CLIMATE RISK COUNTRY PROFILE

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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

- Temperatures in Kazakhstan are projected to rise at a faster rate than the global average and faster than most other Asian nations, with potential warming of 5.3°C by the 2090s, compared with the 1986–2005 baseline under the highest emissions pathway (RCP8.5).
- Warming is projected to be even stronger for maximum and minimum temperatures and the extreme temperatures which will result are likely to threaten human lives, livelihoods, and ecosystems.
- Projected temperature rise in the 2090s under RCP8.5 is 3.7°C greater than the rise projected under the lowest emissions pathway (RCP2.6), indicating the large difference in outcome for Kazakhstan that could be achieved by controlling global emissions.
- Severe droughts are expected to occur more frequently under all but the lowest emissions pathway. Increased drought risk is likely to contribute to land degradation, desertification, and associated issues such as dust storms.
- Temperature rises will accelerate the melting of Kazakhstan's glaciers, which is projected to lead to an increase in river flow and flood risk through the middle of the 21st century, followed by a longer-term decline in river flow.
- Mudflows are forecast to increase in frequency by a factor of 10 and pose a threat to 156 towns and cities in Kazakhstan, among them the country's largest city, Almaty.
- More frequent droughts and reduced water security could damage agricultural productivity of crop and livestock farming. In the absence of adaptation, spring wheat yields in Kazakhstan are projected to decline by as much as 50% by the 2050s due to higher temperatures and reduced soil moisture.
- Grain yield losses due to climate change in Kazakhstan are expected to have serious implications for global food security as the nation represents one of the world's largest exporters.
- In combination, the above changes represent a major threat to the lives and livelihoods of the poorest and most marginalized communities in Kazakhstan. Unless adaptation and disaster risk reduction support is provided, inequalities are likely to grow and poverty to prevail.

COUNTRY OVERVIEW

The Republic of Kazakhstan is a landlocked country and is the ninth largest country in the world by area. Located in Central Asia, the country shares borders with the Russian Federation to the north, China to the east, and Turkmenistan, Uzbekistan and the Kyrgyz Republic to the south. The Caspian Sea forms a natural boundary to the west. Kazakhstan contains forest-steppe, steppe, semi-arid and desert climate zones and precipitation is low throughout. Kazakhstan has one of the lowest population densities in the world, with a population of 18.5 million (2019) spread over its 2.7 million square kilometer area, and 57% of this population lives in urban areas.

Kazakhstan's economy is dominated by a large minerals sector. This includes oil and gas (which accounted for 21% of GDP and 62% of exports in 2017), uranium (of which Kazakhstan is the world's largest producer) and other metals. The service sector accounted for 55.5% of Kazakh GDP in 2019, whereas the share of agriculture in GDP was only 4.5% in 2019, having fallen sharply since the country's independence in the early 1990s. Kazakhstan is classified as an upper middle-income country where GDP per capita more than tripled between 1990 and 2017.[1]

[1] World Bank (2020). GDP per capita, PPP (current international $). URL: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=KZ

This has allowed for strong employment growth and a significant reduction in poverty, which fell to a reported national rate of 2.6% in 2016 (**Table 1**). Nonetheless, poverty and inequality remain higher in the northern and southern regions than in the east, the west and the major cities.[2]

In 2016, Kazakhstan submitted its First Nationally Determined Contribution to the UNFCCC, which commits the country to a 15% reduction in greenhouse gas emissions by 2030 (relative to 1990 levels). Kazakhstan's Seventh National Communication (NC7) and Third Biennial Update Report (BR3) (2017) identifies the country's vulnerability to climate change in the areas of agriculture (both crops and livestock), water resources, human health and social and economic development.[3] The report sets out adaptation priorities in these areas, including technical and administrative measures and technological and infrastructural improvements. The Ministry of Environment and Water Resources of Kazakhstan was the central executive body coordinating and leading the development and implementation of government policies on environment protection and management, including climate change issues. The Ministry was closed in 2014, and its functions divided between a newly created Ministry of Energy and the Ministry of Agriculture. This function was finally transferred to the Ministry of Ecology, Geology and Natural Resources that was created in 2019. Kazakhstan ratified the Paris Agreement on December 6, 2016.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[4]	<2.5% (2017–2019)	FAO, 2020
National Poverty Rate[5]	4.2% (2019)	ADB, 2020a
Share of Income Held by Bottom 20%[6]	9.8% (2017)	World Bank, 2019
Net Annual Migration Rate[7]	–0.1% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[8]	0.8% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[9]	1.29% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[10]	59 (2020)	UNDESA, 2019
Urban Population as % of Total Population[11]	57.7% (2020)	CIA, 2020
External Debt Ratio to GNI[12]	105.7% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP[13]	18.2% (2018)	ADB, 2020b

2 Hosny, A. & Yoon, S. (2014). Republic of Kazakhstan: Selected Issues. IMF Country Report No. 14/243, International Monetary Fund: Washington DC. URL: https://www.imf.org/external/pubs/ft/scr/2014/cr14243.pdf
3 Ministry of Environment and Water Resources. (2013). The Third–Sixth National Communication of the Republic of Kazakhstan to the UN Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/kaz_nc3%2C4%2C5%2C6_eng%20Kazakhstan%20NC%204.pdf
4 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/
5 ADB (2020a). Basic Statistics 2020. URL: https://www.adb.org/publications/basic-statistics-2020 [accessed 27/01/21]
6 World Bank (2019). Income share held by lowest 20%. URL: https://data.worldbank.org/ [accessed 17/12/20]
7 UNDESA (2019). World Population Prospects 2019: MIGR/1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
8 UNDESA (2019). World Population Prospects 2019: MORT/1-1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
9 UNDESA (2019). World Urbanization Prospects 2018: File 6. URL: https://population.un.org/wup/Download/ [accessed 17/12/20]
10 UNDESA (2019). World Population Prospects 2019: POP/11-A. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
11 CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/
12 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
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

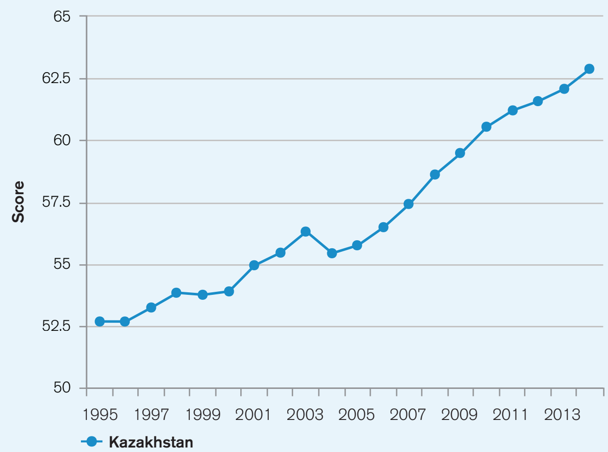
Green, Inclusive and Resilient Recovery

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 succinctly summarize the climate risks faced by Kazakhstan. 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 Kazakhstan, 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.

While Kazakhstan has a relative high degree of readiness, due to a combination of political, geographic, and social factors, Kazakhstan is recognized as vulnerable to climate change impacts, ranked 46th out of 181 countries in the 2020 ND-GAIN Index.[14] 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 higher their score, while the more ready a country is to improve its resilience the lower 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 Kazakhstan'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.[14]



[14] University of Notre Dame (2019). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

Climate Baseline

Overview

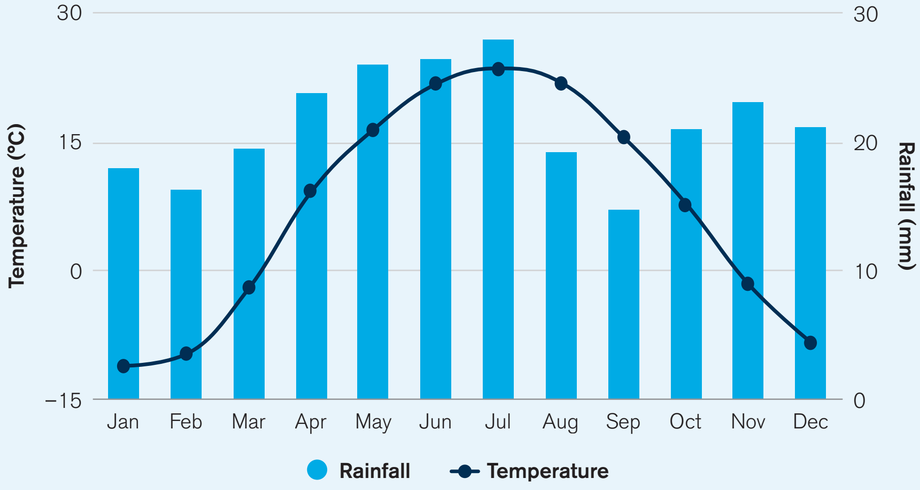
Flat or rolling terrain predominates throughout much of Kazakhstan, with lowlands accounting for one third of the country's total area and low mountains a further fifth.[15] The exceptions to this topography are the very low-lying areas by the Caspian Sea in the west, and Altay mountains that reach altitudes of 7,000 meters (m) on the eastern border with China and the Kyrgyz Republic . Kazakhstan experiences an extreme continental climate, with long, hot summers and cold winters. Winter in the north of the country is long and cold – in some years the temperatures reached - 52°C (Nur-Sultan), but there are also thaws up to 5°C. The shortest season in the north is spring, which lasts 1.5 months, while summer lasts 3 months and winter extends from October to April. Snow primarily falls in November but can continue through April. Kazakhstan's seasonal climate cycle for the latest climatology, 1991–2020, is shown in **Figure 2**.

Due to its great distance from the ocean, Kazakhstan has a highly continental climate and large intraday and annual fluctuations in temperature. This means that temperatures in the winter months (December to February) are extremely cold, with national averages between –9°C and –12°C, whereas summers are hot, with average temperatures of 22°C to 23°C in June, July and August. Precipitation is low throughout the year, with average monthly levels of between 14 millimeters (mm) and 30 mm, although flooding can occur during spring due to increased rain and the thawing of winter snow. Temperatures throughout the year vary with latitude in Kazakhstan, with northern areas experiencing much colder winter temperatures than southern areas, and southern areas relatively hot summers. This means that in January and February temperatures in the capital (Nur-Sultan, in the north of the country) can fall to –16°C, while in the most populous city (Almaty, in the southeast) average temperatures remain above–7°C. Similarly, the average temperature in July can vary from 20°C in parts of the north and northeast to 29°C in southern areas near the border with Uzbekistan. Levels of precipitation can vary significantly between climate zones. Desert areas, such as the central Betpak Dala desert and the southern Kyzylkum desert, receive only 100–200 mm of precipitation per annum, whereas steppe areas receive 200–500 mm per year. Precipitation in the foothills and mountains vary between 500 and 1,600 mm per annum.[3] **Figure 3** shows observed spatial variation for temperature and precipitation across Kazakhstan.

[15] Smith, D., Hambly, G., Sinor, D. & Allworth, E. (2018). Kazakhstan. In Encyclopedia Britannica. URL: https://www.britannica.com/place/Kazakhstan [accessed 13/11/2018]

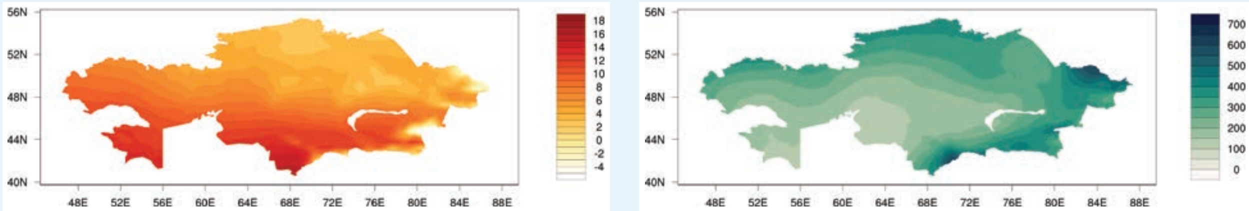
Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Kazakhstan (1991–2020).[16]



Spatial Variation

FIGURE 3. (Left) annual mean temperature (°C), and (right) annual mean rainfall (mm) in Kazakhstan over the period 1991–2020[17]



Key Trends

Temperature

Meteorological data from Kazakhstan show a rise in average temperatures during the 20th century, particularly in the decades since the 1980s. Average annual temperatures were 0.3°C to 1.4°C warmer during the period 1997–2010 than during the baseline period of 1971–2000, and there was an average rise of 0.28°C per decade between 1941 and 2011.[3] These warming trends applied to all areas[18] and were relatively more pronounced in the north, west and south of the country.[3] Temperature rises were highest during the autumn and winter, with increases of 0.32°C and 0.35°C per decade, respectively, while warming was less extensive during the summer, with an increase of 0.18°C per decade.[19]

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[16] WBG Climate Change Knowledge Portal (CCKP, 2020). Climate Data: Historical. URL: https://climateknowledgeportalworldbank.org/country/kazakhstan/climate-data-historical

[17] WBG Climate Change Knowledge Portal (CCKP, 2020). Climate Data: Historical. URL: https://climateknowledgeportalworldbank.org/country/kazakhstan/climate-data-historical

[18] World Bank. (2015). Kazakhstan: Nationwide assessment of climate-change related risks and formulation of mitigation strategy. Washington, D.C. World Bank Group. URL: https://openknowledge.worldbank.org/handle/10986/22488

[19] Salnikov, V., Turulina, G., Polyakova, S., Petrova, Y., & Skakova, A. (2015). Climate change in Kazakhstan during the past 70 years. Quaternary International, 358, 77–82. https://doi.org/https://doi.org/10.1016/j.quaint.2014.09.008

Precipitation

The trend in precipitation levels in Kazakhstan in recent decades is not as clear as for temperature. There was a slight decrease in average annual precipitation between 1941 and 2011, equivalent to a fall of 0.5 mm per annum every decade (or a 0.3% decrease in the annual total). This varied throughout the year: there was a statistically significant increase in precipitation during winter months affecting most parts of the country, whereas during the rest of the year the marginal fall in precipitation levels was not significantly different from zero.[3] Almost all the country had a decrease in the maximum duration of rainless periods, with this effect being especially strong in the north and the southeast.[13] Precipitation in Kazakhstan has a complex relationship with global climate circulation patterns and there is uncertainty regarding historical climate change influences on these phenomena.[20,21]

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.[22] 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.

[20] Malygina, N., Papina, T., Kononova, N., & Barlyaeva, T. (2017). Influence of atmospheric circulation on precipitation in Altai Mountains. Journal of Mountain Science, 14(1), 46–59. https://doi.org/10.1007/s11629-016-4162-5

[21] Bothe, O., Fraedrich, K., & Zhu, X. (2012). Precipitation climate of Central Asia and the large-scale atmospheric circulation. Theoretical and Applied Climatology, 108(3), 345–354. https://doi.org/10.1007/s00704-011-0537-2

[22] 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

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.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Kazakhstan 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[23]

	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	1.7 (–1.0, 4.7)	1.6 (–1.1, 4.5)	1.7 (–0.7, 4.4)	1.6 (–0.8, 4.2)	1.8 (–0.5, 4.1)	1.6 (–0.6, 4.1)
RCP4.5	2.2 (–0.4, 5.0)	2.9 (0.5, 5.9)	2.1 (–0.3, 4.6)	2.9 (0.5, 5.6)	2.3 (0.0, 4.6)	3.1 (0.6, 5.7)
RCP6.0	2.0 (–0.6, 4.7)	3.6 (1.0, 6.8)	2.0 (–0.4, 4.5)	3.6 (1.3, 6.5)	2.0 (–0.3, 4.4)	3.7 (1.4, 6.3)
RCP8.5	2.8 (0.2, 5.7)	5.7 (2.9, 9.0)	2.8 (0.5, 5.4)	5.8 (3.3, 8.6)	3.0 (0.7, 5.4)	6.1 (3.4, 8.7)

TABLE 3. Projections of average temperature anomaly (°C) in Kazakhstan 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[21]

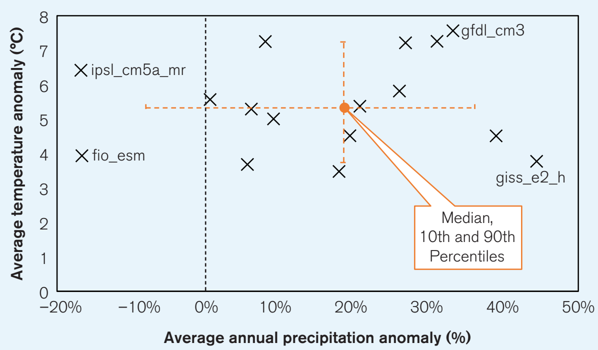
	2040–2059		2080–2099	
Scenario	**Jun–Aug**	**Dec–Feb**	**Jun–Aug**	**Dec–Feb**
RCP2.6	1.6 (–1.3, 4.4)	2.3 (–0.5, 5.2)	1.5 (–1.5, 4.1)	2.2 (–0.7, 5.1)
RCP4.5	2.1 (–0.9, 4.7)	2.4 (–0.3, 5.1)	2.8 (–0.2, 5.8)	3.9 (0.9, 6.3)
RCP6.0	1.8 (–0.2, 4.4)	2.9 (–0.6, 5.5)	3.5 (1.1, 6.7)	4.3 (1.7, 7.2)
RCP8.5	2.8 (0.3, 5.7)	3.0 (0.3, 5.5)	5.7 (2.6, 9.3)	6.3 (4.2, 8.8)

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

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).[24] 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. The range of projections from 16 GCMs for annual average temperature change and annual precipitation change in Kazakhstan 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 Kazakhstan. 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.[25] Four outlier models are labelled.

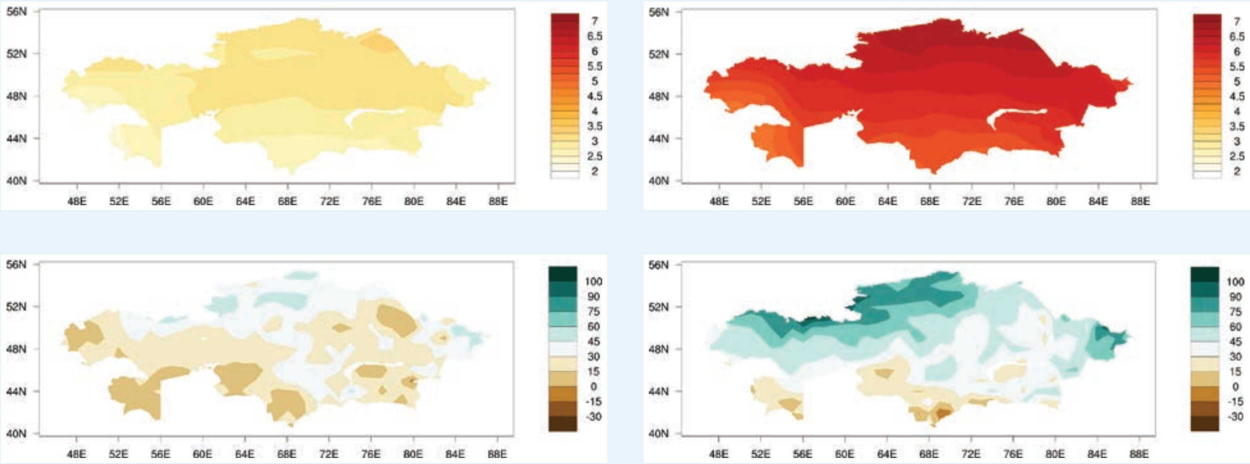


[24] Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W., . . . Rummukainen, M. (2013). Evaluation of Climate Models. Climate Change. (2013). The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 741–866. URL: http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

[25] WBG Climate Change Knowledge Portal (CCKP, 2020). Climate Data: Historical. URL: https://climateknowledgeportalworldbank.org/country/kazakhstan/climate-data-historical

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[26]



Temperature

Projections of future temperature change are presented in three primary formats. **Table 2** shows 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. While 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.

Average annual temperatures in Kazakhstan are expected to rise significantly by the end of the 21st century under all four emissions pathways, with the country projected to see larger temperature increases than the global average and most other Asian nations. Under the highest emissions pathway (RCP8.5), average temperatures in Kazakhstan are projected to rise by 5.8°C by the 2090s, compared with a global average rise of 3.7°C. At 5.8°C, the projected rise in the average daily maximum temperature by the 2090s in scenario RCP8.5 is higher still, as is the rise of 6.1°C in average daily minimum temperatures under the same emissions pathway and timeframe. The temperature rise by the last two decades of the 21st century projected under the most severe warming scenario (RCP8.5) is 3.7°C greater than the low emissions pathway (RCP2.6), indicating the large difference in outcome for Kazakhstan that could be achieved by controlling global emissions.

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

FIGURE 6. Historical and projected average annual temperature in Kazakhstan under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.[27]

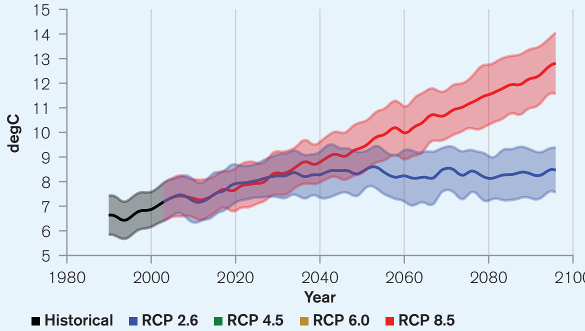
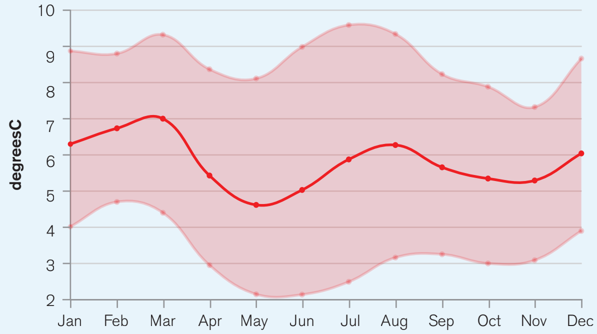


FIGURE 7. Projected change (°C) in monthly temperature, shown by month, for Kazakhstan for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles.[21]

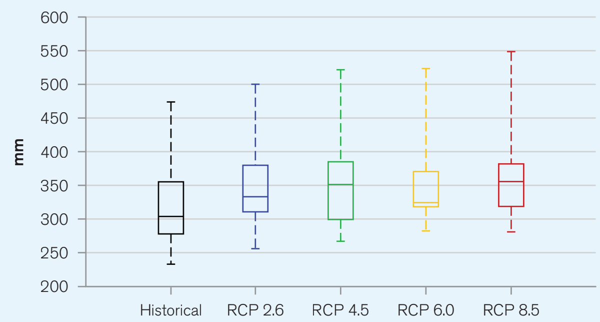


There is a pronounced seasonality to the projected temperature changes in all four emissions pathways, with summer and winter months projected to see the largest rises in temperature, although this trend is less significant in the lowest emissions (RCP2.6) pathway. Average summer temperatures (June to August) are projected to increase by 6.3°C in the highest emissions pathway by 2090s. Increases in average temperatures are expected to be more severe in northern parts of Kazakhstan than in the south.[21]

Precipitation

As shown in **Figures 4** and **8** most GCMs project future increases in average annual precipitation. However, there is considerable disparity between models in the direction and magnitude of change and further work is required to narrow the range of projections. While considerable uncertainty is attached to 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.[28] However, as this phenomenon is highly dependent on local geographical contexts further research is required to constrain its impact in Kazakhstan.

FIGURE 8. Projected average annual precipitation (mm) for Kazakhstan in the period 2080–2099.[21]



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

[28] 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

Kazakhstan faces a diverse set of natural hazards, many of which are expected to be augmented by climate change. Key threats include earthquakes, floods, drought, avalanches, and landslides. Kazakhstan achieved a low ranking of 144th in the INFORM 2019 Index for Risk Management, despite above average levels of drought and flood hazard. The overall risk ranking is mitigated by lower than average social vulnerability and above average readiness and coping capacity (**Table 4**). 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 Kazakhstan. 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.

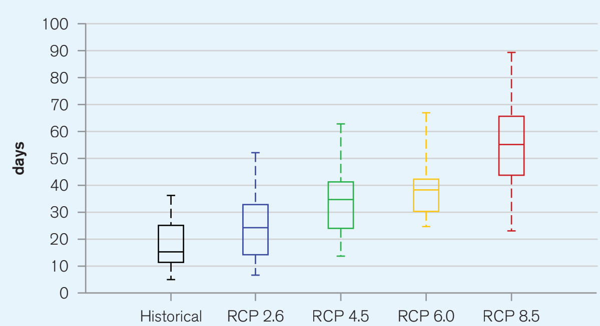
TABLE 4. Selected indicators from the INFORM 2019 Index for Risk Management for Kazakhstan. For the sub-categories of risk (e.g. "Flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st. Global average scores are shown in brackets.

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)
6.0 [4.5]	0.0 [1.7]	5.0 [3.2]	1.0 [3.6]	3.8 [4.5]	2.2 [3.8]	144

Heatwaves

Kazakhstan regularly experiences high maximum temperatures, with an average monthly maximum of around 11.6°C, but an average July maximum of 30°C. The model ensemble projects, under the highest emissions pathways (RCP6.0 and RCP8.5), that the likelihood of heatwaves could increase significantly over the 21st century in Kazakhstan. As a heatwave is defined here with reference to the baseline period 1986–2005, the probability of heatwave conditions grows in part simply as a result of the long-term warming trend. Another way of interpreting future heat issues is to examine the frequency of days with temperatures exceeding the threshold of 35°C. By the 2090s, the number of days in this category increases dramatically, particularly under higher emissions pathways (**Figure 9**). These projects suggest that peak summer temperatures could reach levels dangerous to the health of humans and many plant and animal species.

FIGURE 9. Historical (1986–2005) and projected (2080–2099) number of days during which temperatures exceed 35°C in Kazakhstan under four emissions pathways.[21]



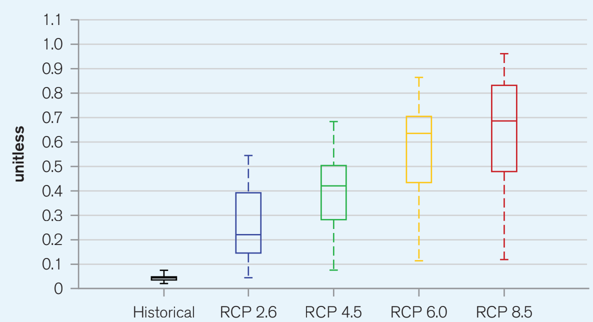
Drought

Two primary types of drought may affect Kazakhstan, 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). When combined with local soil characteristics and land and crop management practices, hydrological deficits can also lead to agricultural drought. At present Kazakhstan faces an annual median probability of severe meteorological drought of around 4%, as defined by a standardized precipitation evaporation index (SPEI) of less than –2.[21] Droughts currently affect two thirds of Kazakhstan's land area and have been a regular feature of Kazakhstan's climate, occurring in 11 of the 20 years between 1986 and 2006. Grain output in rain-fed farming areas of the north is affected by drought in two out of every five years.[13] To-date there has not been a strong climate change signal in historical drought trends.[29]

Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[30] 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 these warming scenarios.[31]

A significant increase in the annual probability of experiencing a year with Severe Drought conditions is projected by the CCKP model ensemble for Kazakhstan by the 2090s under the RCP4.5, RCP6.0, RCP8.5 pathways (**Figure 10**). This increase in drought probability is expected to affect the whole country, although it is projected to be most severe in the south of the country. Under the higher emissions scenarios (RCP 6.0 and RCP8.5), major parts of the Kyzylorda and Mangystau regions could have an annual severe drought probability of over 80% by the end of the 21st century. This level of increase effectively represents a transition to a more arid environment, with some new areas likely to become chronically drought affected, resulting in potential desertification.

FIGURE 10. Annual probability of experiencing a 'severe drought' in Kazakhstan (–2 SPEI index) in 2080–2099 under four emissions pathways.[21]



[29] Chen, F., Mambetov, B., Maisupova, B. and Kelgenbayev, N. (2017). Drought variations in Almaty (Kazakhstan) since AD 1785 based on spruce tree rings. Stochastic Environmental Research and Risk Assessment, 31(8), pp. 2097–2105. URL: http://www.springerlink.com/openurl.asp?genre=journal&issn=1436-3240

[30] 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. DOI: https://doi.org/10.1002/2017GL076521

[31] 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

Flood and Mudflows

Kazakhstan experienced six major flooding incidents between 1985 and 2013, making floods the second most frequent category of natural hazard during this period.[32] The deadliest flood during this period occurred in 2010, killing more than 40 people, while the more economically damaging floods of 1993, 2008 and 2011 caused $60–$100 million worth of damage each. Flooding is more prevalent in southern and eastern parts of Kazakhstan. Those areas most economically vulnerable to flooding are the western region of Atyrau (where damage equivalent to 11% of GDP is driven by flooding in an average year) and the southern Kyzylorda region (where damage equivalent to 5% of GDP is delivered).[33]

The warming projected by the model ensemble could hasten the melting of Kazakhstan's glaciers, which is expected to increase the risk of flooding in the medium-term, but subsequently lead to a reduction in the flow rate of rivers.[25] The magnitude of future flood peaks will also be influenced by future reservoir operations.[34] River discharge in the Tien Shan mountains (which form part of the southeastern border of Kazakhstan) has already increased significantly in spring, summer and fall due to increased runoff from glacier melting.[35] Melting is also expected to move earlier in the year, shifting the seasonal runoff regime and its peak earlier.[36]

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 Kazakhstan is estimated at 44,000 people and expected GDP impact is estimated at $480 million. Development and climate change are both likely to increase these figures. The climate change component can be isolated and by 2030 is expected to increase the annually affected population by 20,000 people, and GDP impact by $2 billion under the RCP8.5 emissions pathway (AQUEDUCT Scenario B).[37]

Across the country, the number of people exposed to extreme river flooding is expected to rise by 72% in the median forecast, even when assuming no change in population (see **Table 5**, below). Paltan et al. (2018) project little change in the frequency of extremely high river flows in Kazakhstan under lower emissions pathways coherent with the Paris Climate Agreement.[38] This is in contrast with most other Asian countries, which face an

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32 Broka, S., Giertz, A., Christensen, G.N., Rasmussen, D.L., Morgounov, A., Fileccia, T., Rubaiza, R. (2016). Kazakhstan – Agricultural sector risk assessment. Agriculture global practice technical assistance paper. Washington, D.C. World Bank Group. URL: https://openknowledge.worldbank.org/handle/10986/23763

33 GFDRR. (2017). Disaster Risk Profile: Kazakhstan. URL: https://www.gfdrr.org/en/publication/disaster-risk-profile-kazakhstan [accessed 04/12/2018]

34 Arystambekova, D., Jussupbekov, D., Skakova, A., Kujibayeva, G. and Mamirova, K. (2019). Assessment of Changes in the Maximum Flow of Kazakhstan Plain Rivers. Journal of Ecological Engineering, 20(5), pp. 229–234.

35 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

36 Siegfried, T., Bernauer, T., Guiennet, R., Sellars, S., Robertson, A.W., Mankin, J., Baurt-Gottwein, P. and Yakovlev, A. (2012). Will climate change exacerbate water stress in Central Asia? Climatic Change, 112, 881–899. URL: https://orbit.dtu.dk/en/publications/will-climate-change-exacerbate-water-stress-in-central-asia

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

38 Paltan, H., Allen, M., Haustein, K., Fuldauer, L., & Dadson, S. (2018). Global implications of 1.5°C and 2°C warmer worlds on extreme river flows Global implications of 1.5°C and 2°C warmer worlds on extreme river flows. Environmental Research Letters, 13. https://doi.org/10.1088/1748-9326/aad985

TABLE 5. Estimated number of people in Kazakhstan affected by an extreme river flood (defined as the 90th percentile in terms of numbers of people affected) in the historical period 1971–2004 and the future period 2035–2044. Figures represent an average of all four RCPs and assume present day population distributions.[39]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	117,276	224,725	107,449
Median	179,807	308,795	128,988
83.3 Percentile	391,621	513,913	122,292

increase in the frequency of extreme river flows. There is good agreement among models on this trend. The sole exception to this is in the area around the Irtysh River, near the north-eastern border with the Russian Federation, where what was once a 1 in 100-year river flow is projected to become a 1 in 40-year event under a 2°C global warming pathway.

An estimated 26% of Kazakhstan's population lives in areas prone to mudflows, which can occur in tandem with flooding.[40] The projected change in the quantity of rain deposited during high rainfall events, which can drive mudflows, shows a consistent increase across all pathways and time horizons typically in the range of 5%–20%[21]. One study projected mudflow to increase in frequency by a factor of 10 and pose a threat to 156 towns and cities in Kazakhstan, among them Almaty.[41]

Glacial lake outburst floods (GLOFs) are also a threat in Kazakhstan. High temperatures in summer 2015 caused a glacial lake feeding the Kargalinka River to burst its banks, sending a mudflow into the outskirts of Almaty which injured 76 and required 1,000 homes to be evacuated.[42] Research into this phenomenon identified 47 dangerous lakes of this kind in the Tian Shan mountain range, including several posing a direct threat of mudflows to Almaty.[43]

[39] 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/

[40] GFDRR. (2018). Kazakhstan. URL: https://www.gfdrr.org/kazakhstan [accessed 04/12/2018]

[41] USAID. (2017). Climate Risk Profile – Kazakhstan. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Risk%20Profile%20-%20Kazakhstan.pdf [accessed 15/11/2018]

[42] NASA Earth Observatory. (2015). Glacier Lake Outburst Flood near Almaty. URL: https://earthobservatory.nasa.gov/images/86300/glacier-lake-outburst-flood-near-almaty [accessed 04/12/2018]

[43] Bolch, T., Peters, J., Yegorov, A., Pradhan, B., Buchroithner, M., Blagoveshchensky, V. (2012). Identification of Potentially Dangerous Glacial Lakes in the Northern Tian Shan. In: Pradhan B., Buchroithner M. (eds) Terrigenous Mass Movements. Springer, Berlin, Heidelberg. URL: https://www.springerprofessional.de/en/identification-of-potentially-dangerous-glacial-lakes-in-the-nor/3784582

Natural Resources

Water

There is evidence that climate change is causing a reduction in the level of terrestrial freshwater storage (TWS) in eastern, southern, and central Kazakhstan. Data from 2000 to 2013 indicates that the loss of soil moisture in this part of the country was significantly correlated with higher temperatures, increased evapotranspiration and lower precipitation.[44] Soil moisture is a key factor for agricultural productivity in Kazakhstan, and additional losses driven by the forecast temperature increases over the coming decades could have a significant impact on the agriculture sector.[45] Similarly, higher temperatures are expected to speed the drying out of major lakes, such as Lake Balkhash in the southeast. The lake's basin is home to approximately one fifth of the population[46] and any drying out of the lake is likely to exacerbate related issues of desertification, soil salinization and dust storms.[34]

The warming projected by the model ensemble could hasten the melting of Kazakhstan's glaciers, which is expected to increase the risk of flooding in the medium-term, but subsequently lead to a reduction in the flow rate of rivers.[28] There is some disagreement between studies regarding the point when peak flows will occur.[47,48] More frequent flooding in the medium-term is likely to lead to some contamination of water supplies as pollutants from farming, mining and industry risk being washed into rivers. The expected long-term reduction in river flow will pose a risk to agriculture, given that 90% of current water use in Kazakhstan is for irrigation.[34]

Considering these mechanisms through which climate change is likely to put pressure on water resources in the region, a further complication is the transboundary nature of much of Kazakhstan's water supply. Half of its water is from sources originating in other countries[34] and regional water demand for agriculture, industry and power generation is only likely to increase in the coming decades.[49] Novikov and Kelly (2017), in an analysis of climate change and security in Central Asia, identify the basins of the Syr Darya river, the Ili river, Lake Balkhash and the Chu and Talas rivers as potential hotspots for climate-related security risks to Kazakhstan.[38]

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[44] Deng, H. & Chen, Y. (2017). Influences of recent climate change and human activities on water storage variations in Central Asia. Journal of Hydrology. 544. 46–57. URL: http://www.egi.ac.cn/xwzx/kydt/201612/W020161229657217542234.pdf

[45] 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

[46] 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

[47] Lutz, A.F., Immerzeel, W.W., Gobiet, A., Pellicciotti, F. and Bierkens, M.F.P. (2013). Comparison of climate change signals in CMIP3 and CMIP5 multi-model ensembles and implications for Central Asian glaciers. Hydrology and Earth System Sciences, 17, 3661–3677. URL: https://hess.copernicus.org/articles/17/3661/2013/

[48] Kure, S., Jang, S., Ohara, N., Kavvas, M.L. and Chen, Z.Q. (2013). Hydrologic impact of regional climate change for the snowfed and glacierfed river basins in the Republic of Tajikistan: hydrological response of flow to climate change. Hydrological Processes, 27, 4057–4070. URL: http://www.pik-potsdam.de/~fred/CentralAsia/Kure_Tajikistan_HP_2013a.pdf

[49] 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

Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. While Kazakhstan 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 6.7cm per year between 1996 and 2015, with recent research finding that evaporation played a dominant role in this sea-level reduction.[50] 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 and the Ural. If this trend will continue the Northern part of the Caspian Sea will disappear by the end of the century.[51,52] Research into the potential socioeconomic impacts of this likely fall is limited.

Land and Soil

Climate change is projected to impact on the quality of land and soil in Kazakhstan in several distinct ways. The cost to the country of the poor condition of parts of its land is already substantial, with the one estimate by the UN suggesting that pasture degradation had caused $963 million of damage, and that erosion of arable land and soil salinity had been responsible for damage of $779 million and $375 million, respectively.[53] In 2013, the FAO estimated that 23.5% of the population of Kazakhstan was living on degraded land.[54]

Data from 2000 to 2013 indicates a loss of soil moisture in eastern, central and southern part of the country, which was significantly correlated with higher temperatures, increased evapotranspiration and lower precipitation.[37] Soil moisture is a key factor for agricultural productivity in Kazakhstan, and additional losses driven by the forecast temperature increases over the coming decades could lead to a marked decrease in crop yields, especially for cereal crops.[25,55]

Increased temperatures over the coming decades are likely to exacerbate issues of high soil salinity, via increased evapotranspiration and higher water demand for irrigation. This higher soil salinity will reduce crop farming productivity.[56] The country's Seventh National Communication to the UNFCCC cites the risk of increased desertification due to rising temperatures, especially in the south of Kazakhstan.[42] An analysis of the degradation of grasslands in Central Asia between 2000 and 2014 identifies two hotspots at high risk of desertification: the transitional zone between grassland and desert that spans the width of the southern half of Kazakhstan, and a

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[50] Chen, J. L., Pekker, T., Wilson, C. R., Tapley, B. D., Kostianoy, A. G., Cretaux, J.-F., & Safarov, E. S. (2017). Long-term Caspian Sea level change. Geophysical Research Letters, 44(13), 6993–7001. DOI: https://doi.org/10.1002/2017GL073958

[51] Elguindi, N. and Giorgi, F. (2006). Projected changes in the Caspian Sea level for the 21st century based on the latest AOGCM simulations. Geophysical Research Letters, 33(8). URL: https://doi.org/10.1029/2006GL025943

[52] Russian TASS News Agency (2020). Severe shallowing predicted for the Caspian Sea by the end of the 21 Century. URL: https://nauka.tass.ru/nauka/10332517

[53] Ministry of Environment Protection. (2017). Kazakhstan's Seventh National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/20963851_Kazakhstan-NC7-BR3-1-ENG_Saulet_Report_12-2017_ENG.pdf

[54] UNDP. (2013). Population living on degraded land (%). URL: http://hdr.undp.org/en/content/population-living-degraded-land [accessed 07/12/2018]

[55] 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

[56] 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 15/11/2018]

more localized hotspot in the northwest of the country where significant browning is already occurring.[57] As land degrades, both from sub-optimal land management and climate change, the risk of dust storms grows. Dust storms are already a frequent occurrence in Kazakhstan and can act to reinforce soil degradation.[58]

Land degradation is worsened by natural hazards such as droughts, floods, mudflows, landslides and fires. Mudflows are forecast to increase in frequency by a factor of 10 and pose a threat to 156 towns and cities in Kazakhstan, among them Almaty. Fires in steppe and forest areas are projected to become more frequent in the coming decades, driven by higher temperatures and more frequent droughts, leading to degradation of land.[34]

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 submergence 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) 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.[59] 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. It is highly likely that national food consumption patterns will be affected by climate change through direct impacts on internal national agricultural operations, and through impacts on the global supply chain.

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) 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).[60] 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. Although the sector's prominence

[57] Zhang, G., Biradar, C. M., Xiao, X. , Dong, J. , Zhou, Y. , Qin, Y. , Zhang, Y. , Liu, F. , Ding, M. & Thomas, R. J. (2018). Exacerbated grassland degradation and desertification in Central Asia during 2000–2014. Ecol Appl, 28: 442–456. URL: https://pubmed.ncbi.nlm.nih.gov/29205627/

[58] Issanova, G., Abuduwaili, J., Kaldybayev, A., Semenov, O., & Dedova, T. (2015). Dust storms in Kazakhstan: Frequency and division. Journal of the Geological Society of India, 85(3), 348–358. https://doi.org/10.1007/s12594-015-0224-5

[59] 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

[60] 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

has declined steadily since the mid-1990s, agriculture still provided 18% of employment in Kazakhstan in 2017.[61] The sector includes large areas of wheat cultivation in the north of the country, irrigated farming in the south and southeast, and a traditional livestock farming subsector.

Wheat is Kazakhstan's most important crop, typically accounting for over $1 billion of exports per annum,[13] and northern Kazakhstan is considered the breadbasket of Central Asia.[38] Because wheat is mostly rain-fed and much of Kazakhstan's wheat is grown in northern areas with little potential for irrigation, yields are highly vulnerable to variations in precipitation.[34] These areas of the country currently experience drought in two out of every five years, meaning that the further increases in drought probability that are projected by the model ensemble could threaten the sustainability of the livelihoods of wheat farmers in the northern steppe areas. Without adaptation, spring wheat yields in Kazakhstan are projected to decline in the range of 20%–50% by the 2050s due to higher temperatures and reduced soil moisture during the crucial spring/summer growing season[62] The magnitude of the change is likely to vary depending both on the extent of climate change and management choices such as the variety of grain grown.[63] Such a reduction in yields could have a knock-on effect on related economic sectors. Climate change impacts on agricultural output could have indirect effects on employment and living standards in small cities whose economies depend heavily on agricultural processing.[64] As one of the largest grain exporters in the world, yield losses in Kazakhstan due to climate change are also likely to have knock on effects on the food security of import dependent nations.[65]

Livestock farming makes up a considerable proportion of Kazakhstan's agricultural output, though the sector suffers from low productivity as a result of feeding issues.[66] Increased temperatures are expected to reduce the availability of pasture during summer and autumn months, with a detrimental effect on livestock farming.[34] Expected reductions in water availability over coming decades may also impact the livestock sector, as irrigation supports meadows and pastures in some parts of the country.[67]

The pressure of climate change on water supply in the Central Asian region may create issues for irrigated agricultural areas in the southeast of Kazakhstan. Projected increases in average temperature and changes in regional precipitation could affect the melting of glaciers,[28] leading to a reduction in the long-term flow of key rivers such as the Ili and Syr Darya. Due to the transboundary nature of these rivers, a reduction in their water supply could create tension between Kazakhstan and neighbors the Kyrgyz Republic, Uzbekistan, and China.[38]

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61 World Bank. (2018c). Employment in agriculture (% of total employment). URL: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=KZ [accessed 07/12/2018]

62 Pavlova, V.N., Varcheva, S.E., Bokusheva, R. and Calanca, P. (2014). Modelling the effects of climate variability on spring wheat productivity in the steppe zone of Russia and Kazakhstan. Ecological Modelling, 277, pp. 57–67. DOI: https://doi.org/10.1016/j.ecolmodel.2014.01.014

63 Morgounov, A., Abugalieva, A. and Martynov, S. (2013). Effect of climate change and variety on long-term variation of grain yield and quality in winter wheat in Kazakhstan. Cereal Research Communications, 42(1), pp. 163–172. URL: https://link.springer.com/article/10.1556/CRC.2013.0047

64 UNESCAP. (2013). Urbanization in Central Asia: Challenges, Issues and Prospects. URL: https://www.unescap.org/sites/default/files/Urbanization-in-CA-ENG.pdf [accessed 07/12/2018]

65 d'Amour, C.B., Wenz, L., Kalkuhl, M., Steckel, J.C. and Creutzig, F. (2016). Teleconnected food supply shocks. Environ. Res. Lett, 11(035007), pp. 10–1088. URL: https://iopscience.iop.org/article/10.1088/1748-9326/11/3/035007/meta

66 FAO. (2010). Highlights on four livestock sub-sectors in Kazakhstan: Executive Summary. URL: http://www.fao.org/3/a-bl163e.pdf [accessed 04/12/2018]

67 FAO. (2012). Irrigation in Central Asia in figures – AQUASTAT Survey – 2012. URL: http://www.fao.org/nr/water/aquastat/countries_regions/KAZ/KAZ-CP_eng.pdf [accessed 04/12/2018]

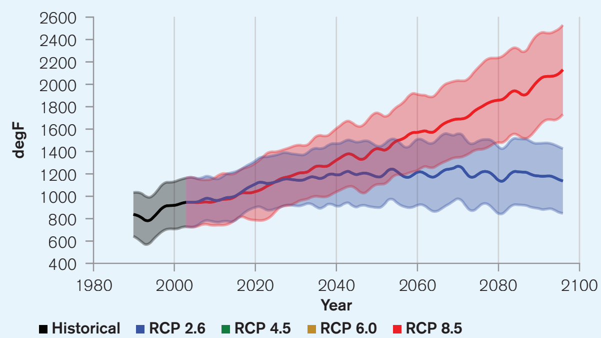
Urban and Energy

Research has established a reasonably well constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[68] 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.

The effects of temperature rise and heat stress in urban areas are increasingly compounded by the Urban Heat Island (UHI) phenomenon. Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[69] 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.[70] As well as impacting on human health (see Impacts on Communities) the temperature peaks that could result from combined UHI and climate change, as well as 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. This UHI effect is a relevant issue in Kazakhstan, where 53% of the population lives in urban areas.[34]

Research suggests that on average a one degree increase in ambient temperature can result in a 0.5%–8.5% increase in electricity demand.[71] Notably this serves business and residential air conditioning systems. This increase in demand places strain on energy generation systems which is compounded by the heat stress on the energy generation system itself, commonly due to its own cooling requirements, which can reduce its efficiency.[72] The number of cooling degree days (when such cooling systems would be required) is projected to increase significantly by the 2090s in the highest emissions (RCP 8.5) pathway (**Figure 11**).

FIGURE 11. Historical and projected annual cooling degree days in Kazakhstan (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[21].



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[68] 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

[69] 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

[70] 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

[71] 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://doi.org/10.1016/j.enbuild.2014.09.052

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

On the other hand, increases in minimum temperatures are expected to lead to a significant fall in heating degree days by 2090s under the RCP4.5, RCP6.0 and RCP8.5 pathways. This 15%–30% fall in heating degree days may lead to a reduction in electricity demand during winter months, offsetting the increase in demand seen during summer. Further research is required to quantify the net human and economic impacts.

In addition to these effects on energy demand, climate change could affect energy supply in Kazakhstan in various ways. Any reduction in river flows as a consequence of glacial loss could reduce the country's long-term generation capacity via hydroelectricity,[34] which accounted for 11% of electricity production in 2016 and remains the only form of renewable energy that is operating at scale in Kazakhstan.[73] More frequent extreme weather events such as floods and mudflows are also expected to cause damage to Kazakhstan's extensive energy transmission grid.[34]

Communities

Poverty and Inequality

Many of the climate changes projected are likely to 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.[74] Poorer households and businesses are least able to afford air conditioning, an increasing need given the projected increase in cooling days. In the southern regions of Kazakhstan, which are the hottest parts of the country and expected to experience the most severe maximum temperatures in coming decades, poverty is more prevalent, with 10% living on incomes below subsistence level as opposed to just 2% in Nur-Sultan and Almaty. This suggests that the people of southern Kazakhstan may struggle to afford the adaptation measures needed to cope with extremely high temperatures.

Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation. The risk of flooding, landslides and mudslides is expected to be most severe in the foothills of the south and east of Kazakhstan, where terrain is more mountainous and rainfall levels are higher. Farmers in these areas are generally relatively poor, own small farms and produce mostly for their own subsistence, meaning that the threat to their livelihoods from the aforementioned hazards is significant.[25]

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

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[73] IEA. (2018). Electricity generation by fuel. URL: https://www.iea.org/statistics/?country=KAZAKHSTAN&year=2016&category=Key%20indicators&indicator=ElecGenByFuel&mode=chart&categoryBrowse=false&dataTable=ELECTRICITYANDHEAT&showDataTable=true [accessed 16/11/2018]

[74] 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

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.[75]

Vulnerability to Climate-Related Disaster

Among the natural hazards that pose the highest threat to Kazakhstan are droughts (8 major events between 1985 and 2013), floods (6 major occurrences in the same period), pests and diseases (6 major occurrences).[25] Droughts in the country can decimate crop yields, cause death of livestock, threaten drinking water supplies, stifle power generation via hydroelectricity and speed the process of soil degradation.[25]

The deadliest recent flood occurred in 2010, killing more than 40 people, while the more economically damaging floods of 1993, 2008 and 2011 caused $60–100 million worth of damage each. Flooding is more prevalent in southern and eastern parts of Kazakhstan where these is significant economic vulnerability to their impacts. Locust infestations occur periodically in Kazakhstan, affecting northern wheat-growing areas more severely. Recent disasters of this kind wiped out 220,000 hectares of wheat in 1999 (out of a total of 8.7 million hectares under cultivation) and a further 200,000 hectares in 2008 (out of a total of 12.9 million hectares).[25] The temperature increases that are projected by the model ensemble could widen the geographical range of locusts in Kazakhstan.

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.[76] Springmann et al. assessed the potential for excess, climate-related deaths associated with malnutrition.[77] 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 42.97 climate-related deaths per million population linked to lack of food availability in Kazakhstan 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.[78] 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. The model ensemble projects an increase (albeit with high uncertainty) in the number of days with temperatures above 35°C, with an ensemble median increase from around 8 days per year to 38 days per year over the 21st century.

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75 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

76 WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Programme. URL: https://documents.wfp.org/stellent/groups/public/documents/communications/wfp288231.pdf

77 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

78 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. https://advances.sciencemag.org/content/3/8/e1603322

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.[79] More specifically, one study showed a 1°C rise is associated with a 1.9% increase in the daily number of deaths from cerebrovascular diseases and a 3.1% decrease in the number of deaths from hypertensive diseases among women.[80] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[81]

Disease

The impact of climate change has the potential to increase the threat of disease in Kazakhstan in various ways. More frequent flooding (as a result of the retreat of glaciers and more erratic precipitation patterns) is expected to negatively affect drinking water quality, as pollutants from industry, mining and agriculture are washed into water resources. This could increase the threat of gastrointestinal disease, which is already a major cause of death in Kazakhstan.[34] Warming is also projected to hasten the spread of infectious diseases carried by ticks, mites and rodents, such as Crimean-Congo Haemorrhagic Fever.[34] An outbreak of Crimean-Congo Haemorrhagic Fever in 2009 led to 30 deaths in Kazakhstan.[82] Although there is a lack of available data on air pollution in Kazakhstan, what data are available suggest that the concentration of key air pollutants is rising in Nur-Sultan and Almaty. The effect of poor air quality on mortality and respiratory diseases in these cities is expected to worsen as climate change developed.[83]

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 (NDC) to Paris Climate Agreement	Submitted	December, 2016
Technology Needs Assessment (TNA)	Completed	2013
National communications to the UNFCCC	Seven submitted	Latest: 2017
Name of National Adaptation Plan (of Action) or local equivalent	No official submission	See: Adaptation processes

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79 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: 10.1007/s12199-013-0354-6

80 Grjibovski, A., Nurgaliyeva, N., Kosbayeva, A., Sharbakov, A., Seysembekov, T. and Menne, B. (2012). Effect of high temperatures on daily counts of mortality from diseases of circulatory system in Astana, Kazakhstan. Medicina, 48(12), p. 94.

81 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: 10.1038/s41558-018-0210-1

82 WHO (2009). Kazakhstan. URL: http://www.euro.who.int/__data/assets/pdf_file/0010/132949/Protecting_health_KZH.pdf?ua=1 [accessed 04/12/2018]

83 Russell, A., Ghalaieny, M., Gazdiyeva, B., Zhumabayeva, S., Kurmanbayeva, A., Akhmetov, K. K., . . . Althonayan, A. (2018). A Spatial Survey of Environmental Indicators for Kazakhstan: An Examination of Current Conditions and Future Needs. International Journal of Environmental Research, 12(5), 735–748. https://doi.org/10.1007/s41742-018-0134-7

Climate Change Priorities of ADB and the WBG

ADB – Country Partnership Strategy

In ADB's Country Partnership Strategy 2017–2021 with Kazakhstan, ADB commits to support the government in building a more economically diversified, socially inclusive, and environmentally sustainable Kazakhstan that enjoys high growth rates and stable macroeconomic conditions. Climate change issues are featured in Pillar 3 of the CPS, "Fostering sustainable, green growth in response to climate change", under which ADB will foster sustainable, green growth in response to climate change by promoting energy efficiency and the use of renewable energy sources, and supporting climate change mitigation and adaptation efforts.

Priority Areas	Interventions
Promoting energy efficiency and renewables	ADB will support achieving Kazakhstan's commitments at the Paris climate agreement by formulating and implementing resolute energy efficiency policies, including updating technologies and equipment. ADB will help resolve bottlenecks in electricity grids and promote the use of renewable energy sources. It will support the development of green housing and green transport systems, and the adoption of reforms to facilitate cross-border energy and emissions trade.
Supporting climate change mitigation and adaptation efforts	ADB will help Kazakhstan reach its climate change mitigation and adaptation goals identified in its national plans and INDCs. Interventions may include efficient low-carbon, alternative electricity, heat production and transmission, expansion and modernization of climate-proofed infrastructure, and focused financial products promoting energy efficiency and climate resilience. ADB will support enhancing solid waste management and sanitation systems to improve water quality and reduce environmental pollution. Interventions will be in line with Kazakhstan's greenhouse gas mitigation efforts and commitments to reduce climate change vulnerabilities.

WBG – Country Partnership Framework

Kazakhstan and the World Bank have recently completed its most recent Country Partnership Framework (CPF) for 2020–2025.[84] Climate change featured strongly and both parties have confirmed efforts for "ensuring development is environmentally sustainable". This aligned with Kazakhstan's own development goal to "fight climate change with a cleaner environment". Projects focused on rehabilitation of groundwater, reduction in gas flaring, reforestation, and rehabilitation of water supply systems.

[84] WBG (2020). Kazakhstan Country Partnership Framework 2020–2025. URL: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/950671576378842710/kazakhstan-country-partnership-framework-for-the-period-fy20-25

CLIMATE RISK COUNTRY PROFILE

KAZAKHSTAN

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK