the period 2017–2021. Climate change and the environment are identified as a thematic priority. ADB support to environmentally sustainable growth will commence through knowledge work during the initial years of the CPS period. Turkmenistan's nationally determined contributions identify energy efficiency, the sustainable use of natural gas, and alternative energy sources as ways to contribute to global climate mitigation targets.[40] Separate national action plans on mitigation and adaptation are being finalized. These will provide ADB the basis for engagement during the CPS period. ADB will consider the impact of climate change on infrastructure projects it supports. Turkmenistan is susceptible to high winds, landslides, earthquakes, and droughts; and ADB will be ready to offer support in such eventualities and strengthen resilience. ADB will also initiate dialogue with the United Nations Development Programme and Gesellschaft für Internationale Zusammenarbeit, or GIZ, that are involved in activities to enhance water efficiency and application of integrated water resources management, to explore areas for collaboration.

WBG – Country Engagement Note

The WBG's latest strategy with Turkmenistan is the Country Engagement Note FY16-17 (CEN). The CEN focused on sharing with Turkmen authorities the international knowledge, experiences and best practices in several areas relevant to Turkmenistan's growth and integration into the global economy as well as potential for support to competitive industries (including agriculture); financial sector modernization; improved skills in support of innovation; climate change/water resource management; and the connectivity agenda.[92]

[92] World Bank (2015). Turkmenistan Country Engagement Note for FY16-17. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/371591467987825776/turkmenistan-country-engagement-note-for-the-period-fy2016-17

CLIMATE RISK COUNTRY PROFILE

TURKMENISTAN

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK