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Climate Change Profile: Tajikistan

This profile provides an overview of projected climate parameters and related impacts on the agricultural and health sectors, water resources, and infrastructure in Tajikistan under different **Greenhouse Gas Emissions (GHG) emissions** scenarios (called **Representative Concentration Pathways, RCPs, with its lower radiative forcing RCP2.6 and higher radiative forcing scenario RCP8.5**). By using easy-to-read graphs and text intended for non-experts, this climate change profile is built on the latest climate data and state-of-the-art modelling.

Climate Projections

Compared to the 1986-2005 level, the **annual mean temperature of Tajikistan** is projected to rise between **1.3°C and 6.3°C by 2080,** depending on the future GHG emissions scenario. Under the high emissions scenario, RCP8.5, annual temperatures will increase by approximately **1.7°C in 2030, 3.1°C in 2050, and 5.4°C in 2080**.

Increasing temperatures will lead to a **retreating snowline and** a **loss of glacial mass** which will cause a **decrease in water storage capacity. Increasing temperatures will generate** an **increase in the variability of river discharge** as well as **fluctuations in water availability and quality**; therefore, negative repercussions on agriculture are to be expected. Additionally, increasing temperatures are associated with a likely **increase** in the **risk of spring flooding** and **glacial lake outbursts** during snowmelt.

Winter precipitation will increase while spring precipitation will likely remain at its current level. However, based on the same model ensemble, **heavy rainfall events (>20 mm) will increase during the spring months.**

As a consequence of increasing temperatures**, fewer frost days will occur**. Under the high emissions scenario, RCP8.5, frost days will decrease **to approximately 212 days in 2030, 200 days in 2050, and 170 days in 2080**.

Climate change will likely **increase** the existing **vulnerabilities and risks for infrastructure**. **Roads are particularly susceptible** to damages induced by **changes in temperature** and **extreme heat. Moreover, changes in river flow levels would lead to fluctuations in hydropower generation.** Further **climate-related risks** identified regarding infrastructure are **mudflows, droughts**, **high temperatures,** and **strong winds**.

The **number of heat days above 40°C is expected to increase by 12.5 days by 2080** compared to the 1986-2005 period. Consequently, this will lead to an increase in **heat-related health issues** such as **heat stress** and **heat-related mortality.** An increase in **food insecurity** in conjunction with an expected **reduction in agriculture** and **pasture productivity** will likely cause negative effects on the already-critical **nutritional status** of the population**.** An increase in **gastrointestinal infections** is projected alongside an increase in floods, **flood-related water contamination,** and the increase of exposure to **water and foodborne diseases. Frequent** and **severe infectious disease outbreaks** are more likely because of climate change, **as is the re-emergence of Malaria.**

The **Growing Season Length (GSL)** is **expected to increase**. Under the high emissions scenario, RCP8.5, GSL will be approximately **150 days in 2030, 165 days in 2050, and 200 days in 2080.** Increased temperatures, however, counteract the positive effect of a longer GSL.

Despite an extended GSL, the **agricultural productivity** during the growing season is **at risk** due to **rising temperatures**, **more frequent and intense heatwaves,** as well as the risk of **less irrigation water availability** due to higher evaporation and glacier retreat (especially in late summer).

Summary

Tajikistan is a **low-income country** with an **Int$4,050*** gross national income (GNI) per capita and a **population of 9.1 million as of 2018** [1]. Tajikistan continues to be the poorest country **among** the **former Soviet Republics** [2]. The United Nation's Population Division projects Tajikistan's **population to increase to** about **25 million** people **by 2100** [3]. **Agriculture** is the **second largest sector of the economy**, accounting for **19%** of the country's **GDP** of 7,523 billion USD and **51%** of its **employment** in 2018 [4]. While the agriculture and livestock sector dominates the Tajik economy, only around **30% of the country ʻs total land area** is **classified as agricultural and 7% as arable**. Of these agricultural lands, **81% consist of rainfed pastureland** [5]. Of the **permanent cropland,** only **68%** is being **irrigated** which makes Tajikistan the Central Asian country with the lowest irrigated land to population ratio [5]. Moreover **cotton,** the country's **most important cash crop,** being a water intensive crop while as well being grown under **arid climate conditions** makes Tajikistan's **agriculture heavily dependend on irrigation,** including other primary agricultural products such as fruits and vegetables [6]. This situation partially accounts for Tajikistan's high susceptibility to the effects of climate change. This vulnerability is further enhanced as **remittances**, primarily from migrants working in Russia, accounted for approximately **31% of Tajikistan's GDP** in 2018 [7]. These remittances make Tajikistan one of the countries most economically dependant on external factors and vulnerable to global market fluctuations. In response to this double challenge of a high vulnerability to outside forces and the projected increase in population size, the **government intends to accelerate Tajikistan's industrialization** [8]**.** This industrialization is further facilitated by a planned **increase in energy generation capacity** from its currently installed 5,400 MW to 10,000 MW by 2030, **90%** of which will be **through hydropower plants** [9]. Since **hydropower is important** for Tajikistan's economic development, so is its energy security which is particularly **vulnerable to climatic and hydrologic variability** and the effects of climate change such as rising temperatures, droughts, and storms [10]. It is estimated that the **cost of environmental degradation and climate change** will **reduce** the **GDP per capita** by **up to 15% by 2100** [11]. Some of the ways that the changing climate is already negatively affecting the economy, society, and ecosystems the country are through the accelerated rate of soil erosion caused by extreme weather events, deteriorating water availability and quality from increasing glacier melt, the loss of biodiversity, among other factors [11]. Extreme weather events (such as floods, droughts, avalanches, and landslides) regularly destroy land, crops, infrastructures, and livelihoods. **In 2010, annual losses from climate-induced extreme weather events were estimated at 600 million USD (4.8% of Tajikistan's GDP) and correspondingly, the average annual losses for the period between 1996 and 2015 is estimated at 7.4% of GDP** [13]**.** These losses indicate the need for immediate adaptation activities. The most common impacts are those of land degradation and the erosion of fertile topsoil as well as the impacts on infrastructure due to extreme weather events like mudflows. Additionally, the population's health is already negatively affected by climate change. The combination of the increasingly erratic frequency and increased intensity of extreme weather events, as well as the change in the hydrological cycle, is **reducing agro-pastoral productivity** which majorly **impacts the food and nutrition security** [13] and contributes to biodiversity loss. The higher temperatures combined with higher levels of flood-related water contamination are projected to further augment the risk of infectious disease outbreaks and increase the risks of water and foodborne diseases such as gastrointestinal infections [15]. Simultaneously, much of the country's health care infrastructure is in a precarious state. Most **rural medical institutions** and rural schools are **lacking proper sanitation and water facilities** which is in part why access to adequate health care is considered limited to the urban middle and upper classes. This situation accounts for how Tajikistan is among the Central Asian countries with the weakest health care systems. This situation is further compounded by the **high susceptibility** of many of its **health facilities** to the **effects of extreme weather events** [13]. Considering the high level of agreement around the projected increase in temperature and the change in precipitation patterns in Tajikistan, it is almost certain that climate-induced impacts will increase accordingly. Tajikistan's relatively low level of socio-economic development, its inadequate infrastructure, as well as its high dependency on climate-sensitive sectors make the country extremely vulnerable to the risks associated with climate change and related climate-induced extreme weather events.

*International dollars using purchasing power parity rates

Key Figures for Tajikistan

Demographics

Tajikistan today has
9 101 000 inhabitants
of which **72.8%** live in rural areas

Access to Basic Needs

47% of the population lives in absolute poverty*

*less than USD 1.33 a day

Access to improved drinking water:
Urban: 90.1%
Rural: 66.7%

Access to clean fuel / technologies for cooking and heating: **80%**

Electrification rate: **100%**

Food Security

76% of the rural population is **food insecure**, while on average, **70-80%** of the **household income** is spent on food supplies

30.1% of the of the Tajik population is undernourished

Child stunting (6 months – 5 years): **26.8%**
Child wasting (6 months – 5 years): **10%**

Topography & Farming

Altitude range **300 – 7 495 m.a.sl.**

Of the total area of **142 600 km²**, **30%, is agricultural land** and only **7% is arable land**

81% of the agricultural land is rainfed **pastureland**

51% of the population is employed in the **agricultural sector**, of which **69% are women**

69%

Agricultural Land Distribution

Household plots: **5-6%**
Dekhan* farms: **60%**
Female-owned Dekhan farms: **19.4 %**

*privately owned commercial farms

88% of Tajikistan's farmers work on Dekhan farms, earning **40%** of their income from crop production.

Small farms (<0.2 ha) sell approx. **18%** of their total production

Water Usage

Irrigation & Livestock: **90%**
Municipal: **6%**
Industry: **4%**
Water-use efficiency: **27 – 46%**

Sources:
World Bank – Development Indicators (WDI, 2014, 2016, 2018), Central Intelligence Agency World Factbook (CIA, 2016, 2018); World Food Programme (WFP, 2012, 2015, 2019); United States Agency for International Development (USAID, 2016); Agency for Statistics under the President of the RT (TAJSTAT, 2017); Food and Agricultural Organization of the United nations (FAO, 2007); and FAO – Global Information System on Water and Agriculture (AQUASTAT, 2006)

Topography and environment

Tajikistan is a **land-locked** country and **93%** of its total land area, 142,600 km², is **covered by mountain ranges** which are dominated by the Alay Range in the north and the Pamir Mountains to the southeast. Ismoil Somoni Peak's altitude is 7,495 meters, which is the highest elevation in both the country and the former Soviet Republics. Additionally, there are 24 more peaks with an altitude of over 6,000 meters situated in Tajikistan and more than **half of the country is above 3,000 meters** in elevation. The lowest elevations are in the northwest, the southwest, and the Fergana Valley – which dominates the country's far northern section. The mountain ranges are interspersed with deep valleys formed by a complex network of rivers [15].

The Fedchenko Glacier, which covers 700 square kilometers in the east of Tajikistan, is the largest non-polar glacier in the world; however, it is only one of the numerous glaciers and lakes located in the eastern mountain ranges of Tajikistan [15]. The stark differences in elevation and the especially varied climatic conditions in these bio-geographical zones have led to a **rich biological diversity** dispersed throughout the country. However, the combination of the high amount of livestock movement between the valleys in winter and the high mountain pastures in summer plus the lack of well-defined land-use rights and insufficiently mapped pasture corridors has led to severe land degradation and biodiversity loss [6].

Only about **3%** of the country's total surface area is still categorized as **forest** - of which the **majority is degraded**. The destruction of Tajikistan's remaining forests started immediately after its independence and it accelerated during the civil war from 1992 to 1997. In the post-Soviet era, rural households were not guaranteed coal, oil, or gas for their daily energy needs. This lack of guaranteed supply in energy led to the accrued need for alternative sources of fuel, such as wood, which resulted in the degradation of Tajikistan's surviving forest resources [16].

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Climate trends from 1900 to 2016

***Present Climate*:**

Tajikistan is located in the subtropical zone and has a **mainly continental climate**, however, it has drastic differences in climatic conditions according to elevation. Depending on the altitude, the **climate can vary between arid to semiarid, summers can vary between long and hot to short and warm, and winters can vary between short and mild to long and severe**. Using the popular Köppen-Geiger climate classifications[1], the two most prevalent climates in Tajikistan are the **Cold semi-arid (BSk)** and the **Hot-summer Mediterranean climate (Csa).** The changes between the four main seasons are relatively abrupt. In the subtropical southwestern lowlands, which experience the highest temperatures, the climate is **particularly dry**. The **summer temperature** range in these **lowlands** is generally between **27°C to 30°C** with extremes of up to +50°C. The **winter** range is from **–1°C to 3°C.** In the **eastern Pamirs** on the other side of the country, the **summer temperatures** range from **5°C to 20°C**, and in **winter,** from **–15°C to –20°C**. In some areas (such as the province Murgab which borders China) winter temperatures can drop to –45°C; moreover, extremes of -60°C can be reached in the highest mountains. **Annual precipitation** in the lowlands and the mountain **valleys** average between **100 and 250 mm per year**; while at the **higher elevations** (such as the high plateau of the **Eastern Pamirs),** average precipitation is only between **60 and 80 mm per year**. The highest precipitation rate in a year was 2,236 mm and was measured near the Fedchenko Glacier in eastern Tajikistan [15].

Climate Trends over the last century:

Figures 1 and 2 (shown below) illustrate existing trends for the annual mean temperature and precipitation observed over the last century[2]. Here, precise values for temperatures and precipitation for specific locations cannot be applied because precise values – especially for temperature – strongly vary with elevation (approx. 0.6°C per 100 meters). The observed annual mean temperatures for Tajikistan show an increasing trend over the 20th century. Winter precipitation shows high fluctuation but overall an increasing trend (3.3 mm per 10 years), while similarly volatile spring precipitation shows only a slight increase in the last century that does not indicate a significant trend over 10 years.

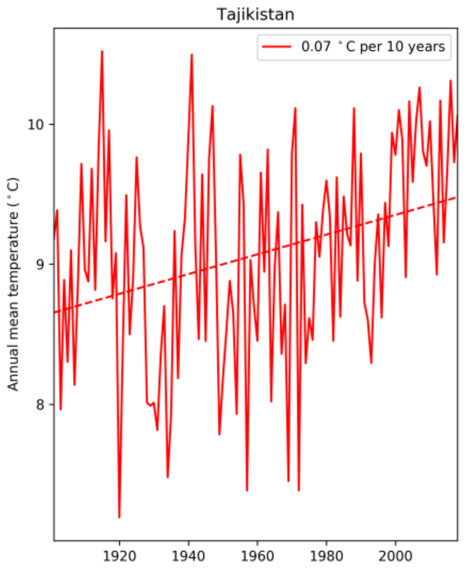

Figure 1: Past climatic trends for annual mean temperature from 1900 to 2016. Dotted lines represent the linear trend over time. The significant change per 10 years is noted in the upper right corner

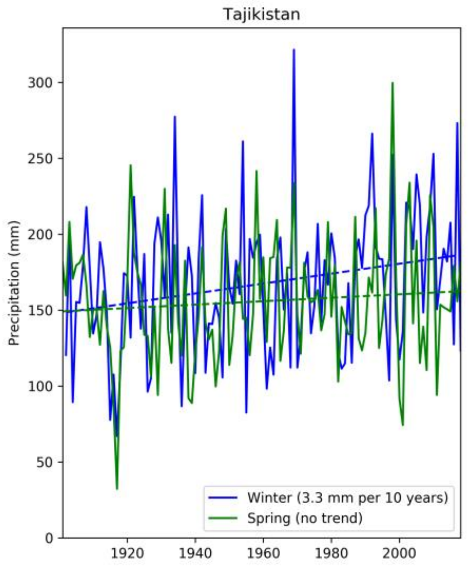

Figure 2: Past climatic trends for winter and spring precipitation from 1900 to 2016. Dotted lines represent the linear trend over time. The significant change per 10 years is noted in the lower right corner.

[1] *The Köppen climate classification divides climates into five main climate groups, with each group being sub-divided based on seasonal precipitation and temperature patterns. Each group and subgroup is represented by a letter. The five main groups are A (tropical), B (dry), C (temperate), D (continental), and E (polar).*

[2] *The time series for past annual mean temperatures and precipitation are based on the dataset of the University of East Anglia's Climatic Research Unit (CRU), which has combined data of local stations, which are part of the World Meteorological Organization (WMO) station network, into a grid data format of half degree resolution (https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.03/)*

Climate Change impacts on Agriculture

Agriculture is among the sectors **most exposed to climate change** globally and especially in Tajikistan. Recent reports and simulation studies predict adverse effects on the global yields of all major crops due to climate change [17]. In Tajikistan, agriculture is increasingly being challenged by the **change in the hydro-meteorological regime** which results from climate change. **68%** of the **permanent cropland of Tajikistan depends on irrigation.** The **expected reduction in river flow** due to accelerated glacier melting – which is expected to increase – poses a further existential challenge to the country's crop production. This challenge is especially relevant for irrigation-dependent crops, specifically cotton [5]. Climate-induced impacts on crop yields will nevertheless be varied, crop-specific, and site-specific.

In terms of crop productivity, it is important to note that although the multi-model mean of the high emission scenario (RCP8.5) indicates an **increase in extreme precipitation** (above 20 mm/ day), this increase is **rather moderate** with an approximate **increase by 1 day** reaching a **total of 3.5 days by 2080**. On the other hand, the multi-model mean for the same high emissions scenario projects an **increase for heat days (>40°C)** by **12.5 days** and for **tropical nights** to a value of **almost 10 nights per year by 2080**. These projections can be translated indirectly into potentially more intense and frequent droughts which will impact agricultural yield quality and quantity. In addition, **tropical nights intensify the impacts of heatwaves** as a livestock's ability to cope with high temperatures during the day is diminished due to insufficient cooling for recovery at night.

Furthermore, the **negative consequences of** more frequent and intense **heat waves** would likely **jeopardize** any potentially **positive results** for agricultural productivity due to a projected **increase in the growing season length (GSL)**. Under the high emissions scenario, the projected **reduction in frost days** will reduce the risk of frost damage to crops and livestock, but will also likely increase the risk of pests and diseases which no longer can be eradicated by low temperatures.

Overall, to make it possible to **"Climate Proof**" the **agricultural sector,** various adaptation options to climate change need to be evaluated against the projected climate risks, and the **alternatives to current agricultural practices** must be identified. Amongst these, the following strategies should be considered accordingly: Facilitating changes in the production systems by promoting sustainable and resilient agriculture techniques; The bridging of respective transitional costs or adaptation costs due to the introduction of new methods of production; Increasing awareness and the building of a sound knowledge base regarding climate trends, risks, and options for producers and other agricultural businesses and financial institutions; Providing access to and facilitating the interpretation of weather and climate information for seasonal as well as long-term planning by the Ministry of Agriculture, local producers, and extension service providers; Supporting alternative income options, diversification, and introducing risk-sharing strategies.

Climate Change impacts on Water Resources

An **increase in mean temperatures** will lead to more evaporation and consequently, vegetation (such as **pastures** and **crops)** will **require more water** to sustain their production. If precipitation during the vegetation period does not increase – as is the case during spring – periods of water scarcity will last longer and affect more people both directly and indirectly.

An **increase in the mean precipitation** at locations **above the snowline** causes a **potential increase** of the **snow-depth** if slopes are level enough. But at the same time, the **snowline** can generally be **expected to retreat** due to higher temperatures. Whether the total amount of snow increases or decreases depends strongly on local conditions such as elevation and sun exposure. For the moment, only local hydrological observations can offer definitive answers to these questions. Regardless of these local circumstances, the fact remains that if **less water** is **stored as snow** – the source responsible for providing the **largest portion of irrigation water** during the vegetation period – then water availability might **become unreliable and** eventually **scarce**. Moreover, the **retreat of glaciers**, the **loss of glacial mass,** and the related **decreased water storage capacity** resulting from the projected higher temperatures will **increase the flow variability of rivers and** strongly contribute to **fluctuations in water availability and quality.** These factors are especially concerning **at the end of summer and the end of the vegetation period** when most other water sources have already been exhausted.

In summary, the observed trends contribute to an **increased risk of water scarcity** for different sectors that rely on irrigation water. Additionally, there is a likely **increase** in the **risk of spring flooding** as well as **glacial lake outbursts** during snowmelt due to the quantity of meltwater exceeding its historical level.

Climate Change impacts on Human Health

Climate change related increases in the frequency and intensity of **extreme weather events** (such as heatwaves and droughts and **changes in hydrological cycles** favoring mudflows, landslides, glacier lake outbursts, floods, and avalanches) are predicted to lead to various **direct** as well as **indirect,** detrimental **effects on human health.**

Climate change is projected to lead to a **reduction in agriculture** and **pasture production** capacity which will have ramifications on the **food security** and the **nutritional status** of the population. **More frequent** and **severe,** infectious **disease outbreaks** as well as an **expansion** in the **exposure** to **water and foodborne diseases are likely** consequences of shifting habitat conditions and the projected reduction in the ecosystem's capacity to provide important services and a loss in biodiversity [13]. Increasing temperatures and **flood-related water contamination** are equally projected to further **increase the rates of gastrointestinal infections** [18] and they will also create more favorable conditions for the reproduction of Malaria mosquitoes; therefore, increasing the country's subjectivity to Malaria [19]. **Rising temperatures** will result in **more frequent heatwaves** in Tajikistan leading to an increase in **heat-related issues** such as **heat stress** – which is particularly dangerous for vulnerable groups such as the elderly and small children and infants. Furthermore, **heat stress** might have secondary effects in terms of labour capacity since increasing temperatures could impact the **activities of labourers**, especially in the southern and northern lowland regions. The **number of heat days above 40°C is expected to increase**. Under the high emissions scenario, RCP8.5, the multi-model mean for heat days (>40°C) shows an increase of up to **12.5 days by 2080** (relative to 1986-2005 period). In addition, under the high emissions scenario, RCP8.5, there is a projected **increase** of the multi-model mean for **tropical nights** to a value of almost 10 nights per year by 2080.

At the same time, Tajikistan already suffers from **chronic weaknesses of its health care infrastructure,** an example of which is the insufficient and improper sanitation and water facilities in most rural medical facilities and schools. Much of the **physical infrastructure** of the country's rural **health facilities** (e.g. heating, electricity, communication systems, water supply, sewage, and sanitation infrastructure) are **highly vulnerable to the effects of extreme weather events**. This further reduces the capacity of the health care system to cope with the emerging challenges of climate-induced health issues and the effects of extreme weather events on the population [13].

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Climate Change impacts on Infrastructure

Extreme weather and climate risks in Tajikistan have **led to frequent damages to** houses, roads, bridges, riverbank enforcement structures, and other **infrastructure** such as irrigation channels and electric lines. A study from 2019 identified **mudflows, droughts**, **high temperatures,** and **strong winds** as main **climate-related risks** that cause damages and losses on many types of infrastructure [20].

In general, **roads** are **particularly exposed** to changes in temperature and **extreme heat** events [21]. To partially reduce this risk in Tajikistan, vehicles of more than 6t per axle are not allowed to drive from 10am to 8pm during the summer months when the temperature reaches above 26°C to avoid pavement deformations. Such **measures,** though **necessary to preserve the condition of the road, cause traffic disruptions,** and have direct impacts on the local and national economy [22]. **High precipitation** events plus increases in water levels **impact road foundations** as well as the capacity of drainage and overflow systems to deal with stronger or faster water flows that lead to floods and siltation **that affect bridges** [21].

The **vulnerability of transport infrastructure** is at the heart of **local resilience to climate change.** Infrastructure is simultaneously **vulnerable to extreme weather events** and also **essential for livelihoods** and access to socio-economic services such as healthcare, education, and credit (especially in rural and remote areas). Infrastructure is additionally **very important for post-disaster recovery and reconstruction** [22].

Extreme weather events (such as mudflows triggered by heavy rains, droughts, **high temperatures,** and strong winds) can also have **devastating effects on economic production** sites and settlements. The **incurred damages** of such events highly **depend** on the **quality of the building materials** which are related to the availability of **financial resources.** Due to the important role of remittances for the local economy, new houses are often built by families receiving remittances and are more likely to be constructed from high-quality, sturdy materials. A decrease in remittances consequently influences the quality of the houses built [22].

Overall, climate change will decrease the **life span of infrastructure,** while significantly increasing the **maintenance costs** to keep infrastructure functioning [23].

A **hotter climate** will also amplify the effect of **less snow** and **more rain in winter** as well as **early snowmelt in spring** which will lead to **more water during a reduced period in spring and less water for the rest of the year**. The resulting **droughts** and **floods** equally **affect infrastructure such as hydropower generation** plants [24].

Furthermore, the risks resulting from the impacts of **droughts and mudflows** are **likely connected** because **droughts increase land degradation** and may consequently lead to a **higher** susceptibility towards **erosion and mudflow**. However, **erosion and mudflows** have to be considered as **intermediate impacts** since these impacts are not entirely caused by climate-related hazards, but rather, they **require a precondition such as land degradation** [20].

It can hence be established that the **most important factors aggravating** these **climate risks** in the region in the last decades are the **increase in vulnerability due to socio-economic developments.** As such, the increase in intensity in sediment – and mudflows in the case of heavy rain events – is mainly caused by **land degradation** due to **higher livestock numbers** and **lack of adequate pasture management** [20]**.**

Additionally, **population growth** and **remittances have further increased** the **exposure to hazards** in the last 20 years due to the construction of new houses, roads, bridges, riverbank enforcement structures, and other infrastructure (irrigation, electricity network) in the vicinity of rivers, gullies, and other vulnerable areas [20].

The following **key figures** are an attempt to **quantify** the above-described **risks to infrastructure** related to climate change:

Of the 14,000 kilometers of registered roads in Tajikistan, over **500 km are annually exposed to adverse natural events**, among which climatic factors play the main role. Today, there are about **1,200** reported **landslide areas** that directly pose a threat to settlements, roads, irrigation facilities, and other infrastructure [25]. **Annually,** roughly **100,000 people** are **affected by flooding** [26]. Overall, in the period **from 1992 to 2016,** major **disasters** caused **economic losses above 1.8 billion USD** and affected more than **80% of the population** of Tajikistan [27].

In summary, the above-described **occurrences of disasters** such as **landslides, mudslides, floods, and droughts** are indicative of the already **high level of exposure** of Tajikistan's **population** and **infrastructure to weather and climate events**. The combined catalyzing effects of land degradation and climate change are now further augmenting this high level of risk [29].

Projected climate change

It is **virtually certain** that **annual mean temperatures will increase** – not only within the near future, but also to the end of the 21st century and beyond. Similarly, rainfall patterns are expected to shift throughout seasons as well as geographical locations. These are the conclusions from state-of-the-art climate modelling techniques which have already successfully modelled the past climate of not only of the last century, but also the climate over the past period of some hundred-thousand years in agreement with data from ice-cores.

Therefore, it is not a question of whether a warming climate is to be expected, but rather, **how much will mean temperature increase and how fast?** The main contributing factor for the warming is the amount of future global greenhouse gas emissions. Fortunately, even if we do not know the exact future global greenhouse gas concentration pathway, (as this depends on future emissions and climate action efforts taken under the Paris Agreement), we can nevertheless estimate an upper and lower value for possible future global greenhouse gas concentrations based on different scenarios that determine the future climate. It needs to be noted that only existing trends over time can be identified thus, **no statements about individual years can be made**. Further, the geographic resolution of climate projection is limited to approximately 20km. Therefore, in mountainous regions, it is neither possible to apply precise values for temperatures nor precipitation for a specific location (e.g. a village) because precise values – especially for temperature – **strongly vary with elevation** (approx. 0.6°C per 100 meters). However, relative changes correlate over much larger areas than the constraining resolution. Climate trends can either be depicted as maps to show the changes in geographic locations or as time series to depict the trend over time. Depicting climate trends as a map is especially interesting in regions with a large range of altitudes, such as Tajikistan.

The following explanation of the different, future emission scenarios and climate change scenarios presented as maps and time series is intended to facilitate the reader's experience.

Future emission scenarios and climate change scenarios

All figures and analyses of projected climate change presented in this document are based on simulations and climate model outputs produced in phase 5 of the Coupled Model Intercomparing Project (CMIP5)[3] in 2014, and are also used for the 4th Assessment report of the Intergovernmental Panel on Climate Change (IPCC).

All used global climate models of CMIP5 based their simulations on different **Representative Concentration Pathways (RCPs)**. RCPs are comprehensive future greenhouse gas concentration pathway scenarios adopted by the IPCC. The term, 'pathway' emphasizes not only the long-term concentration levels of interest, but also the trajectory taken over time to reach that outcome. The number at the end of every RCP identifier represents the strength of the radiative effect at the top of the atmosphere due to a change in the concentration of all greenhouse gases projected to be emitted under the corresponding emissions scenarios by the year 2100. The higher this number, the stronger the associated global warming.

RCP2.6 requires the **emissions to start declining by 2020** as well as increased CO_2 sequestration and is likely to keep **global temperatures below 2** degrees by 2100 (corresponding to the Paris Agreement). **RCP4.5** expects emissions to **peak around 2040** with the consequence that **warming** (mean over models) **is limited to 2-3°C** until the end of the 21st century. **RCP6.0** expects emissions to **peak around 2080. RCP 8.5** expects **emissions to rise throughout the 21st century**. For each scenario, a multi-model ensemble is considered where each model provides a result. This leads to a multi-model range for each scenario.

Data sources are the **Climate Explorer of the Royal Netherlands Meteorological Institute**[4] **(KNMI)**, the **Climate Change Knowledge Portal**[5] **of the World Bank,** and the **WorldClim** dataset.

Climate change scenarios presented as maps	Climate change scenarios presented as time series
Here, simulations are based on 16 models and two different emission scenarios **(RCP 4.5 and RCP 8.5)** to assess the range of potential climate change in Tajikistan for the 2050s and 2070s.	**Projections are presented for RCP2.6 (the Paris agreement target), RCP 6.0 (business as usual), and RCP 8.5. (unabated high emissions).** The colour shaded areas in the diagrams show the range of the multi-model ensemble between the 25th and 75th percentile.

[3] *http://cmip-pcmdi.llnl.gov/cmip5/*
[4] *https://climexp.knmi.nl/plot_atlas_form.py?id=someone@somewhere*
[5] *https://climateknowledgeportal.worldbank.org*

Changes in Temperatures

The annual mean temperature is projected to increase significantly. Depending on the scenarios applied, these changes are more or less severe; although the projected increase will be substantial regardless. The maps below present the lower and upper estimate of the change in temperature in the near and far future compared to the present conditions based on two scenarios of future climate change. This is followed by a presentation of temperature change projections for different GHG emissions scenarios including changes in tropical nights over time.

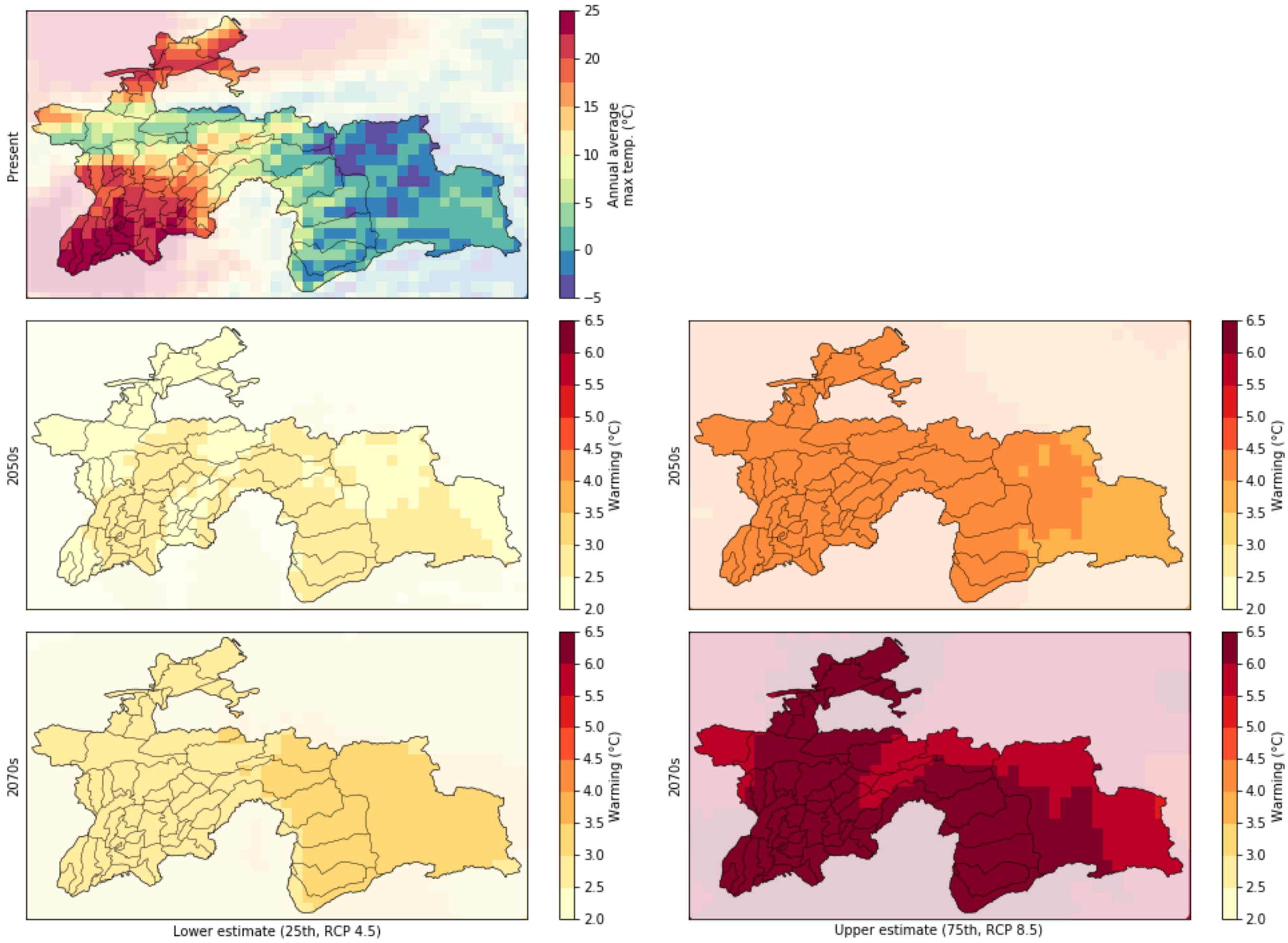

Figure 3: Baseline (top subfigure) for mean temperatures (1961-1990) in Tajikistan and the range of possible increase in °C, where the left subfigure indicates the lower limit and the right subfigure the upper limit for 2050s (middle row) and 2070s (last row). The lower limit corresponds to a scenario with effective global climate action (RCP4.5) whereas the upper limit assumes no global climate action (RCP8.5).

Temperatures

Compared to the 1986-2005 level, the annual mean temperature is projected to rise between **1.3°C and 6.3°C by 2080**, depending on the future GHG emissions scenario. Under the high emissions scenario, RCP8.5 (red), its multi-model mean (coloured line) **temperature will increase approximately by 1.7°C in 2030, 3.1°C in 2050, and 5.4°C in 2080**.

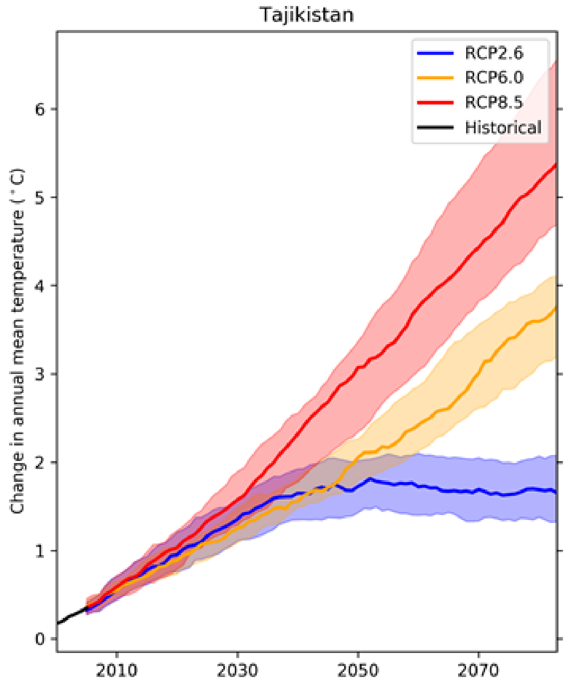

Figure 4: Temperature change projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.

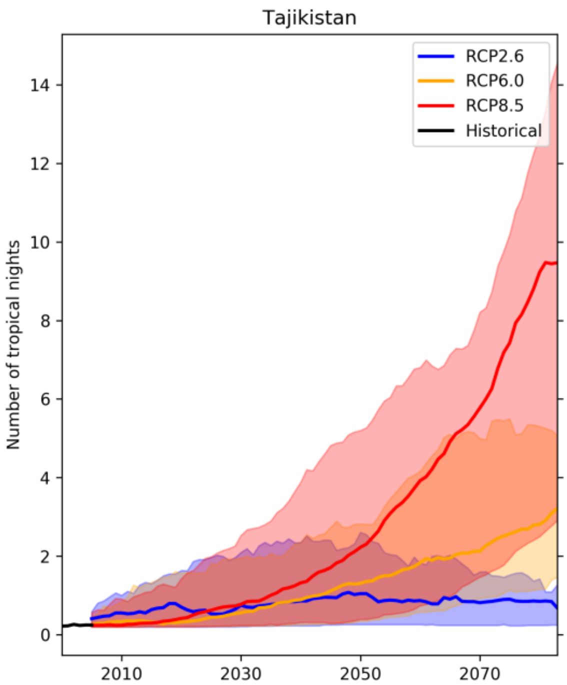

Figure 5: Number of tropical nights projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.

Tropical nights

During a tropical night, the temperature does not fall below 20°C. **An increase of tropical nights influences human well-being directly.** The increase in health threats can be monitored through the frequency of tropical nights. The energy sector is affected by a higher electricity demand during summer due to increased use of air conditioning. Under the high emissions scenario, RCP8.5, the multi-model mean for **tropical nights increases to a value of almost 10 nights by 2080**.

It needs to be noted that these numbers are geographic averages over the indicated region. Tropical nights are highly sensitive to elevations and can vary from location to location within the region, if the elevation differs.

Changes in Precipitation

Precipitation changes vary drastically throughout the seasons. An increase in winter precipitation is projected while the average spring precipitation indicates only a slight increase; however, more frequent heavy rain events are to be expected. The maps (below) present the lower and upper estimate of the change in precipitation in the near and distant future compared to the present conditions based on two scenarios of future climate change. This is followed by a presentation of projected changes in precipitation, and heavy precipitation events, for different GHG emissions scenarios over time.

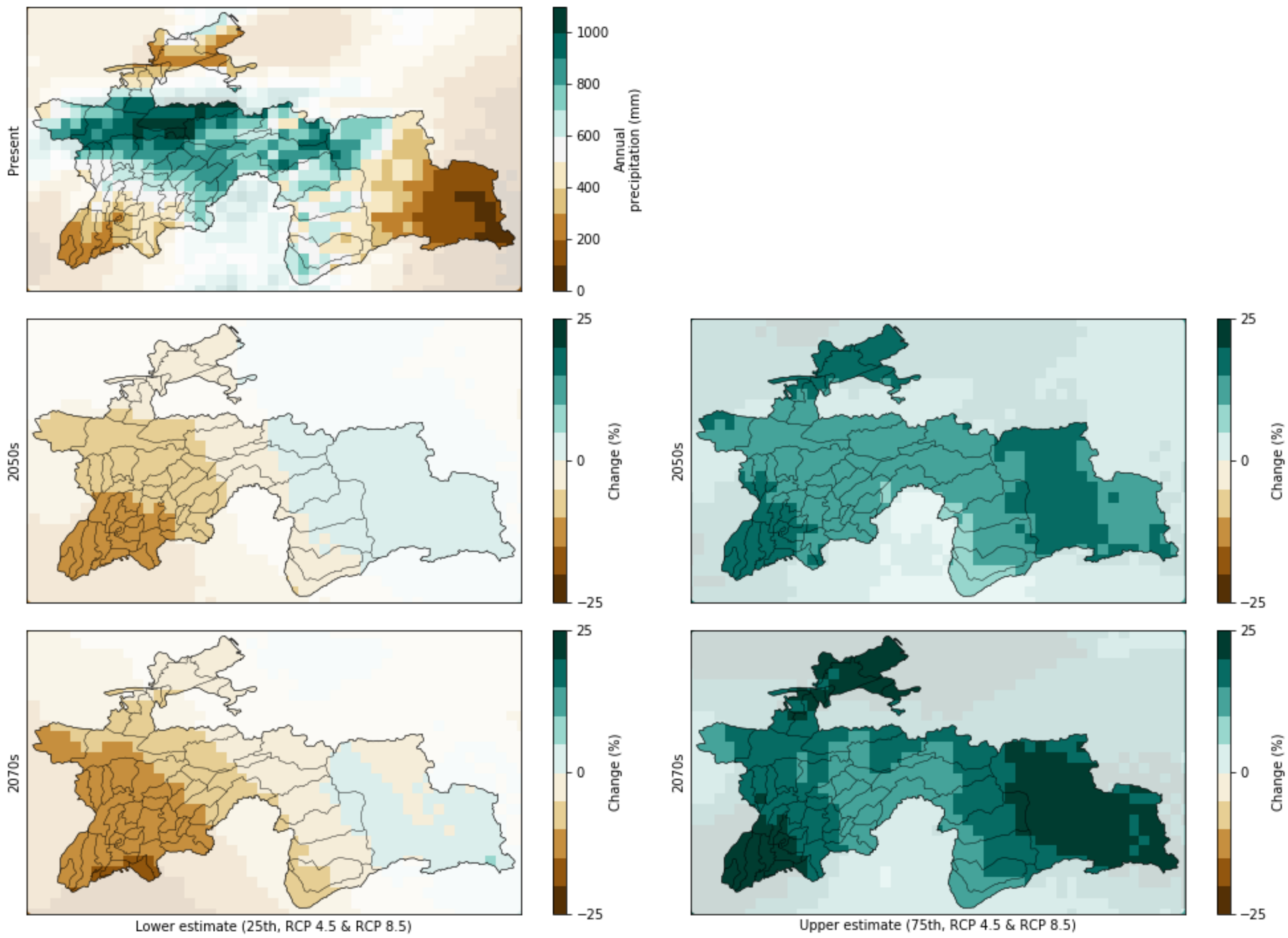

Figure 6: Baseline (top subfigure) for mean annual accumulated precipitation (1961-1990) in Tajikistan and the range of possible future change in %, where the left subfigure indicates the lower limit of decrease and the right subfigure the upper limit for 2050s (middle row) and 2070s (last row). Two scenarios were taken into account, a low emission scenario (RCP 4.5) that assumes effective global climate action and a high emission scenario (RCP 8.5) without global climate action. Both, the lower and upper limit for precipitation change accounted for multi-model results from both scenarios (RCP 4.5 & RCP 8.5).
Data source: Worldclim.org. Details on the used models and the method of processing are found in the technical description at the beginning of this section

Precipitation

In contrast to projected temperature, **future trends for precipitation are more uncertain.** This is due to the large natural variability on multi-decadal time scales and considerable modelling uncertainty. Projected ranges (coloured shade for multi-model range) for changes in winter and spring precipitation allow an increase and decrease of precipitation under each scenario. Under RCP8.5, the multi-model range covers **a range of -4% to +30%** for **winter and -6% to +10% for spring by 2080.** However, the mean of the model ensemble (coloured line) for all emissions scenarios show a positive trend in winter. Under RCP8.5, the multi-model mean increase for winter precipitation reaches 14% in 2080. During spring, all emission scenarios show a slightly increasing trend. Multi-model means for spring precipitation increase by 2.5% (RCP2.6) and 5% (RCP6.0).

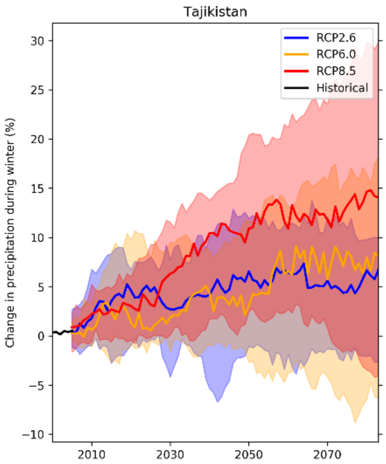

*Figure 7: **Winter precipitation** change projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.*

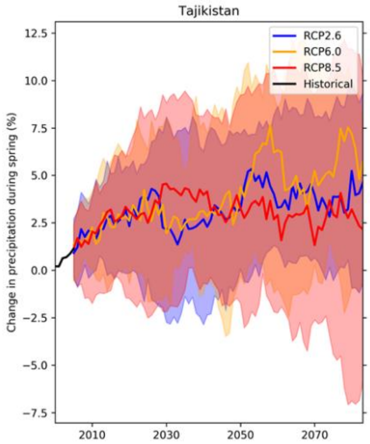

*Figure 8: **Spring precipitation** change projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.*

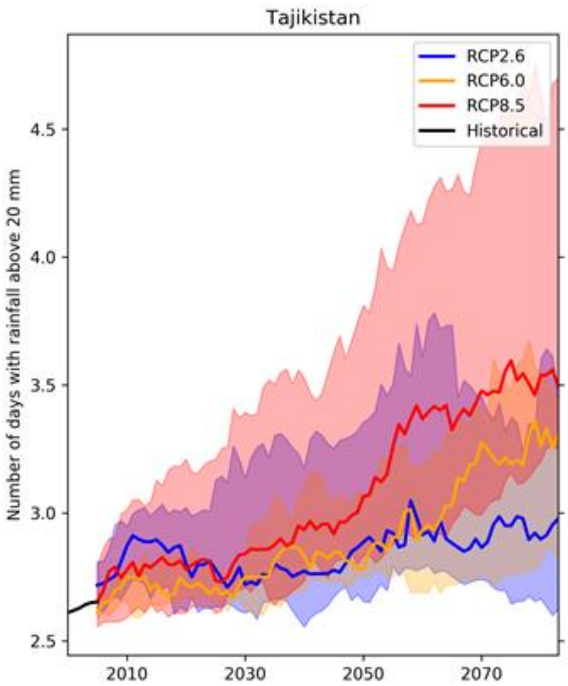

*Figure 9: **Heavy precipitation events** change projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.*

Heavy precipitation events

Heavy precipitation events are expected to become more intense due to the increased water vapour holding capacity of a warmer atmosphere. Here, we define extreme precipitation as a daily precipitation above 20 mm. Projections show an increasing trend for extreme precipitation. Under RCP8.5, the multi-model mean for heavy precipitation days indicates an **increase of approx. 1 day to a total value of 3.5 days by 2080**

Frost days and growing season length (GSL)

As a consequence of increasing temperatures, **fewer frost days will occur on average and the GSL is expected to increase.** GSL is defined as the length of the period between the first spell of five consecutive days with mean temperature above 5°C and the last such spell of the year. Under RCP8.5, **frost will occur on approximately 202 days in 2030, 190 days in 2050, and 163 days in 2080.**

For the same scenario, the GSL will be **approximately 175 days in 2030, 190 days in 2050, and 212 days in 2080.** Despite an increasing GSL, the productivity during the growing season is at risk due to **more frequent and intense heatwaves and the risk of less irrigation water due to higher evaporation and glacier retreat (especially in late summer).**

It needs to be noted that these numbers are geographic averages over the indicated region. Frost days and GSL are highly sensitive to elevations and can vary from location to location within the region, if the elevation differs.

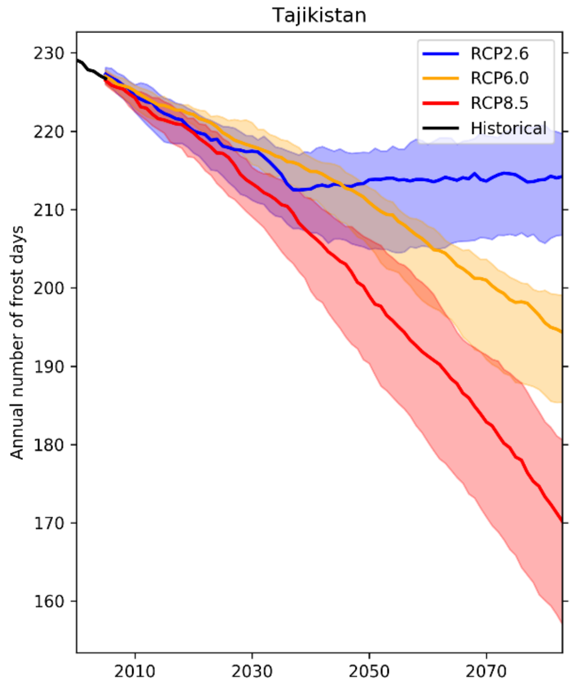

*Figure 10: **Number of frost days** change projections for different GHG emissions scenarios (colour) and historical values (black). Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario. Shaded areas represent the range of the model ensemble.*

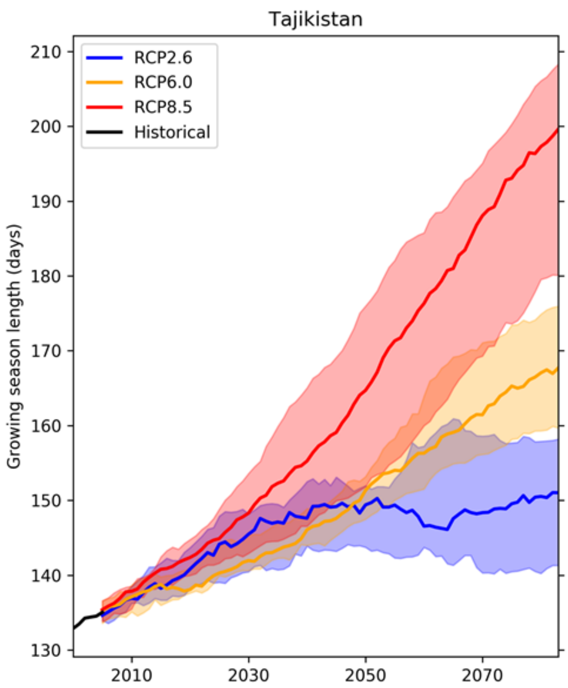

*Figure 11: **Growing season length (GSL)** change projections for different GHG emissions scenarios (colour) and historical values (black). GSL is defined as the length of the period between the first spell of five consecutive days with mean temperature above 5°C and the last such spell of the year. Each coloured line represents the 30-year running mean of the model ensemble under a given emissions scenario.*

Technical Description

With the climate change scenarios, presented above as maps and time series, it is important to note that the upper and lower limit of the estimates within these scenarios are defined by the use of the 25th and the 75th percentile. In other words, the multi-model range for each scenario was reduced the following way: **the lowest 25% and the upper 25% of model results are dismissed.** These highest and lowest results were regarded as outliers. The method for calculating the lower and upper limit of estimated change differs hereby for temperature and precipitation.

For **temperature changes**, the upper limit of the range corresponds to the 75th percentile of the model spread under the **RCP8.5 scenario,** a **high emission scenario** in which no effective global climate action policy is being implemented. In contrast, the lower limit of the range corresponds to the 25th percentile of the model spread under the **RCP4.5** scenario that **assumes the implementation of climate actions** with the consequence that **warming** (mean over models) **is limited to 2-3°C** until the end of the 21st century.

For **precipitation changes**, the lower limit in the maps to the left in Figure 6 is given by the 25th percentile of **the high emission scenario (RCP 8.5) and the low emission scenario (RCP 4.5)** combined while the upper limit in the maps on the right of the same figure is given by the 75th percentile of the two scenarios. The calculation of the 25th and 75th percentile was done separately for both scenarios.

The difference in calculating the lower and upper limit of change for temperature and precipitation accounts for the fact that the **model range for precipitation changes behaves differently than for temperature changes**. Whereas for temperature, a higher emission scenario under normal conditions leads to higher temperatures, this is not always the case for precipitation. In other words, the lower and upper estimate for precipitation in the future is in **some locations determined by the lower emission scenario, and in others, by the higher emission scenario.**

Disclaimer

Like all projections, the climate change scenarios presented in the maps and time series above have uncertainty embedded within them. Sources of uncertainty include data and modelling constraints, the random nature of some parts of the climate system, and limited understanding of some physical processes. Uncertainty is addressed and visualized by using **state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations, and recent peer-reviewed literature.** Even so, the projections are not true probabilities and the potential for error should be acknowledged.

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