Climate Adaptation and Mitigation Program for the Aral Sea Basin (CAMP4ASB)

Building Adaptive Capacity and Resilience to Climate Change in the Central Asia

Climate Risks and Vulnerability Assessment (CRVA)

(D-1.7)

National Level Report for Kyrgyzstan

Joint Venture

Climate Adaptation and Mitigation Program for the Aral Sea Basin (CAMP4ASB)

Building Adaptive Capacity and Resilience to Climate Change in the Central Asia

Climate Risks and Vulnerability Assessment (CRVA) (D-1.7) National Level Report for Kyrgyzstan

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Abbreviations

CA	Central Asia
CAMP4ASB	Climate Adaptation and Mitigation Program for Aral Sea Basin
CAREC	Central Asia Regional Environmental Center
CB	Capacity Building
CC	Climate Change
CRVA	Climate Risks and Vulnerability Assessment

1 INTRODUCTION

Climate change requires adaptation at all levels: from local to national to regional levels. Adaptation interventions, to be successful, should be coordinated between administrative levels and harmonized between sectors to address the direct and indirect impacts of climate change. The Climate Risk and Vulnerability Assessment (CRVA) is a systematic approach to build a bridge between a country or region's climate exposure and risks and the adaptation interventions that would be most effective to address them.

The CRVA approach introduces sensitivity, adaptive capacity and vulnerability into the process of adaptation planning. By defining the impacts and identifying vulnerabilities, it sets the scope of the adaptation interventions needed and provides a targeted approach to multifaceted problems. Importantly, it also allows for the identification of critical, underlying factors causing or exacerbating sectoral vulnerabilities, which may, or may not, be the climate exposure itself. The result of this process is a set of priority interventions for and between regions and sectors.

Once the assessment has been carried out, potential options for adaptation can be formulated, analysed, prioritised and selected. At that point, an implementation arrangement can be established as well as the need for any technical support and capacity building. The CVRA process also provides the inputs for the design of a robust and practical monitoring and evaluation framework, which is necessary to provide feedback to policymakers and to build climate resiliency knowledge in the region.

2 COUNTRY CONTEXT

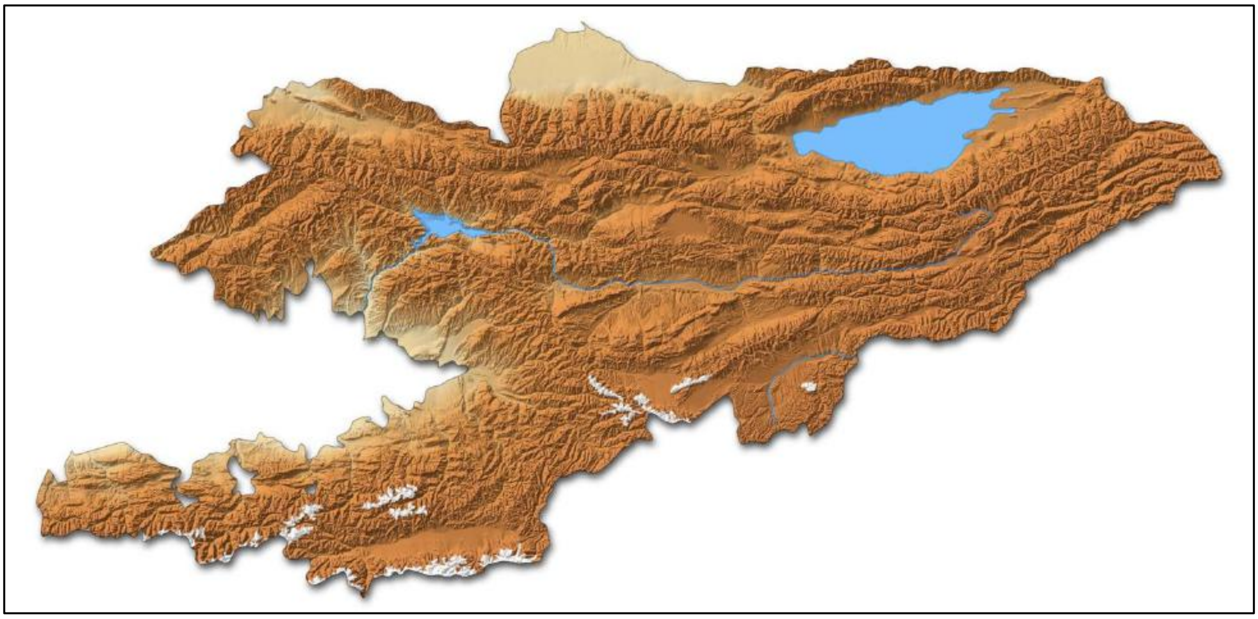

Figure 1: Kyrgyzstan map

The Kyrgyz Republic (Figure 1) is a landlocked country located in north-eastern Central Asia between two major mountain systems, the Tien Shan and the Pamirs. Over 80% of the country is within the Tian Shan mountain chain and 4% is permanently under ice and snow. The majority of the population lives in the foothills of the mountains, where they are most vulnerable to climate hazards. Forty-three percent of the population lives below the poverty line and 50% are rural dwellers. Agriculture is by far the most important livelihood activity, contributing to one-third of gross domestic product (GDP) and employing 65% of the population. In fact, over half of Kyrgyz Republic's GDP is derived from climate and weather-sensitive activities. Notably, Kyrgyz Republic experiences between 3,000 and 5,000 earthquakes every year, with large-scale catastrophes taking place every 5-10 years. On average, destruction and loss from natural disasters totals up to US $30-35 million per year.

The State Agency on Environment Protection and Forestry of the Kyrgyz Republic (established in 2005) is the focal point for coordination and implementation of environmental and climate change policies. The Law on the State Regulation and Policy of Greenhouse Gas Emissions and Absorption (2007) sets the legal framework for national policies that mitigate climate change. The Kyrgyz Republic also submitted their

Second National Communication to the United Nations Framework Convention on Climate Change in 2007. The country's Intended Nationally Determined Contribution are also available[1] (Figure 2, 3).

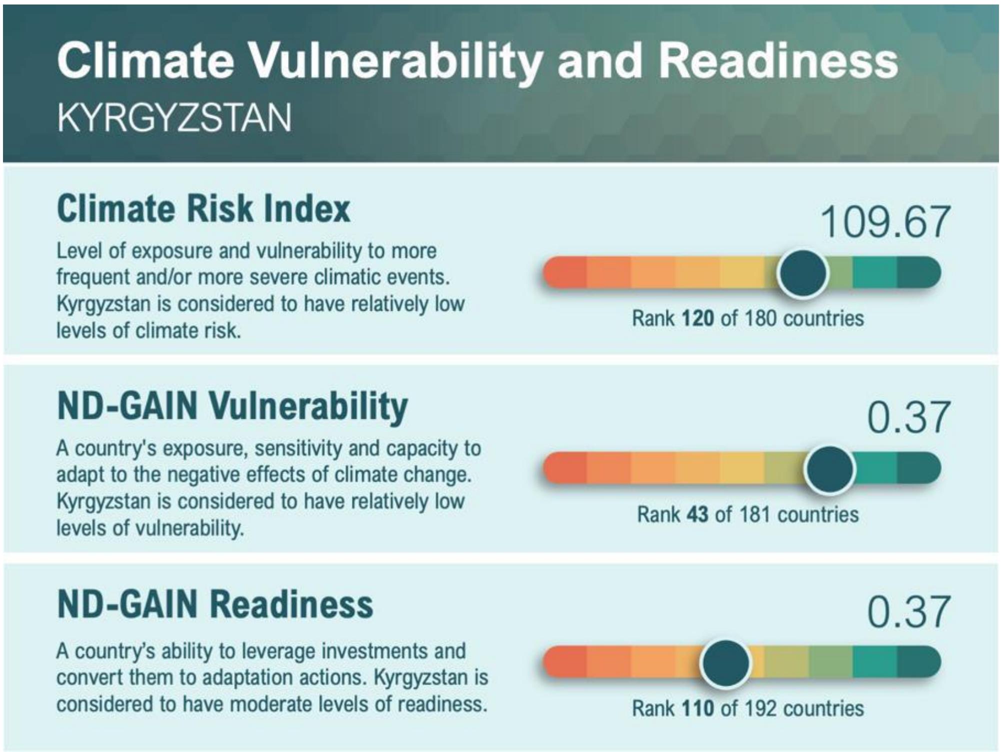

Figure 2: Climate vulnerability and readiness

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[1] Intended Nationally Determined Contribution – Kyrgyzstan (https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Kyrgyzstan%20First/Kyrgyzstan%20INDC%20_ENG_%20final.pdf)

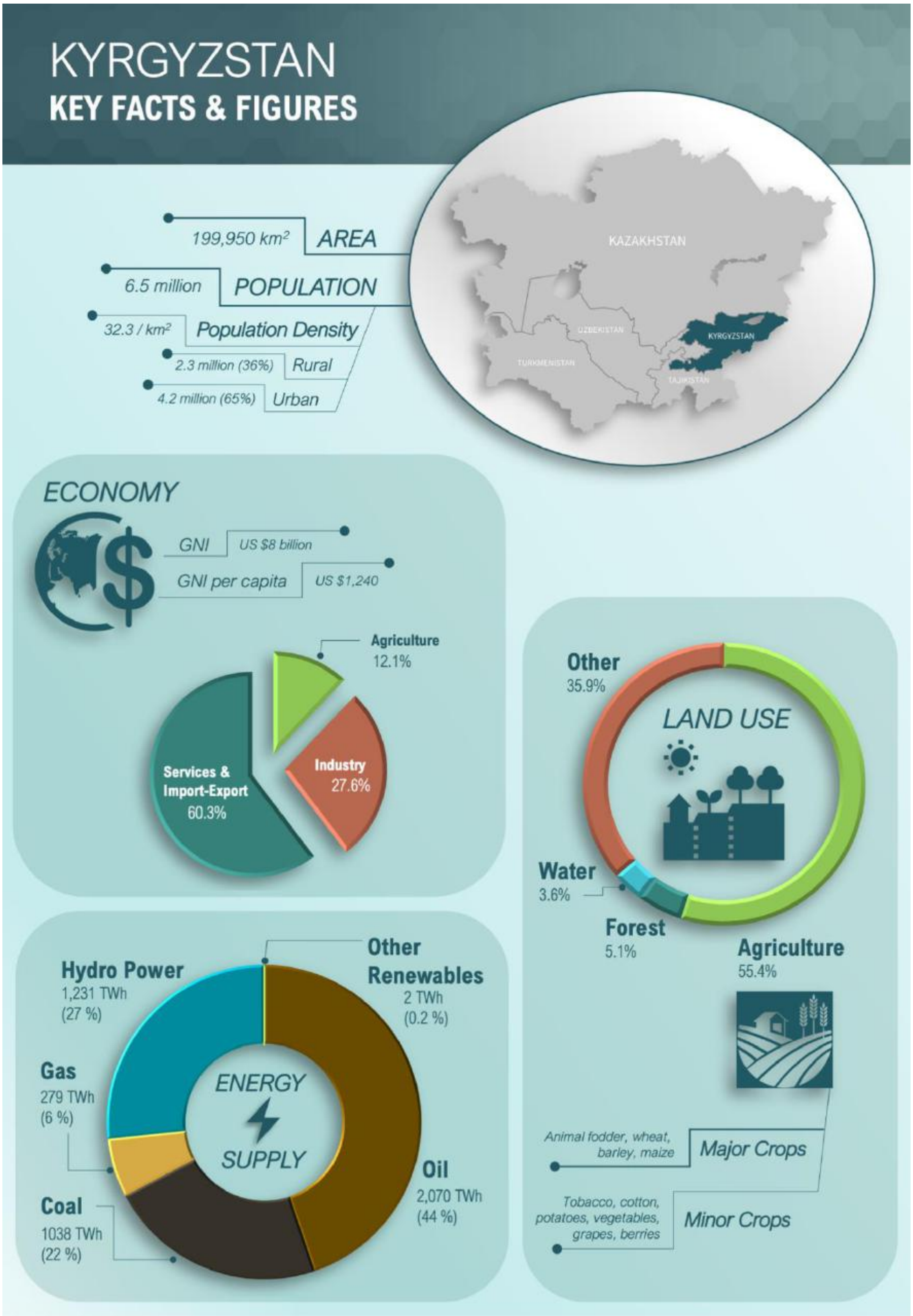


Figure 3: Key facts and figures

3 MAJOR CLIMATIC PROCESSES IN CENTRAL ASIA

3.1 Regional Processes

Different climate systems (Figure 4) have influence on the climate of Central Asia:

- Jetstream / Rossby waves
- Westerlies (rain)
- Anticyclones (Siberian high / Persian high)
- Monsoon (extreme precipitation)
- La Nina (drought)

Jetstream and Rossby waves are the forcing mechanism to push cyclone and anti-cyclone eastwards. The speed of the move of the Rossby waves is dependent of the difference in temperature between the North pole and the temperate areas. Less temperature difference, like caused by climate change, results in reduced speed or even halting of the Rossby waves. As result the weather in between of the waves fixates in place. For Central Asia this means in summer fixation of the high-pressure areas, resulting in heat and drought.

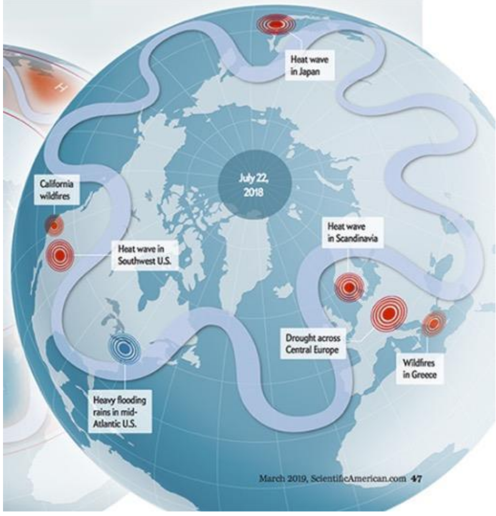


Figure 4: Climate systems from Central Asia

Typical result of the halting of the Rossby waves is in one area causing heat and drought, in parallel in neighbouring areas it results in extreme precipitation.

The **Westerlies** transport the Atlantic and Mediterranean humidity to Central Asia. The Westerlies are in winter under strong influence of the Siberian High, in summer of the Persian High.

Weakening of the **Siberian High** results in warmer and shorter winters, precipitation on lower altitude and more precipitation in northern parts of Central Asia. It also allows more influence from the Baltic Low in the region.

The **Persian High** is in summer under pressure of the Sahara High and is increasingly pushed towards the Caspian Sea. As result the Westerlies are bended Southwards and delivering the soft summer rains to southern regions like Pakistan. This process is further increased by the halting of the Rossby waves.

The **Monsoon** is moving northwest wards and becoming more extreme as result of the warming Indian Ocean. The chance the Monsoon jumps over the Hindu-Kush is therefore increasing. This effect especially the Pamir and in less extend the Tien Shan, causing extreme precipitation (Figure 5).

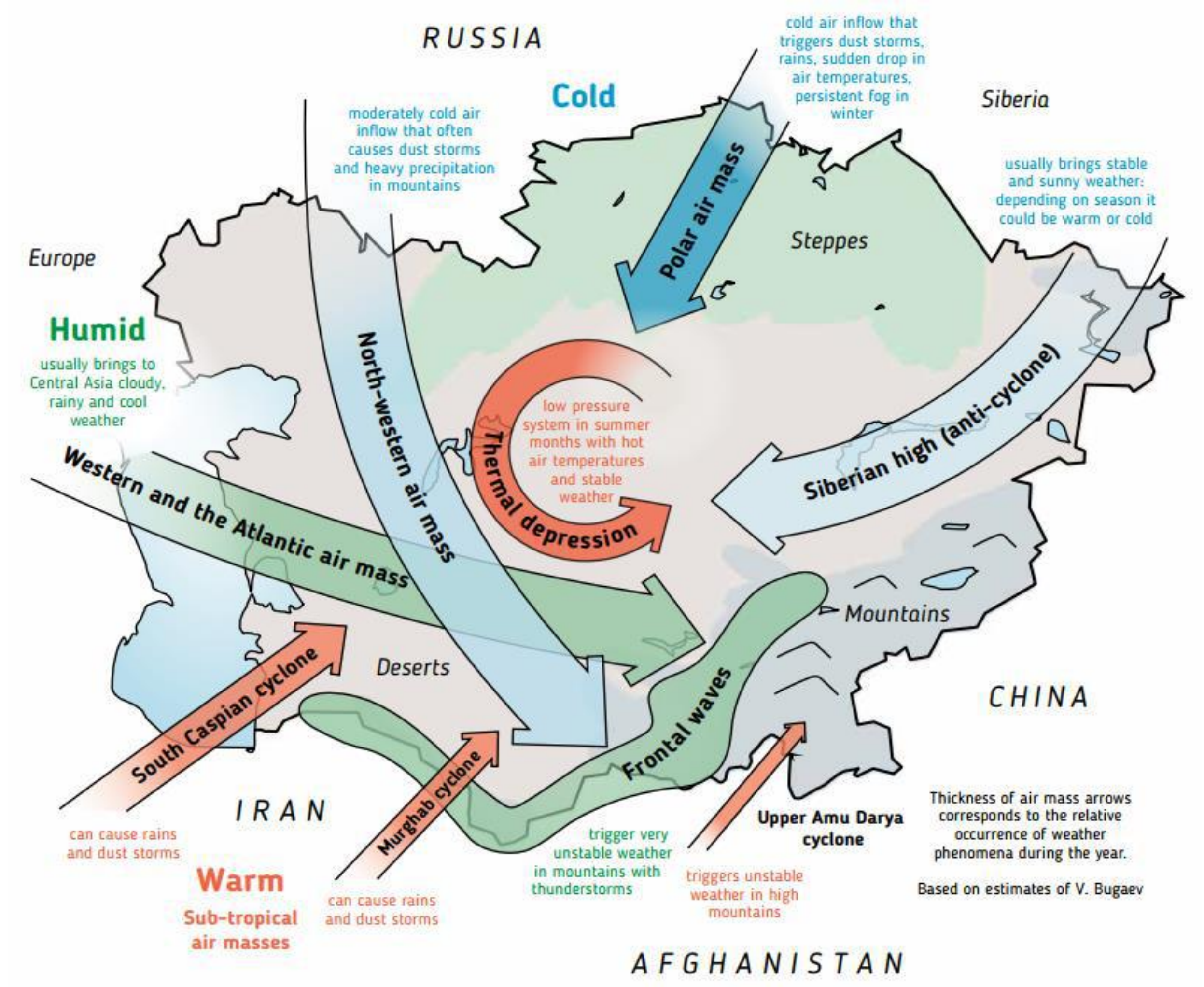


Figure 5: Major climate systems processes influencing the climate of Central Asia

The mountains of Central Asia are the main geographic feature, decisive for the climate and water resource of the region. The Westerlies are losing their humidity when they are pushed up against the mountains. As a result of the processes describe above, more precipitation is in the form of rain, precipitation is on lower elevation, and the temperature on high altitude increases. This result in glacier melt (Figure 6).

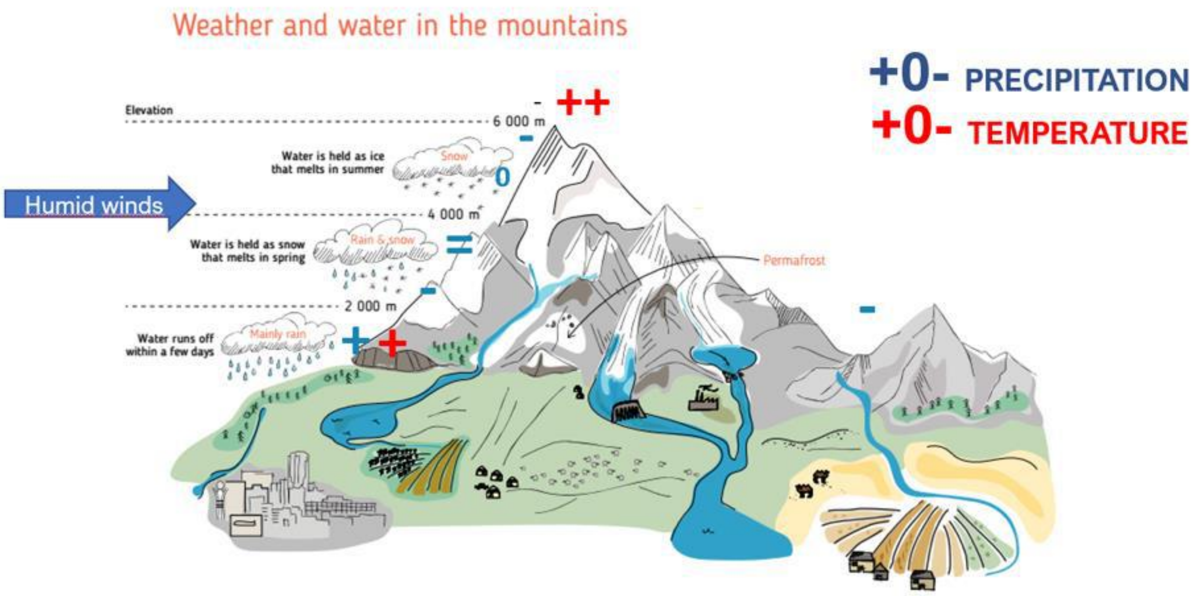
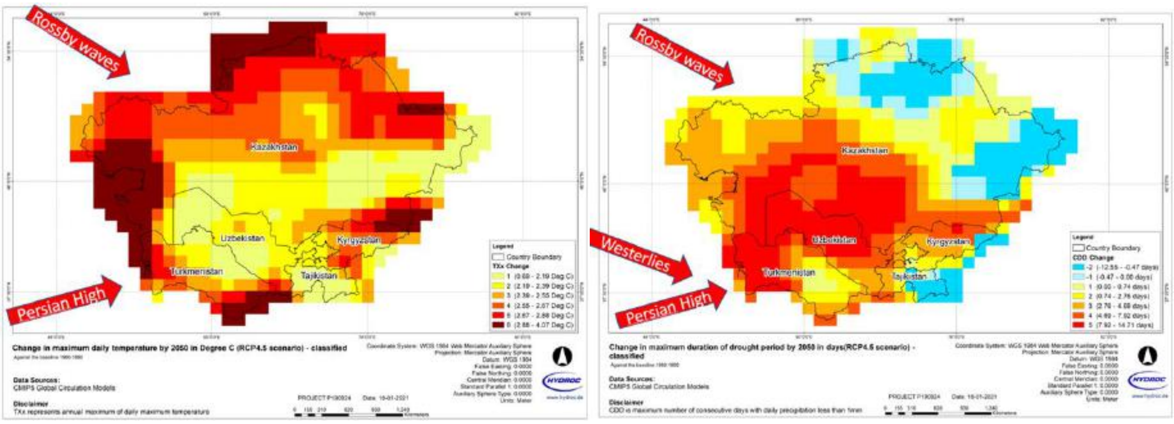


Figure 6: Changes in temperature and precipitation by elevation

3.2 Consequences for Central Asia

As result of the climatic processes described above the following Climate exposure maps are prepared for Central Asia (Figure 7).


Heat

Drought

Figure 7: Changes in temperature and precipitation by elevation

Heat and drought are mainly ruled by the same climatic processes.

- Halting Rossby waves in summer stop the eastwards move of anticyclones resulting in heat wave and drought

Move of the Persian High northwards causes dry and hot weather and bends the humid westerlies to the south. As result the heat and duration are increasing in Central Asia. With exception of the Pamir. In Northeast Kazakhstan it results in decreased drought periods (Figure 8).

Total precipitation **Extreme precipitation**

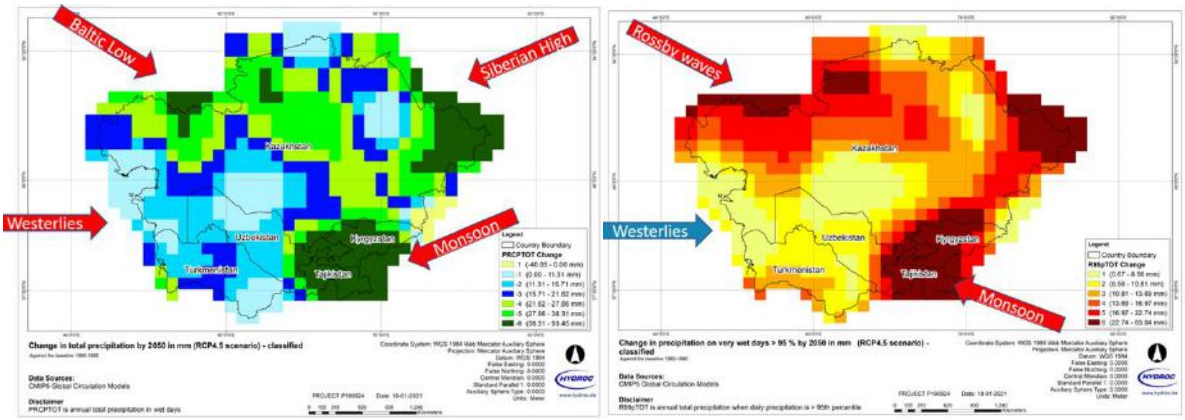


Figure 8: Precipitation maps of Central Asia

- Monsoon moving northwest and causes heavy precipitation in southwest CA
- Westerlies bringing soft rain, Baltic Low bring rain
- Weakening Siberian High causes more influence in winter of westerlies and Baltic low and precipitation at lower altitude, As result the total precipitation in Central Asia is increasing, especially in the mountain areas.
- Monsoon moving northwest and becomes more extreme
- Halting Rossby waves results in cyclone and anticyclones halt in place for longer period. As result the weather can stay the same for a longer period. In summer this results in drought but also in increase of extreme precipitation. This effect is the strongest in the mountain areas.

4 SECTORAL IMPACT OF CLIMATE CHANGE

Information and analyses provided in this section combines findings and analysis which are original of this study with information and graphics derived from the World Bank Climate Change Knowledge Portal[2].

Additional information and graphics are also provided in the Climate Change Vulnerability Analysis chapter of this report (Figure 9).

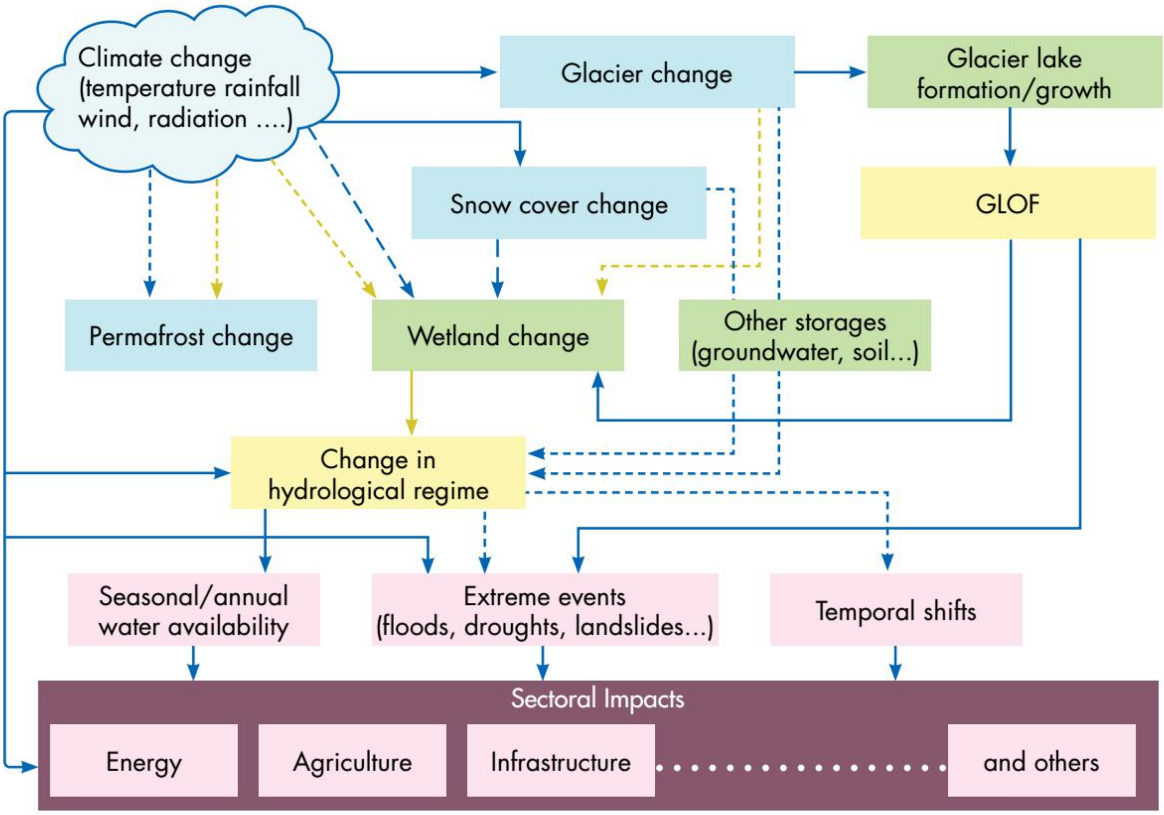


Figure 9: *Source: Impacts of Climate Change on the Cryosphere, Hydrological Regimes and Glacial Lakes of the Hindu Kush Himalayas, Lutz et all., ICIMOD, 2016*

4.1 Agriculture

Food security will be threatened due to projected impacts of global climate change and extreme weather on crop nutrient content and yields, livestock, fisheries and aquaculture, and land use. Climate changes have already affected crop suitability in many areas, resulting in changes in the production levels of main agricultural crops. Crop production is negatively affected by the increase in both direct and indirect climate extremes. Direct extremes include changes in rainfall extremes, increases in hot nights, extremely

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[2] The Climate Change Knowledge Portal (CCKP) – World Bank (https://climateknowledgeportal.worldbank.org/)

high daytime temperature, drought, heat stress, flood and chilling damage. And indirect effects include the spread of pest and diseases, which can also have detrimental effects on cropping systems[3].

Some of the most direct impacts that climate change might have on the agriculture sector are listed in the following table (

Table 1).

Table 1: Summary of the impacts that different climate indicators have on the agriculture sector in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
When temperatures increase past 37ºC most crops experience stress or stop growing altogether. Temperature over 40 ºC may render the plans infertile. Such risk exists most for Northern Kyrgyzstan. Also, with the increase of temperature pest and diseases develop earlier in the season Early heat will reduce the flowering of cereals, resulting in decreased harvest. Suitability of crops changes	In general, the higher amount of precipitation expected over most of the country would increase the productivity. However, the expected shift in seasonality and increase in the frequency of heavy precipitation events will basically eliminate the positive impacts for the sector.	The increase of heavy precipitation causes erosion and waterlogging, less infiltration and therefore less effective water capacity. Risk of crop damage / failure	Drought spell put great stress on crop growth and increases the water requirements for rainfed and irrigated arable land. It also effects the fodder production for livestock Wildfires damage increases Land degradation and wind erosion increases

The linkages between climate change and its impact on the agriculture sector are further explored in the following paragraphs.

4.1.1 Monthly Mean of Daily Maximum Temperature by 2050

The warm conditions of the day are important for crop growth cycles. However, there are upper heat thresholds beyond which crop productivity is reduced or stalled. This threshold is different with each crop type. As temperatures rise globally, assessing the local trends in daily maximum temperatures its important as it provides a way to assess if upper thresholds might get reached more frequently and the potential impacts this might have on overall yields (Figure 10).

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[3] Global Warming of 1.5° – IPCC special report, 2020 (https://www.ipcc.ch/sr15/)

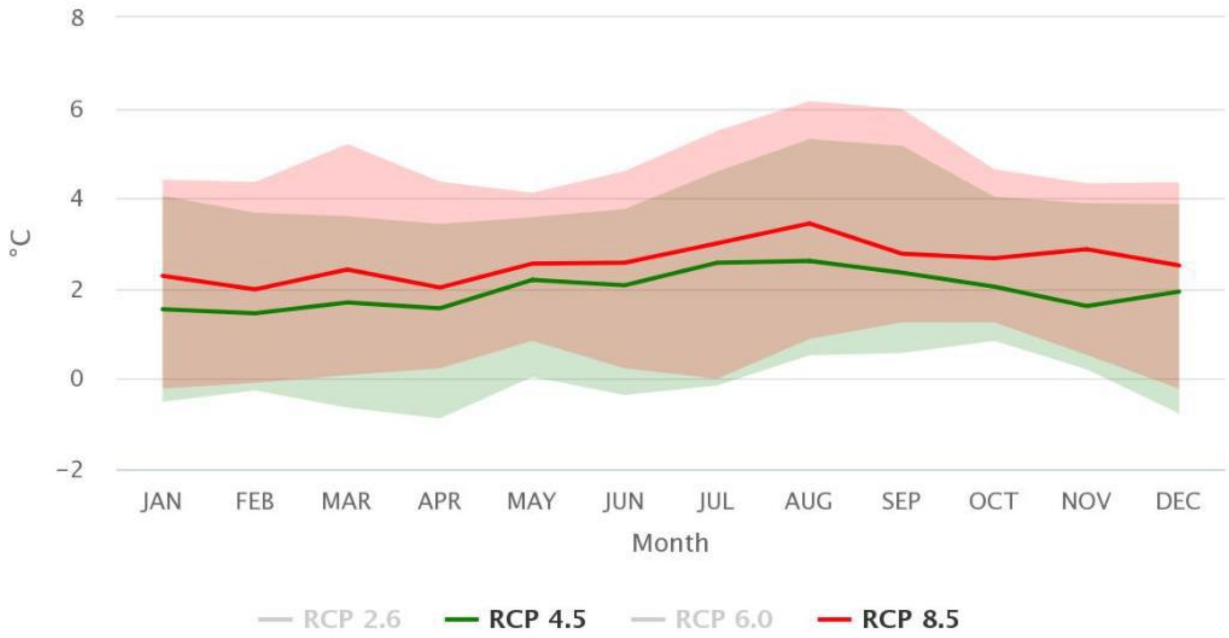

Figure 10: The graph shows projected change in Monthly Mean of Daily Maximum Temperature by 2050 compared to the reference period (1986-2005) under all RCPs of CIMP5 ensemble modeling. Positive values indicate that warmest daily maximum temperatures will likely to increase compared to the baseline, and vice versa. The shaded area represents the range or spread between 10th and 90th percentile of all analyzed models.

4.1.2 Change in Projected Mean Annual Precipitation by 2050

Annual precipitation is one of the most fundamental climatic conditions for rain-fed agriculture and livestock productivity. A gain or a decrease over the coming decades could determine if certain crops or farm practices remain viable, and if reduced water availability might require a shift to more drought resistant crops or if farmers are required to shift investments into irrigation. The annual rainfall amount provides a critical background on top of which other factors can become important, such as the temporal gaps between individual rainfall episodes, the availability of water during critical times of the seasonal cycle, or the intensity of individual rainfall events. Together with these other indicators, mean annual rainfall is a useful measure toward estimating water balance to ensure sustainable food production (Figure 11).

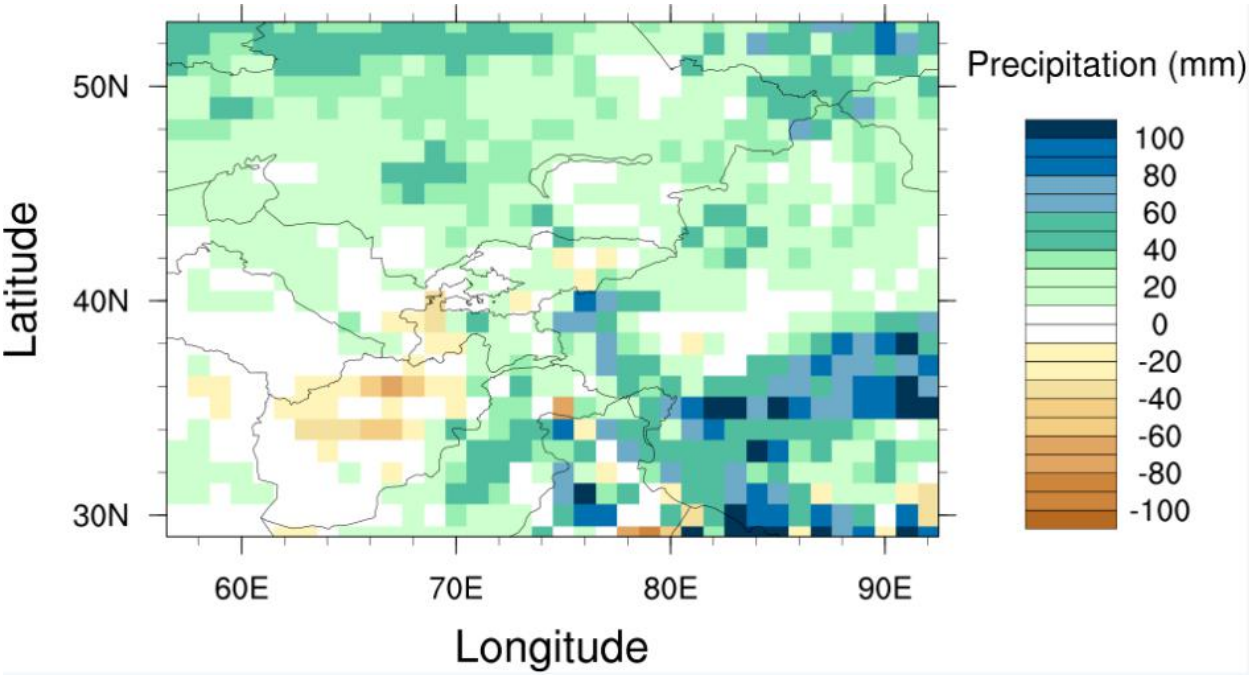

Figure 11: The map shows change in projected Mean Annual Precipitation by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modeling. Blue/Green areas are likely to receive more annual rainfall compared to the reference period and to Brown/Yellow areas.

4.1.3 Maximum Number of Consecutive Dry Days for the Period 1986-2099

A "dry day" is a day without any agriculturally meaningful rainfall, which is generally defined by a threshold of 0.1 mm/day. The maximum number of consecutive dry days is an important metric for rain-fed agriculture as it directly impacts soil moisture, and thus crop growth. As climate warms, one of the signals is the increase in contrast: when it rains, it might rain harder, but when its dry it might get drier. The trend toward more consecutive dry days and higher temperatures will increase evaporation and add stress to limited water resources, affecting irrigation and other water uses. Long periods of consecutive days with little or no precipitation also can lead to drought. In general, the average annual maximum number of consecutive dry days are projected to increase for the higher emissions scenarios. Some crops, however, might benefit from this change, particularly when the dry conditions exist in specific parts of the crop cycle (Figure 12).

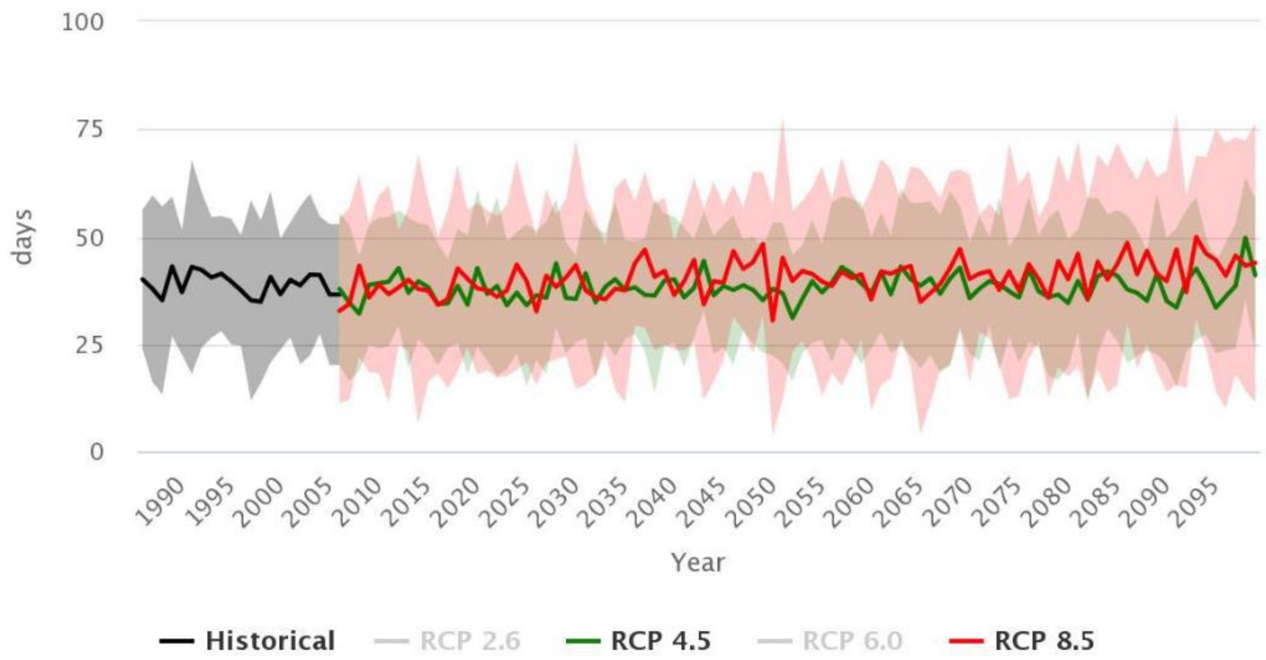

Figure 12: The graph shows the recorded maximum number of Consecutive Dry Days (CDD) per year for 1986-2005, and projected maximum number of CDD for 2020-2100 under all RCPs of CIMP5 ensemble modeling. Note, the shaded ranges (or model spread) illustrate the inter-model differences, here using the +/- one standard deviation. The reason for using a narrower metric compared to the 10th and 90th percentile is that the inter-model difference is large for precipitation, and in particular for the count of days with rainfall.

4.1.4 Monthly Precipitation: 10-year return Level in for period 2040-2059

An anticipated impact of climate change is the increase in climate variability. In particular, warmer air has a higher capacity to carry moisture in form of water vapor, which is then available for rainfall. It generally depends on location if the long-term average rainfall will exhibit a positive or negative trend, but it is thought that extremes could change more systematically towards higher intensity events. With every Degree-Celsius, the moisture carrying capacity of air increases ~7%. Therefore, the systematic warming of multiple degrees can lead to non-trivial increases in moisture that could potentially be transported and thus rained out (though not every rainfall event will increase). Extreme rainfall directly affects agriculture where it can damage crop, flood fields and streams, and the water can strip soils of their nutrients or the soil mass itself (Figure 13).

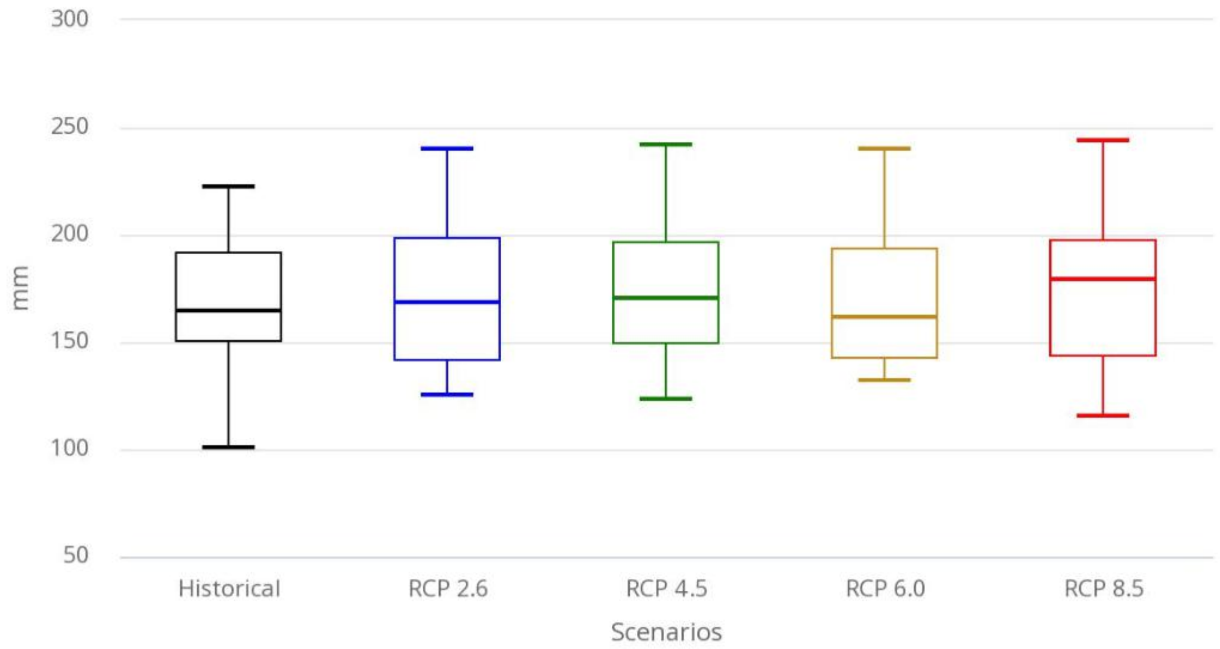

Figure 13: The boxplot shows recorded Maximum Monthly Rainfall for 1986-2005 and projected Maximum Monthly Rainfall 10-yr Return Level by 2050 under all RCPs of CIMP5 ensemble modeling. This indicator focuses on the maximum monthly rainfall amount that can be expected within a 10-yr period.

4.2 Energy

The energy sector is linked to climate variability and change in numerous ways. On one side, global energy production is a strong contributor to the drivers of climate change, namely through the emission of greenhouse gases. On the other side, it is also exposed to the diverse impacts of climate variability and change through changes in energy supply (e.g. disruption of operations and distribution) and demand (growing populations and evolving power needs). The consequences can be complex, yet they are often both positive and negative.

Some of the most direct impacts that climate change might have on the energy sector are listed in the following table (Table 2).

Table 2: Summary of the impacts that different climate indicators have on the energy sector in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
Fossil energy requires water for cooling. An increase in the temperature of the water bodies will inevitably cause a decrease	More precipitation means more water in the river and an increase in hydropower potentials.	Due to the increased risk of flooding, normal operation levels will have to be lowered thus reducing the overall	Droughts limit the availability of water required for cooling fossil power plants

Heat	Precipitation	Extreme Precipitation	Drought
in cooling capacity. Furthermore, water discharged into the environment from the cooling systems will have an higher temperature thus increasing the environmental risks. It is expected that the energy required for cooling will increase as much as 25%. Reduced generation effectivity Reduced transmission capacity	However, the occurrence of more extreme precipitation means that reservoirs will need to increase their ability to buffer dangerous floods thus reducing the overall efficiency of hydropower schemes	production efficiency of the hydro schemes. Furthermore, flood risks may hinder energy transmission and transportation. In addition to that, larger floods will cause more sediments transport, an increase in water turbidity and increase in wear of the mechanical equipment.	thus reducing energy production. To account for more frequent droughts, reservoir will need to retain more water thus reducing the hydro power production.

The linkages between climate change and its impact on the energy sector are further explored in the following paragraphs.

4.2.1 Annual Mean Temperature Change

Annual temperature provides the broadest assessment of the climate of a region. It is important to recognize a change of this quantity over time because it reflects the expected pressure on the general need for heating or cooling, one of the driving factors for broad power needs. In many countries, the temperature changes are fairly uniformly distributed across the year and thus the annual mean changes are representative. Sometimes, however, changes are more pronounced in particular seasons, particularly in higher latitudes and the change over the seasonal cycle should be consulted. In addition, extremes might not linearly follow the mean temperature change. But overall, annual mean temperature change offers the first order impact from the changing climate with some regions changing faster than others (Figure 14).

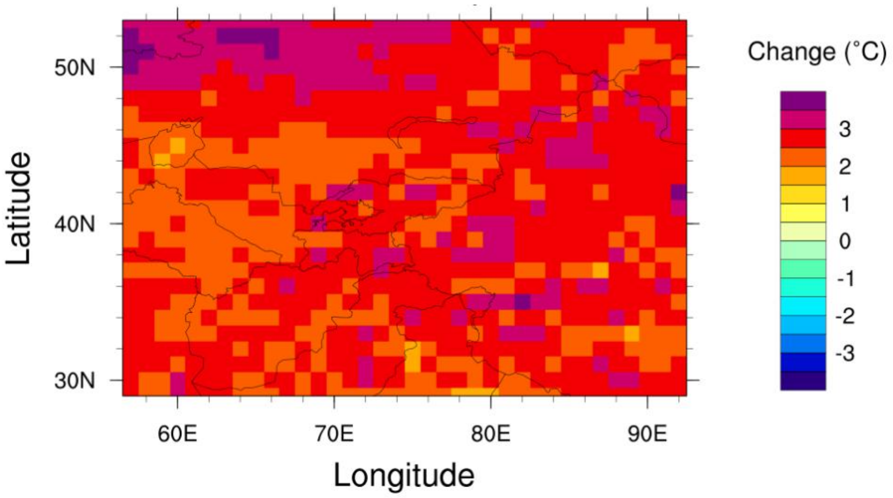

Figure 14: The map shows change in projected Annual Mean Temperature by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modeling. Purple/Red areas are likely to experience annual temperature increase compared to baseline period. Meanwhile, Blue/Green areas are likely to experience annual temperature decrease.

4.2.2 Change in Cooling Degree Days for the period 2040-2059

The relationship of daily heat with the demand for electricity can be estimated through a quantity called the Cooling Degree Days. This quantity accumulates the temperatures above 18C threshold which broadly represents a comfortable living environment. The cooling degree days capture the amount of heat that society would like to get rid of by period through some form of active cooling, be it through air conditioning or through evaporative processes that generally require pumps for water. The monthly changes provide insight into potentially extended seasons of power demand for cooling or highlighting when during the year likely power demand increases might occur. Low emissions connected to the RCP2.6 will likely lead to significantly smaller warming than high emissions of the RCP8.5, with the intermediate scenarios somewhere in-between (Figure 15).

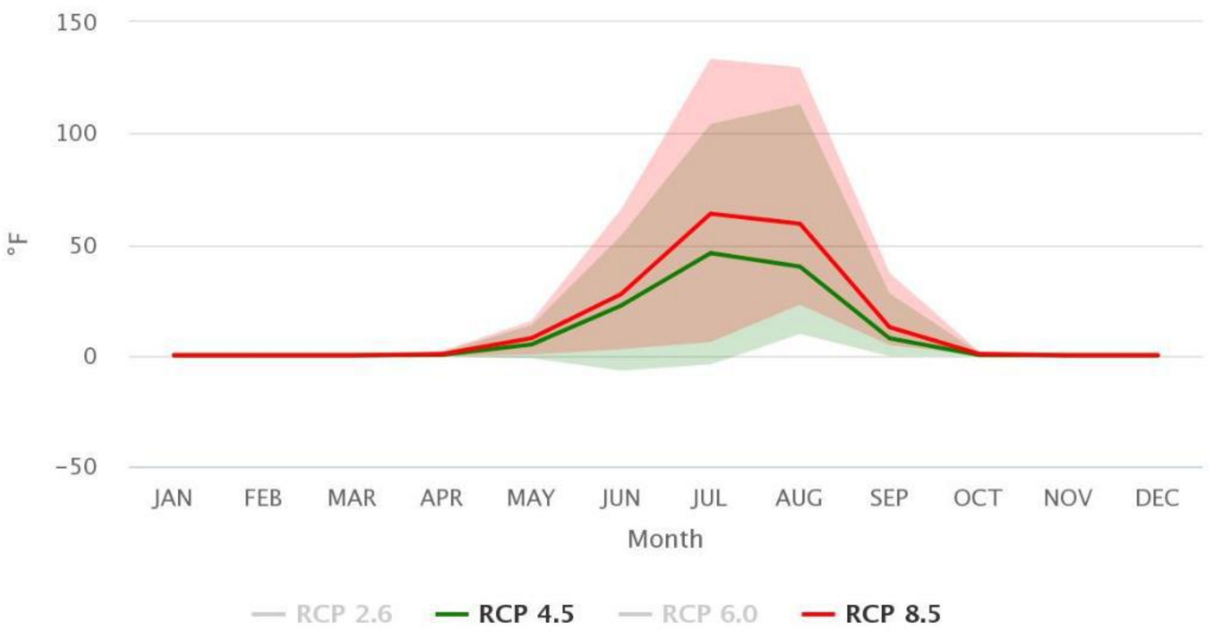

Figure 15: The graph shows projected change in Cooling Degree Days per month by 2050 compared to the reference period (1986-2005) under all RCPs of CIMP5 ensemble modeling. Positive values indicate that cooling degree days will likely to increase compared to the baseline, and vice versa. The shaded area represents the range between the 10th and 90th percentile of the model projections.

4.2.3 5-Days Precipitation: 10-year Return Level for period 2040-2069

As warmer air has a higher capacity to carry moisture in form of water vapor, future climate raises the likelihood for strong rainfall events and particularly towards extremes. The 10-year return period rainfall episodes, such as the 5-day cumulative rainfall, is a good measure of these extremes. In many places around the world, the maximum expected amount of rainfall in a 10-year period is projected to increase, which can lead to flooding. As a result, power production can be largely affected. For example, the transportation lines for fuel can be interrupted by local flood, or distribution networks can be disturbed by excessive rainfall and flooding (Figure 16).

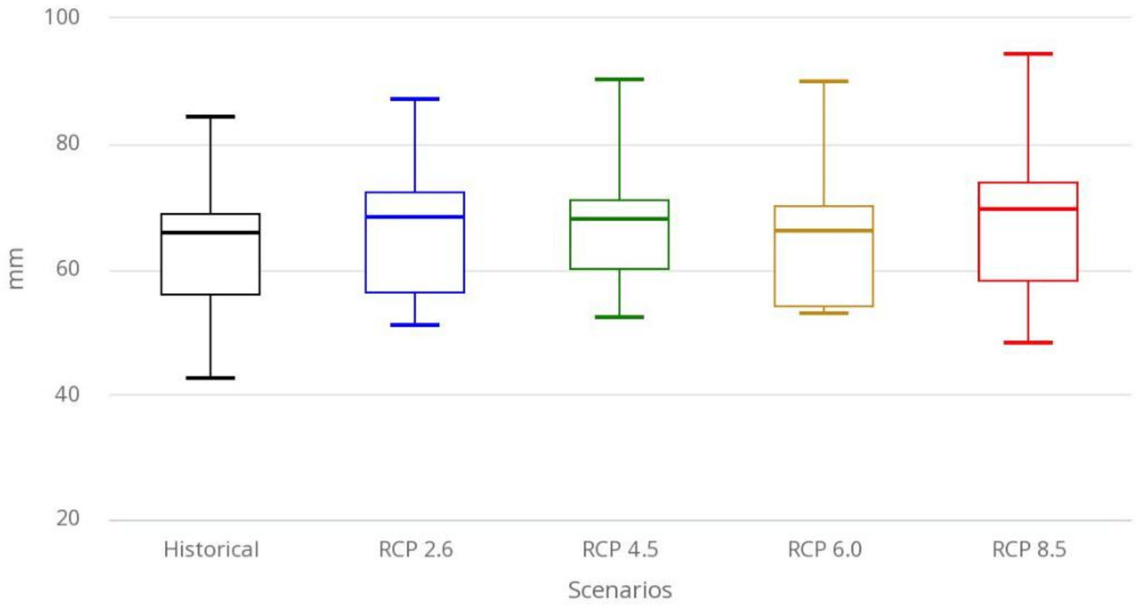

Figure 16: The boxplot shows recorded 5-Day Cumulative Rainfall for 1986-2005 and projected 5-Day Cumulative Rainfall 10-yr Return Level by 2050 under all RCPs of CIMP5 ensemble modeling. This indicator focuses on the maximum 5-day cumulative rainfall amount that can be expected within a 10-yr period.

4.2.4 Drought / Wet Conditions (SPEI) for Period 1986-2099

The direction of SPEI changes provide insight into increasing or decreasing pressure on water resources for direct power production or indirectly through cooling. At regional scales, the trends separate generally quite well between high and lower emission scenarios. Both power demand and production are also tied to water availability. Obviously, this is most directly the case in hydropower systems. But dry conditions might also come along with higher temperatures and thus heightened cooling needs and an increase in demand for water pumping, particularly in regions of intense agriculture. On the production side, water is required for cooling of power plants. If there is not enough water, then cooling is restricted and thus production might need to be slowed. In some places, there are regulations preventing power plants from causing an increasing the temperature of returned water above specific thresholds dangerous for local fish and plants. These thresholds are more quickly reached if stream flows are low during dry conditions. In a few regions, too much moisture can also be of an issue as water might need to be removed (Figure 17).

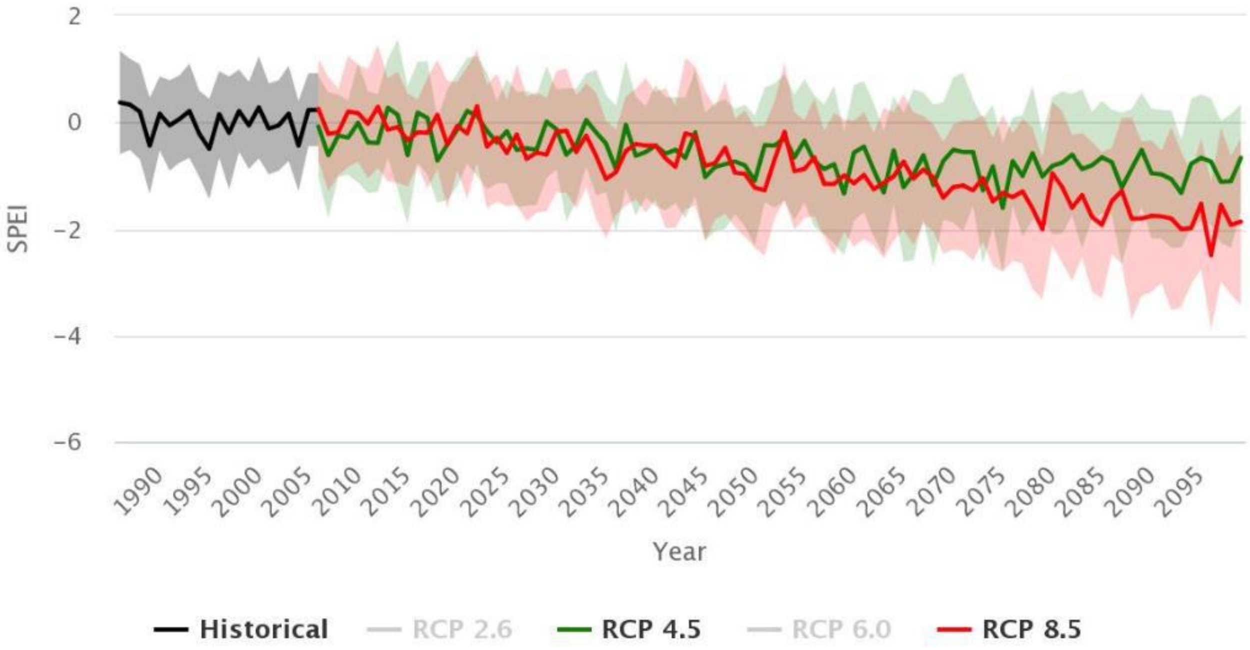

Figure 17: The graph shows the recorded Mean Drought Index (or Standardized Precipitation Evapotranspiration Index, SPEI) per year for 1986-2005, and projected SPEI for 2020-2100 under all RCPs of CIMP5 ensemble modeling. Note, the shaded ranges illustrate the inter-model differences, here using the +/- one standard deviation. The reason for using a narrower metric compared to the 10th and 90th percentile is that the inter-model difference is large for precipitation, and in particular for the count of days with rainfall.

4.3 Water

Over the past century, substantial growth in population, industrial and agricultural activities, and living standards have exacerbated water stress in many parts of the world, especially in semi-arid and arid regions. Climate change, however, will regionally exacerbate or offset the effects of population pressure for the next decades. It is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions. In contrast, water resources are projected to increase at high latitudes. Proportional changes are typically one to three times greater for runoff than for precipitation. Furthermore, Climate change is projected to reduce raw water quality, posing risks to drinking water quality even with conventional treatment[4].

Some of the most direct impacts that climate change might have on the water sector are listed in the following table (Table 3).

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[4] Climate Change 2014 – Synthesis Report IPCC (https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf)

Table 3: Summary of the impacts that different climate indicators have on the water sector in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
Heat increases the request for water, and water losses due to evaporation increases. Glacial melt increases temporary the discharge but reduces the water stock, Water quality decreases and pests increases	In general, an increased precipitation means that more water is available for use.	An increase in more extreme precipitation events means a higher risk of floods. Multipurpose reservoirs will need to keep normal operation levels lower to account for the increase in flood risks. Lower Normal Operation levels means that less water is available for downstream uses when needed. Further it leads to increase of turbidity and sedimentation, less infiltration to the aquifer and increased load of parasite into reservoir and wells	Drought increases the water request, but also the evaporation. It leads to reduced water stock

The linkages between climate change and its impact on the water sector are further explored in the following paragraphs.

4.3.1 Change in Mean Monthly Precipitation for period 2040-2059

The annual distribution of rainfall is of great interest to the water industry. Particularly in areas with large seasonality, the distribution of water throughout the year is critical for planning of resources as well as for safety against disasters. Infrastructure and management are closely tuned to the annual cycle of supply and demand. Operational monitoring of the supply is critical for optimal management of the resources. systematic changes in the annual cycle are initially not beyond what the interannual variability has been providing, but changes over time might limit the flexibilities in response, or the more extreme conditions might surpass previously experienced conditions and a reanalysis of the infrastructure and management system might be warranted. The projected changes in the seasonal cycle of rainfall offer insight into systematic trends in the water supply in a warming world. Depending on location, the separation between the different RCPs is clearer (Figure 18).

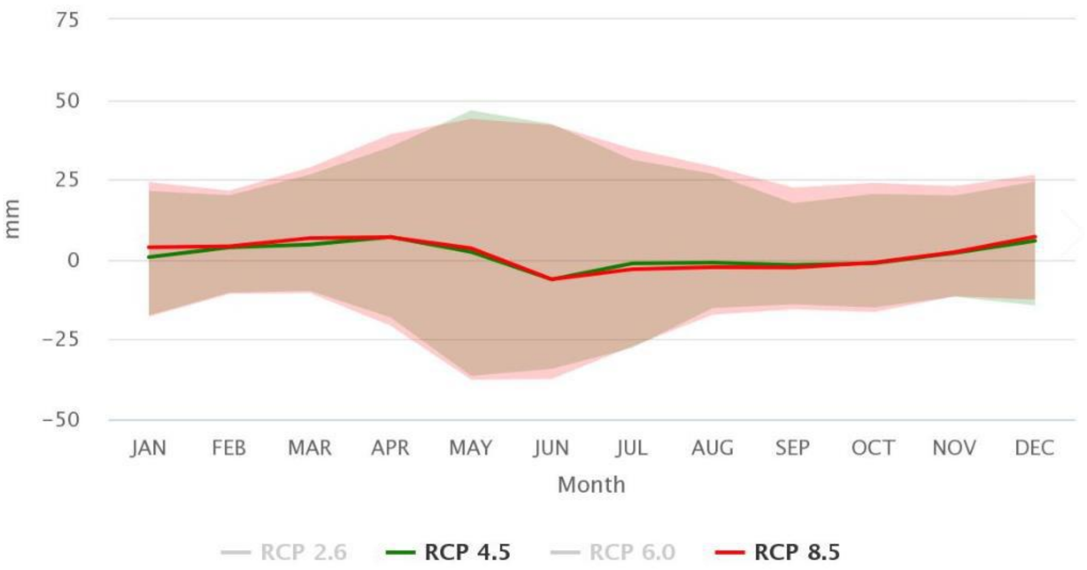


Figure 18: The graph shows projected change in Monthly Mean Precipitation per month by 2050 compared to the reference period (1986-2005) under all RCPs of CIMP5 ensemble modeling. Positive values indicate that monthly rainfall will likely to increase compared to the baseline, and vice versa. The shaded area represents the range between the 10th and 90th percentile of all climate projections.

4.3.2 Number of Days with Very Heavy Precipitations for period 1986-2099

Raising temperatures bring along a change in the potential carrying capacity of moisture in the air. With ~7% increase of theoretical water holding with every degree Celsius, the potential for heavy rainfall is increasing. Looking at the changes in the number of days with at least 20mm of daily rainfall helps to estimate how likely the impacts are of heavy rainfall. Water routing, and thus storage and other management options, are often very different if the input comes in form of many weak or a series of heavy rainfall events. 20mm is one of the thresholds used and represents very heavy precipitation. In some regions, this might be quite common, in others such amounts are exceedingly rare. Other absolute thresholds could be chosen, or return levels for a particular time interval could be looked at. Together, these indicators provide a picture of potential impact of the projected changes (Figure 19).

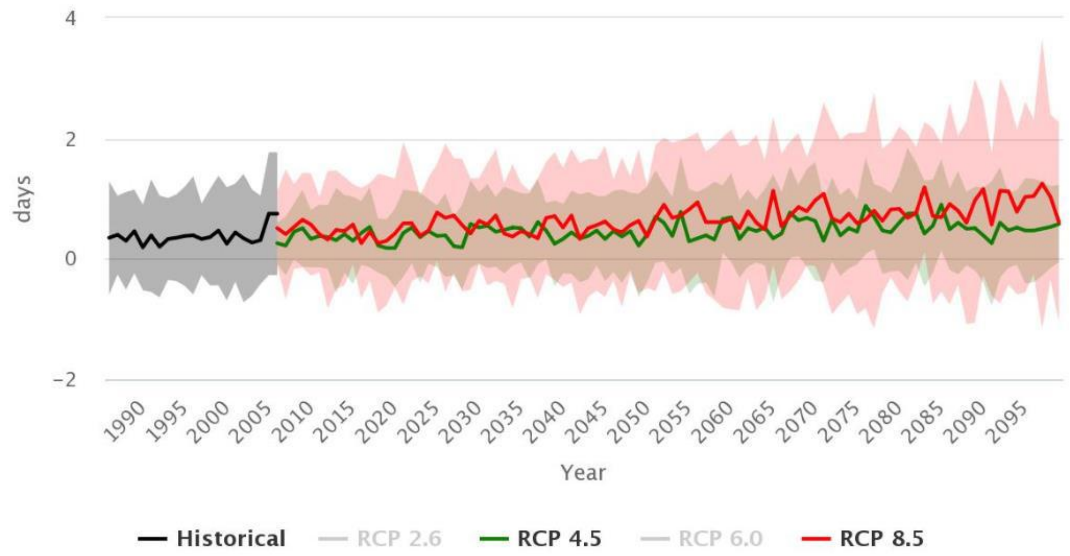


Figure 19: The graph shows the recorded number of Days with Vey Heavy Rainfall (20mm/day) each year for 1986-2005, and projected values for 2020-2100 under all RCPs of CIMP5 ensemble modeling. Note, the shaded ranges illustrate the inter-model differences, here using the +/- one standard deviation. The reason for using a narrower metric compared to the 10th and 90th percentile is that the inter-model difference is large for precipitation, and in particular for the count of days with rainfall.

4.3.3 5-Day Precipitation: 25-yr Return Level for period 2040-2059

The most extreme rainfall episodes generally have the danger of leading to significant floods. Individual daily rainfall is often linked to flash-floods of limited spatial extent, but multi-day rainfall generally has a broader spatial footprint and thus more extensive flooding can be explained. The 5-day cumulative rainfall indicator shown here focuses on the maximum rainfall amount that is expected over a 25-yr period. Any changes can have significant impacts on infrastructure and endanger life and property through direct physical effects and potentially through water quality issues. Any significant changes in their magnitudes need to be understood (Figure 20).

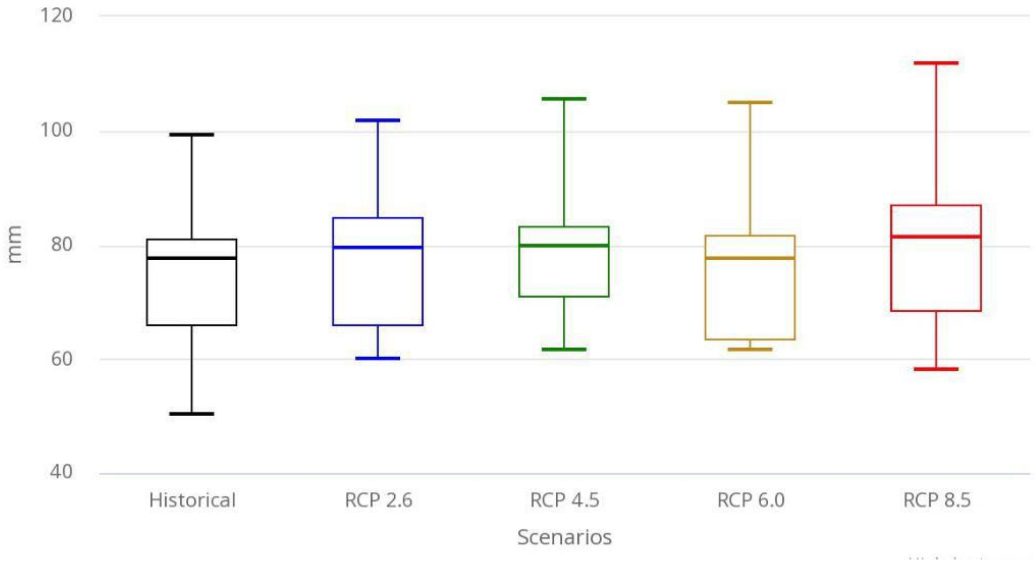


Figure 20: The boxplot shows recorded 5-Day Cumulative Rainfall for 1986-2005 and projected 5-Day Cumulative Rainfall 25-yr Return Level by 2050 under all RCPs of CIMP5 ensemble modeling. This indicator focuses on the maximum 5-day cumulative rainfall amount that can be expected within a 25-yr period.

4.3.4 Change in Annual Likelihood of Severe Drought

Changes in the water balance is of increasing concern on a warmer planet. As a broad rule of thumb, areas that are traditionally dry are expected to become drier, and areas traditionally wet will likely become wetter. But that average pattern is also reflected in the interannual variability as higher temperatures enhance the feedback from more quickly drying soils, even if precipitation doesn't change. Therefore, there is a need to plan for more severe and more frequent drought years, almost anywhere. The standardized precipitation evapo-transpiration index (SPEI), computed over 12 month periods, captures the cumulative balance between gain and loss of water across the interannual time scale. The likelihood for severe drought analyzes the frequency at which prolonged dry conditions are expected, and shown in the map is the probability for change by 2050, using the most aggressive RCP8.5. Other scenarios will show similar direction of changes, albeit as somewhat reduced probabilities (Figure 21).

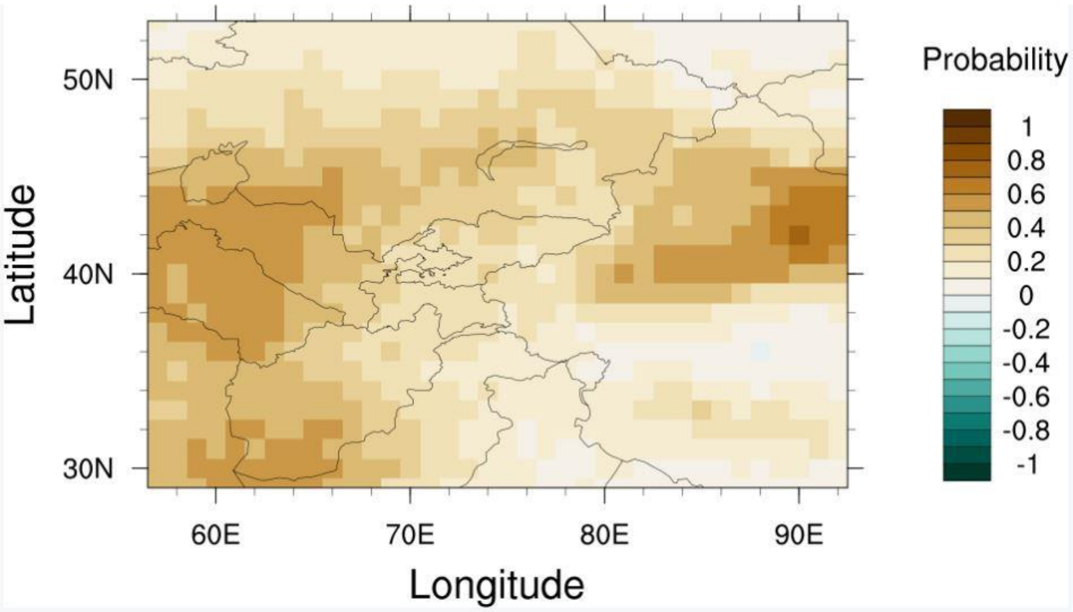


Figure 21: The map shows change in projected Annual Likelihood of Severe Drought by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modeling. Brown/Yellow areas are more likely to experience severe drought compared to the baseline period. Meanwhile, Blue/Green areas are less likely to experience severe drought.

4.4 Transport

An increase in temperature and extreme precipitation has clear and direct impacts on the transportation sector. Temperature increases in the northern part of Kyrgyzstan will inevitably cause a deterioration of the road conditions, rutting of the asphalts and wear of the infrastructures. Extreme precipitation will also cause the risk for flooding and the risk of temporary or permanent damages to roads and bridges.
Some of the most direct impacts that climate change might have on the transport sector are listed in the following table (Table 4).

Table 4: Summary of the impacts that different climate indicators have on the transport sector in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
Pavement is most vulnerable to heat. Higher temperature requires other and new types of asphalt, more resistant against rutting and melt.	Shift in seasonal precipitation and elevation, increases the risk of avalanches and glacier lake breaches	The increase in the frequency of extreme precipitations events will mean that the design conditions of roads and bridges might become inadequate. The risk of temporary or permanent	

The number of accident is strongly related to heat		disruption to transportation routes might become inevitable Extreme precipitation is a major cause of hazards like mudflow, flash flood, landslide, flooding disrupting infrastructure It puts impact on road and bridge foundation and causes overload drainage system	

4.5 Health

The human health sector has clear links to climate variability through both direct exposure as well as indirect pathways. Obviously, negative health impacts come from extreme climate events, such as heat waves, hurricanes/storms, floods and droughts. Gradual changes of climate affecting water, food and air quality also have negative influence on human health around the world. Beyond the physical effects are issues related to mental health. Research has shown that increased numbers of extreme events can leave significant fractions of the population with PTSD-like symptoms. Although controversial, studies indicate that there is linkage between rising temperatures and increase in aggression and violence in society.

Some of the most direct impacts that climate change might have on the health sector are listed in the following table (Table 5).

Table 5: Summary of the impacts that different climate indicators have on the health sector in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
With every degree C of temperature increase, the call into hospital increase approximately 2,5%. This means that the Government of Kyrgyzstan will need to allocate additional budget and capacity. Increase respiratory, cardiovascular disease Decrease of food safety Increased accidents risk		Extreme precipitation increases risk of drinking water to be polluted. In addition, the impact of hazards will increase.	Drought pressure on health by dehydration and reduced drinking water availability

The linkages between climate change and its impact on the health sector are further explored in the following paragraphs.

4.5.1 Temperature: Spatial Variability in Record High Temperatures

Climate change impacts on human health can come in many forms. One of the most obvious is through an increase in likelihood of the warmest temperatures, and particularly the highest temperature in a region. These extremes of temperature are what have some of the highest impacts on people and infrastructure that could ameliorate these peaks. Although alone not sufficient to quantify heat impacts in general, record high temperature estimates are a quantity that people can easily relate to, more so than for example the successive number of warm nights, where the organisms can't cool down and recover from the temperature stress during the day. Overall, the projected changes are one measure in a portfolio of factors, and interestingly the expected changes in peak temperatures are often larger than the changes in mean temperatures (Figure 22).

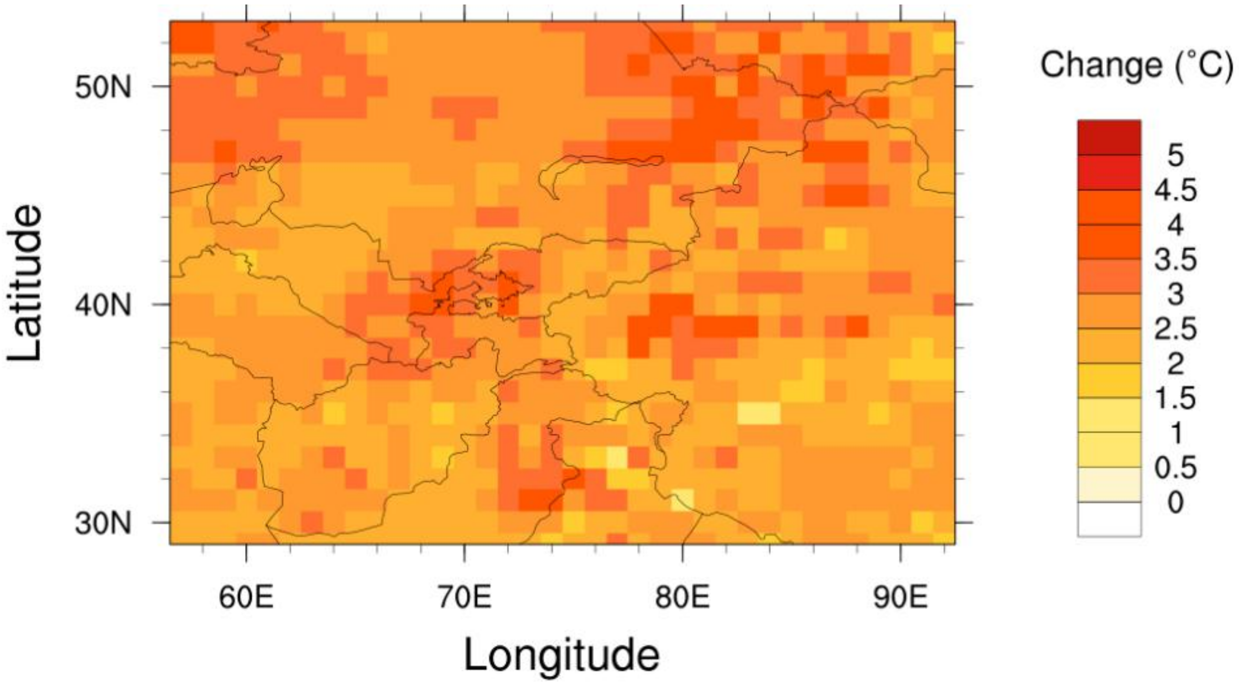


Figure 22: The map shows projected change in Maxima of Daily Maximum Temperature by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modeling.

4.5.2 Seasonal Variability: Change in Number of Heat-Days for the Period 2040-2059

The annual distribution of days with a high heat index provides insight into the health hazard of heat. Computed by combining temperature and relative humidity, the heat index provides a measure of apparent temperature, the temperature that reflects comfort or discomfort. Often, high temperature alone can be compensated for by evaporative cooling such as from transpiration. But if the air is nearly saturated with moisture, then that cooling potential is reduced and the apparent temperature increases. Here a standard heat index is used where 35 degrees is a high threshold beyond which humans not only feel uncomfortable but where health dangers increase rapidly (Figure 23).

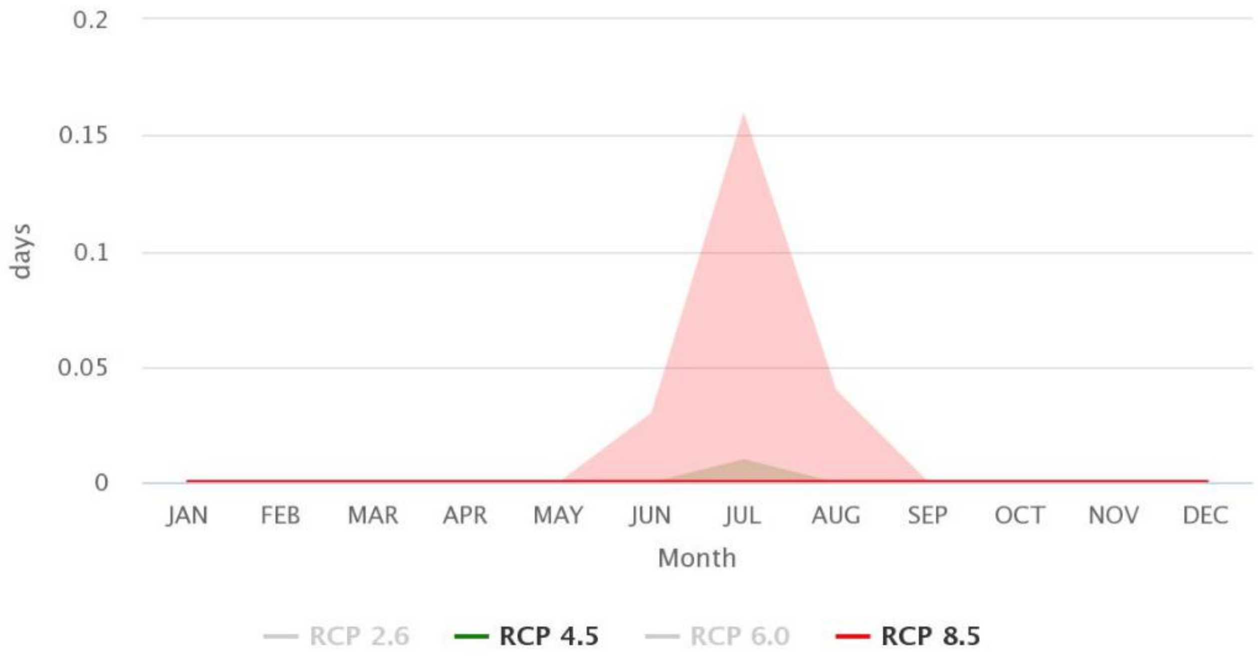


Figure 23: The graph shows projected change in Number of Heat Days (Tmax > 35°C) per month by 2050 compared to the reference period (1986-2005) under all RCPs of CIMP5 ensemble modeling. Positive values indicate that number of heat days will likely to increase compared to the baseline, and vice versa. The shaded area represents the range between 10th and 90th percentile of the projection.

4.5.3 Temperature: Tropical Nights (>20°C) for period 1986-2099

The counterpart to daily peak temperatures is the nighttime cooling. Many organisms can cope with high temperatures during the day if there is sufficient cooling for recovery at night. If the daily minimum temperatures don't drop below the 20°C threshold, then the night is called a "tropical" (or hot) night. The increase in health threats can be monitored through the frequency of tropical nights. In the projection shown in the time series graph, the difference in expected numbers of tropical nights can be seen across the different RCPs. Generally, a drastic increase is found for the high-emission related scenario of RCP8.5 and significantly less for the lower scenarios (Figure 24).

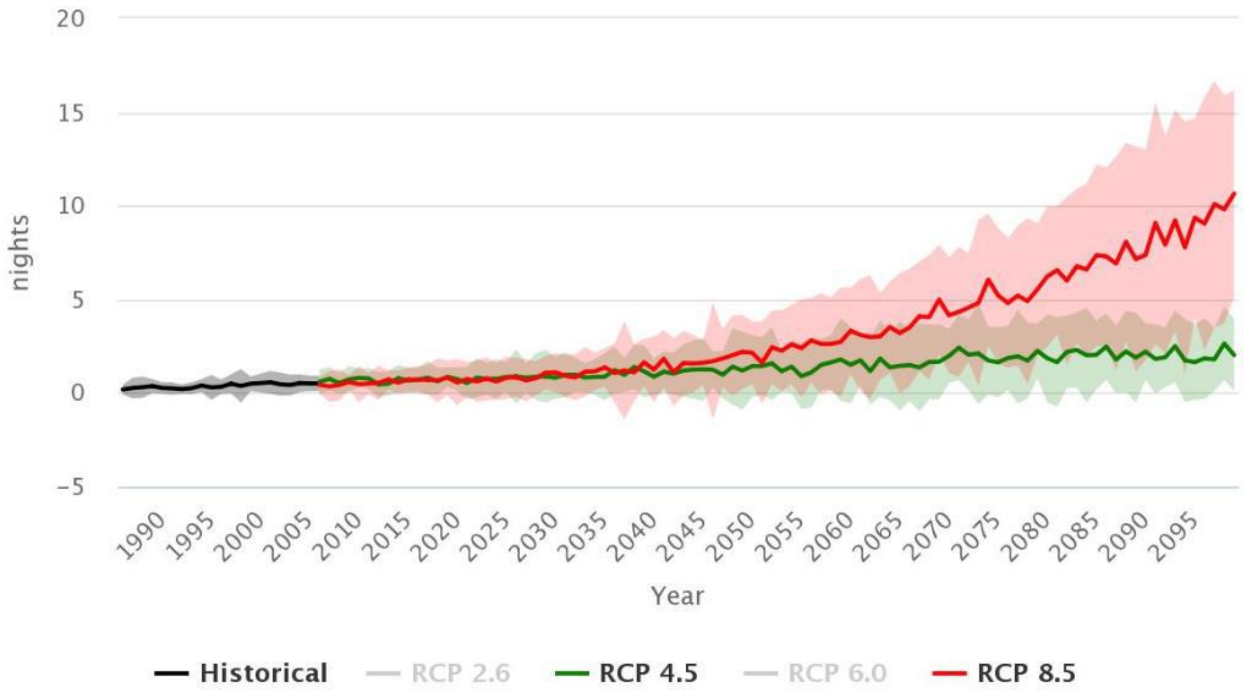


Figure 24: The graph shows the recorded number of Tropical Nights (Tmin > 20°C) per year for 1986-2005, and projected values for 2020-2100 under all RCPs of CIMP5 ensemble modeling. Note, the shaded ranges illustrate the inter-model differences, here using the +/- one standard deviation. The reason for using a narrower metric compared to the 10th and 90th percentile is that the inter-model difference is large for precipitation, and in particular for the count of days with rainfall.

4.5.4 Extreme Events: Warm-Spell Duration Index (WSDI) for period 2040-2059

The hottest places in low latitudes don't necessarily have longer warm spells, because they generally exhibit a large variability over the course of a few days. In the tropics, however, where day-to-day variability and even month-to-month variability is small, a phase of warming can immediately generate large numbers. The cumulative nature of a sequence of multiple days with high temperatures can raise the impact on the human body and lead to health issues in broad segments of the population. Many studies have reported associations between temperature extremes and mortality rates of circulatory diseases (WHO, 2009). In addition, Heat amplified levels of some urban-industrial air pollutants could cause respiratory disorders and exacerbate heart and blood vessel disease (Turn Down the Heat, 2012) (Figure 25).

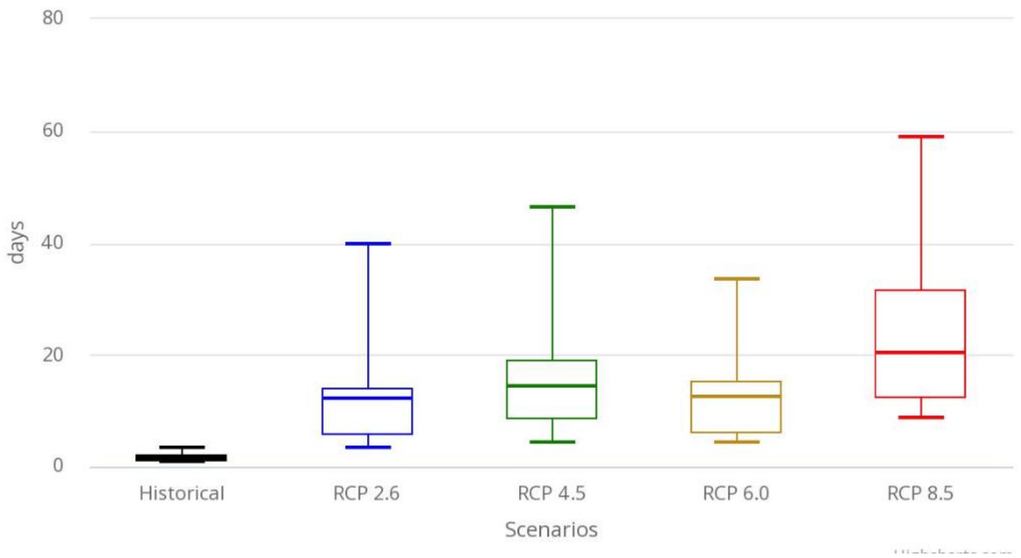


Figure 25: The boxplot shows recorded Warm Spell Duration Index (WSDI) for 1986-2005 and projected WSDI by 2050 under all RCPs of CIMP5 ensemble modeling. The WSDI is a measure of such an uninterrupted sequence of at least 6 days that surpass the currently observed 95th percentile of temperature. It therefore not only reflects increases in temperature but looks at the likelihood of sequences of conditions that today are considered the warmest conditions in the year.

4.6 Forestry

Just over 5% of Kyrgyzstan is covered by forests. The increase in heat will cause a shift in the ecological zones of the Country and the likelihood that pest / diseases attacking large swath of forest areas. Like for the agriculture sector, an increase in temperature will cause stress in the growth of the forests. Furthermore, although the expected increase in precipitation over Kyrgyzstan might provide a positive impact, the increase in the frequency of extreme precipitation events will equally negatively impact these parts of the country as risk of erosion due to flooding will also increase.

Some of the most direct impacts that climate change might have on the forestry of Kyrgyzstan are summarized in the following table (Table 6).

Table 6: Summary of the impacts that different climate indicators have on forestry in Kyrgyzstan

Heat	Precipitation	Extreme Precipitation	Drought
Pest / disease Ecological zone shift / growth stress Reducing margins of optimal forest growth Increase wildfires	The increase in precipitation that is expected over Kyrgyzstan will positively affect the forest areas	Erosion risk and runoff increases with the heavy precipitation, as less water will infiltrate to the aquifer, increased risk of waterlogging	Over the long-term, the increase in the frequency and severity of droughts will cause a reduction in the forest growth Increase wildfires

4.7 Hazards

Overall risks from climate-related impacts are evaluated based on the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of communities (susceptibility to harm and lack of capacity to adapt), and exposure of human and natural systems. Changes in both the climate system and socioeconomic processes -including adaptation and mitigation actions- are drivers of hazards, exposure, and vulnerability (IPCC Fifth Assessment Report, 2014).

Some of the most direct impacts that climate change might have on increasing the likelihood of hazardous events are listed in the following table (Table 7).

Table 7: Summary of the impacts that different climate indicators have on natural hazards in Kyrgyzstan

Temperature Increase	Precipitation	Extreme Precipitation	Drought
With the increase in temperature as one of the causes, also on high altitude, the glaciers are melting, increasing formation of new glacier lakes and with that the chance on glacier lake outburst flood	Precipitations is now happening earlier in the season and at lower elevations in the mountains thus increasing the risk for avalanches.	Extreme rainfall events increase the risk of floods, flash floods, mudflows, landslides and rockfalls. The risk is also strongly influenced by land degradation	Drought spell. Drought is expected to become one of the biggest economic cost under the hazards. And when drought risk and water stress come together the sensitivity for drought spell is high Increased deforestation (also human induced)

The linkages between climate change and an increased risk on disasters are further explored in the following paragraph.

4.7.1 Key Natural Hazard Statistics

Climate change is now recognized to have a significant impact on disaster management efforts and pose a significant threat to the efforts to meet the growing needs of the most vulnerable populations. The demands of disaster risk management are such that concise, clear, and reliable information is crucial. The information presented here offers insight into the frequency, impact and occurrence of natural hazards (source: World Bank Climate Knowledge Portal) (Figure 26-Figure 27).

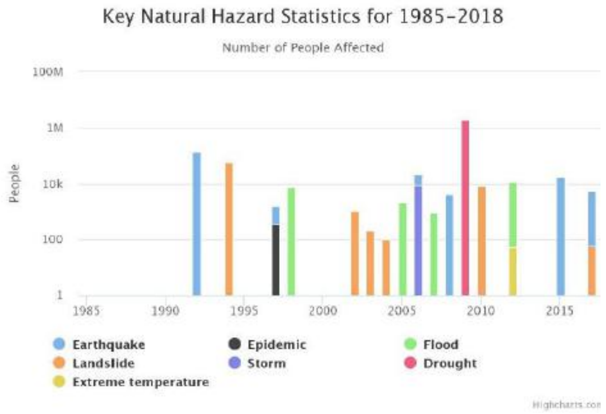


Figure 26: Key Natural Hazard Statistics for the period 1985-2018

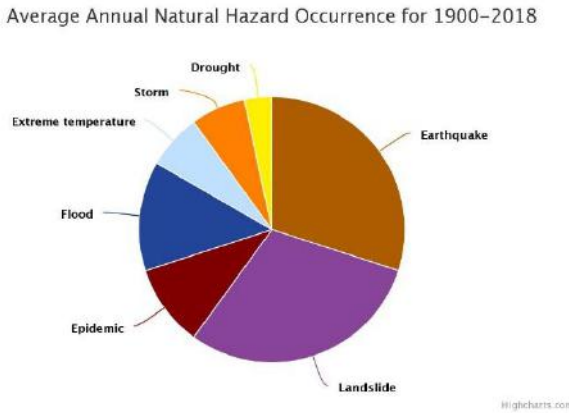


Figure 27: Average Annual Hazard Occurrence for the period 1900-2018

5 CLIMATE IMPACT CHAIN

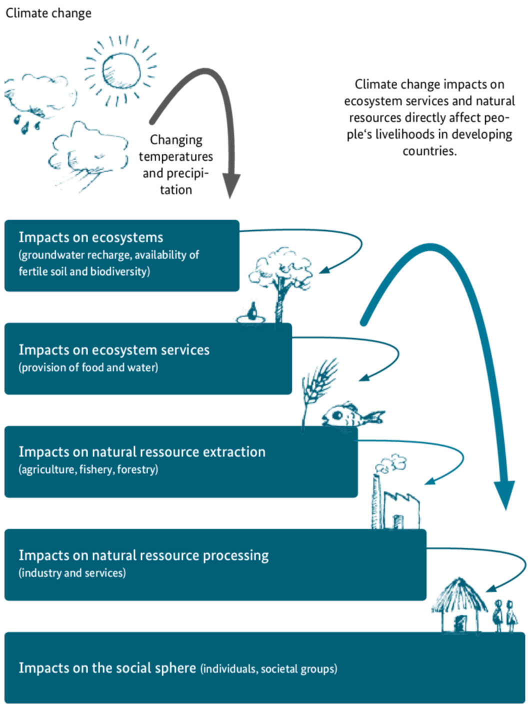


Figure 28: Climate change impacts

Climate change is not putting direct stress on sectors. The pressure of climate change goes through the impact on the ecosystem and ecosystem services and first than our use of natural resource, processing, marketing and human impact (Figure 28).

Besides the ecosystem also the human behaviour is influencing the impact chain, through publics adaptive capacity, but also through its influence on natural resources like land degradation which is multifolding the climate risk on natural hazards. Also infrastructure like dikes influences the impacts (Figure 29).

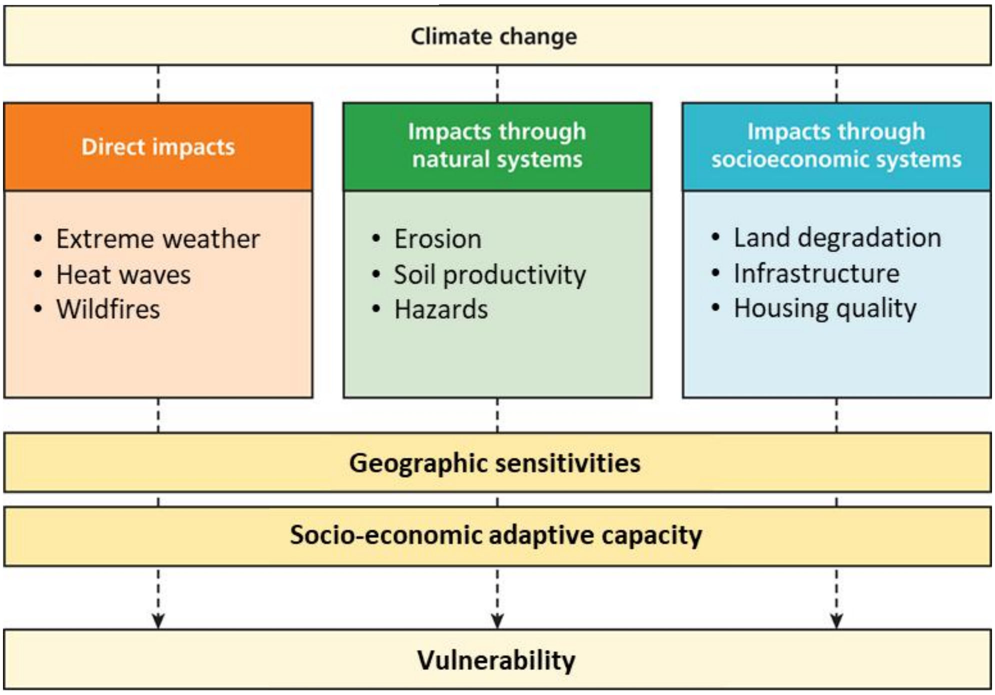


Figure 29: The climate impact chain

6 CLIMATE RISK AND VULNERABILITY ASSESSMENT

6.1 General Aspects

Climate Risk and Vulnerability Assessments aims to bridge the gap between Climate exposure and Climate Change Adaptation. This is done by, besides climate change exposure, to include sensitivity to climate change and adaptive capacity in the process of decision making. This results in a vulnerability assessment. Based on the vulnerability assessment, the adaptation measure can be more easily selected and prioritised.

The Climate Risk and Vulnerability Assessment comprises of 8 main tasks from issue identification through data collection to aggregation of maps. As CRVA is issue driven, in the preparation phase the issues and the sectors involved have to be clearly described. Based on the sectors the climate indices have to be selected (Table 8).

Table 8: Climate indicators used in CRVA for different sectors

Sector	Heat	Length of Growing Season	Total Precipitation	Heavy Precipitation	Drought
Agriculture	V	V	V	V	V
Energy			V	V	V
Water	V		V	V	V
Health	V			V	V
Transport	V			V	
Forestry	V	V	V	V	V
Hazards	V			V	V

Sensitivity can be divided between:

- Geographic sensitivities
    - Water stress, Drought risk, change in Soil cover (additional Soil moisture)
- Social economic sensitivity and potential adaptive capacity
    - Gross National Income per capita, Human Development index (life expectance, education, health), Distance to market (potential for development),
- Additional useful information
    - Land use, Elevation / slope, Market share, flood risk

6.2 Methodology Adaptation to National Level CRVA

To understand the priority adaptation measures (Figure 30), it is needed to understand:

- Climate exposure

Sensitivity

- Adaptive capacity

And as result the vulnerability

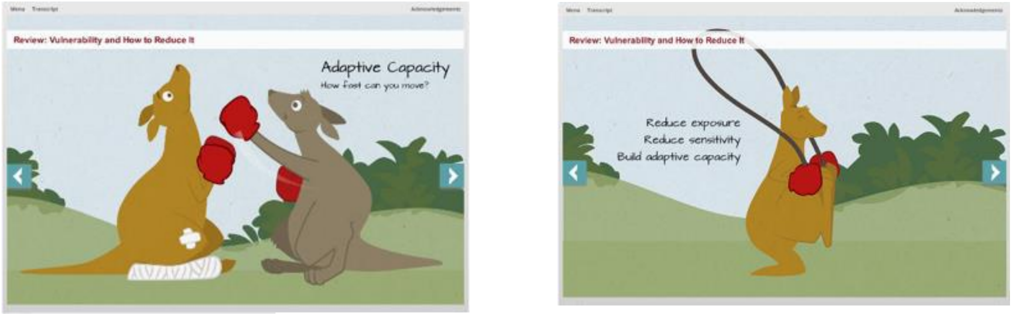


Figure 30: Climate change adaptation

Based on this information Adaptation measures can be selected to reduce sensitivity, and / or increase adaptive capacity.

6.3 Set up of the Climate Exposure

The climate exposure assessment is based on the comparison between the average between 1960-1990 and the modelled data for the scenarios for 4.5 and 8.5 C temperature increase.

The classification is done by making use of the class percentile classification. The score is runs from 6-1 for most negative impact to -1 to -6 for a positive impact.

-6	-5	-4	-3	-2	-1	1	2	3	4	5	6
🟩	🟩	🟩	🟦	🟦	🟦	🟨	🟨	🟧	🟧	🟥	🟫

improved – vulnerability - worsened

The **Climate Exposure map** is combined as follows:

- Heat - Extreme maximum daily temperature and warmth duration
- Total precipitation
- Heavy precipitation - Heavy precipitation, Extreme precipitation, 1 day maximum precipitation
- Drought - Duration of consecutive droughts

The **climate related geographical sensitivity** is combined as follows:

- Water stress (percentage of natural water resources used), Drought risk (combines the water stress index with population, poverty)
- Changes in soil productivity

The **climate related socio-economic sensitivity** (and adaptive capacity) are built on the following indices:

- Gross National Income per capita (poverty), Human Development Index (life expectance, health and education), distance to the market

In the figure below you find schematic how the information is composed.

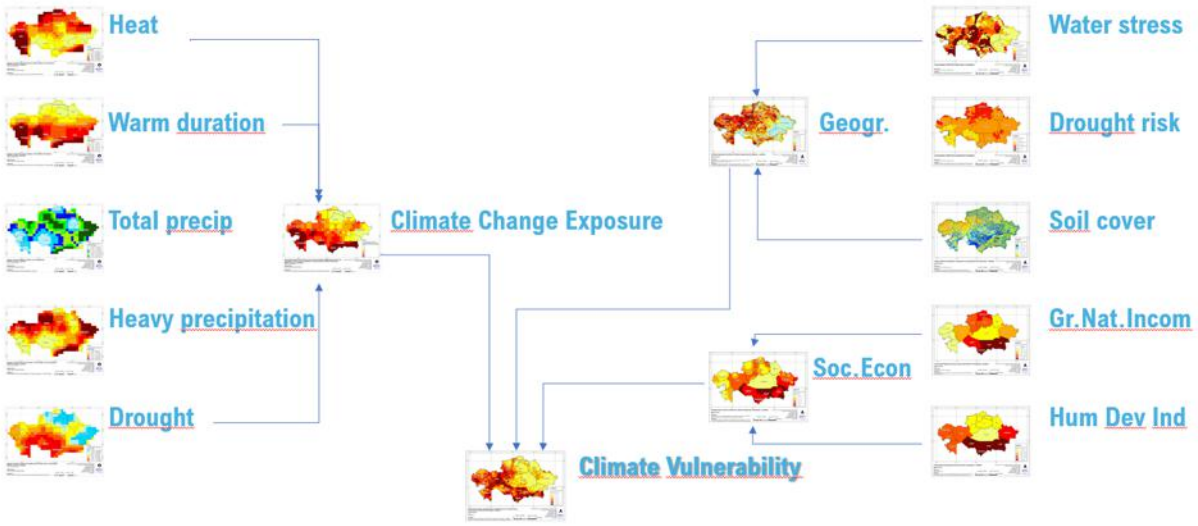


Figure 31: Schematic representation of the Climate Risk and Vulnerability Analysis

7 CLIMATE RISK VULNERABILITY ANALYSIS

The national CRVA is built from the following component:

- Climate Change Exposure
- Climate Change related Geographical sensitivity
- Climate Change related Socio-economic sensitivity

Some of the key takeaways from the analysis graphically presented in the following sections can be summarized as follows:

- **Climate Change Exposure**: Chuy, Jalal-Abad and Osh province are the most exposed to climate change. Heat and share of extreme precipitation and for the southern part of the country the increased drought are the most important impacts. For Jalal-Abad and Osh it is also the increase of heavy precipitation. The increased precipitation will almost fully be received in the form of heavy precipitation. This counts also for Batken. The strong increase of drought spell duration, with 5 up to 8 days per drought spell, is expected for the whole norther part of the country.

  It has to be taken into account that besides the above mentioned climate exposure a seasonal shift and shift in elevation for temperature and precipitation is taken place.
- **Climate Change related Geographical sensitivity**: Water stress and drought risk can be found all over the country, but concentrate in Batken, Osh and Chuy province. Decrease of land productivity is concentrated in Chuy, Talas and Jalal-Abad. The increase of soil productivity can mainly be found on higher elevation. Comparing with soil moisture there is an indication of human induced land degradation.
- **Climate Change related Socio-economic sensitivity:** Adaptive capacity is related to the income per capita, Education, health, life expectation and distant to market. The higher income per capita can be found in Osh and Issyk Kul. Batken and Naryn have the lowest score on income. The Human Development Index (Life expectance, education and Health) is the lowest in the Western provinces Jalal-Abad, Osh and Batken. As result Batken and Jalal-Abad has the highest social-economic sensitivity and as result the lowest adaptive capacity.

In conclusion, the climate-risk vulnerability map derived from the three components described above, provides indication that the higest vulnerability for climate change can be foundin Chuy, Jalal-Abadand Batken, followed by Osh. It has to be mentioned that the vulnerability is strongly influence by the mountain ranges.

The details of the Climate Risk Vulnerability Analysis conducted over Kyrgyzstan are provided in the following sections.

7.1 Sectoral Vulnerability

The different sectors are influenced differently by the climate change.

- **For Agriculture** there are big regional differences in climate exposure. Chuy, Issyk-Kul and eastern part of Jalal-Abad and Osh, are expected to be the most impact. Batken and Osh province may expect thanks to the increased precipitation and less drought risk an increase of productivity. This will not only impact on the producers but also on processing industry, trade and consumers.
- **Energy** may expect decreased cooling capacity for fossil energy, Hydro energy may experience due to glacier melt temporary increased productivity, which is however decreased by the increase of the heavy precipitation in the mountain ranges, which ask for additional buffer capacity. For the provinces Chuy and Osh the transmission capacity will be negatively influenced by the increase of heat.
- **Water** sector may expect increase stress as result of the drought risk in northern provinces. The increased heavy precipitation will increase this impact. This will also impact on drinking water supply with inflow in open water sources and not separated drainage and sewage systems.
- The **transport** sector may experience as result of increased heat increased asphalt melt, especially in the northern part of the country. Infrastructure for drainage and works like bridges may need redesign as result of increased precipitation
- The **health** sector may as result of heat and drought, expect an increase of call into hospitals all over the country, but especially in the northern and western provinces. Also, the emergency capacity will be impacted.
- **Forestry** in the northern provinces like Chuy, Issyk Kul will experience, as result of the heat and drought, a shift in the eco-zoning to colder areas (especially in the mountains) and increase of pests and diseases.
- Main **hazards** which are expected to increase are heat, extreme precipitation, drought and land degradation. Heat, drought and land degradation are expected to become the highest economic costs. Issues is that these are mostly not recognized as hazard as the responsibility is firstly not under Emergency Situations but under other sectoral institutions like agriculture. Northern provinces will be impacted most by drought, western provinces most by extreme precipitation, which will cause increase risk of hazards like mudflow, landslide, flash flood and flooding.

The low adaptive capacity in Jalal-Abad, Naryn and Batken need additional attention.

7.2 Climate Change Exposure

Climate Change is Exposure Analysis has been carried out for two climate change scenarios: RCP 4.5 and RCP 8.5.

A RCP scenario, or the Representative Concentration Pathway is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modelling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m^2, respectively).

7.2.1 Change in Maximum Daily Temperature (TXx)

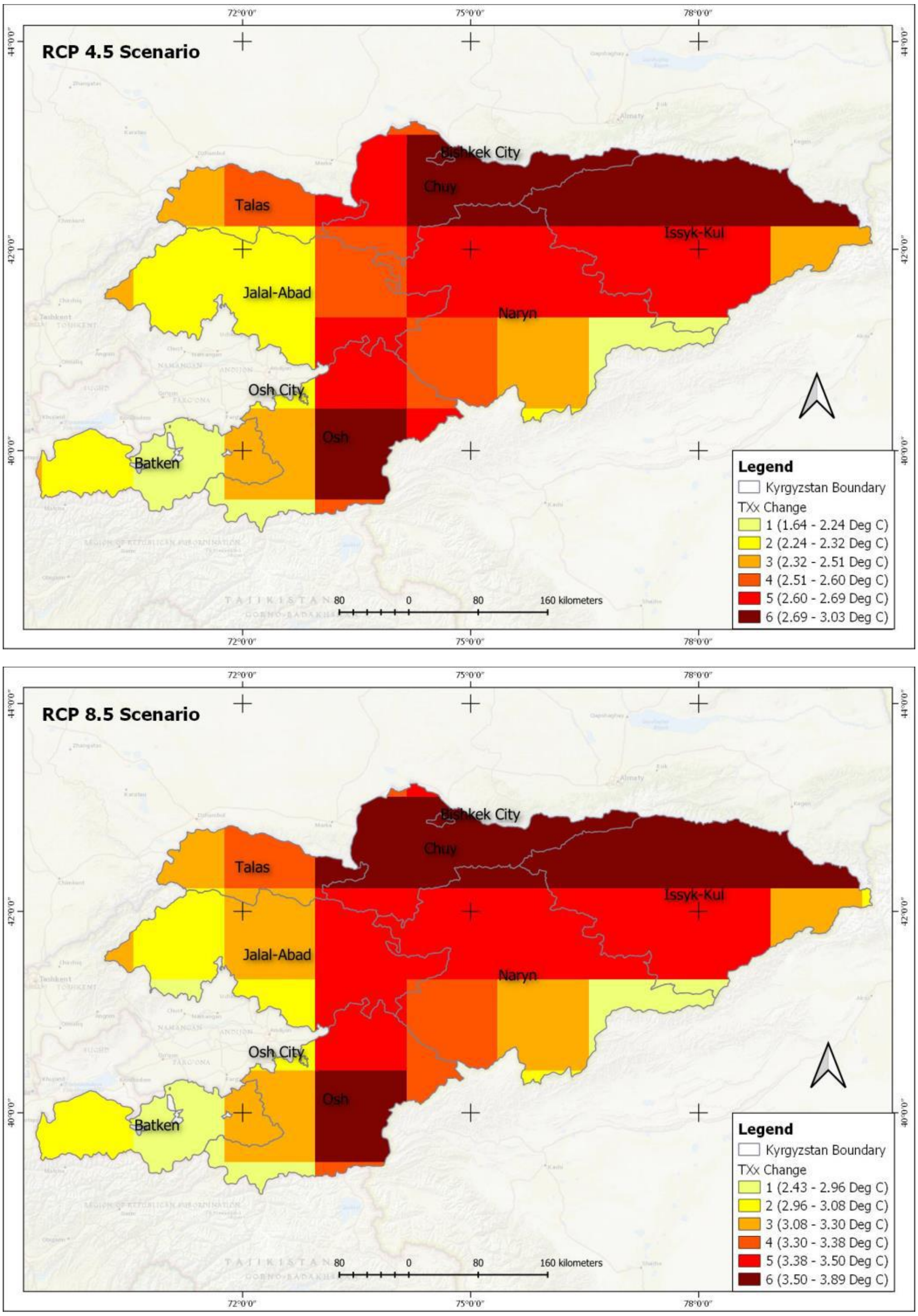


Figure 32: Projected Change in Maximum Daily Temperature (TXx) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. TXx represents annual maximum values of daily maximum temperatures.

7.2.2 Change in Warmth Duration (Tx90p)

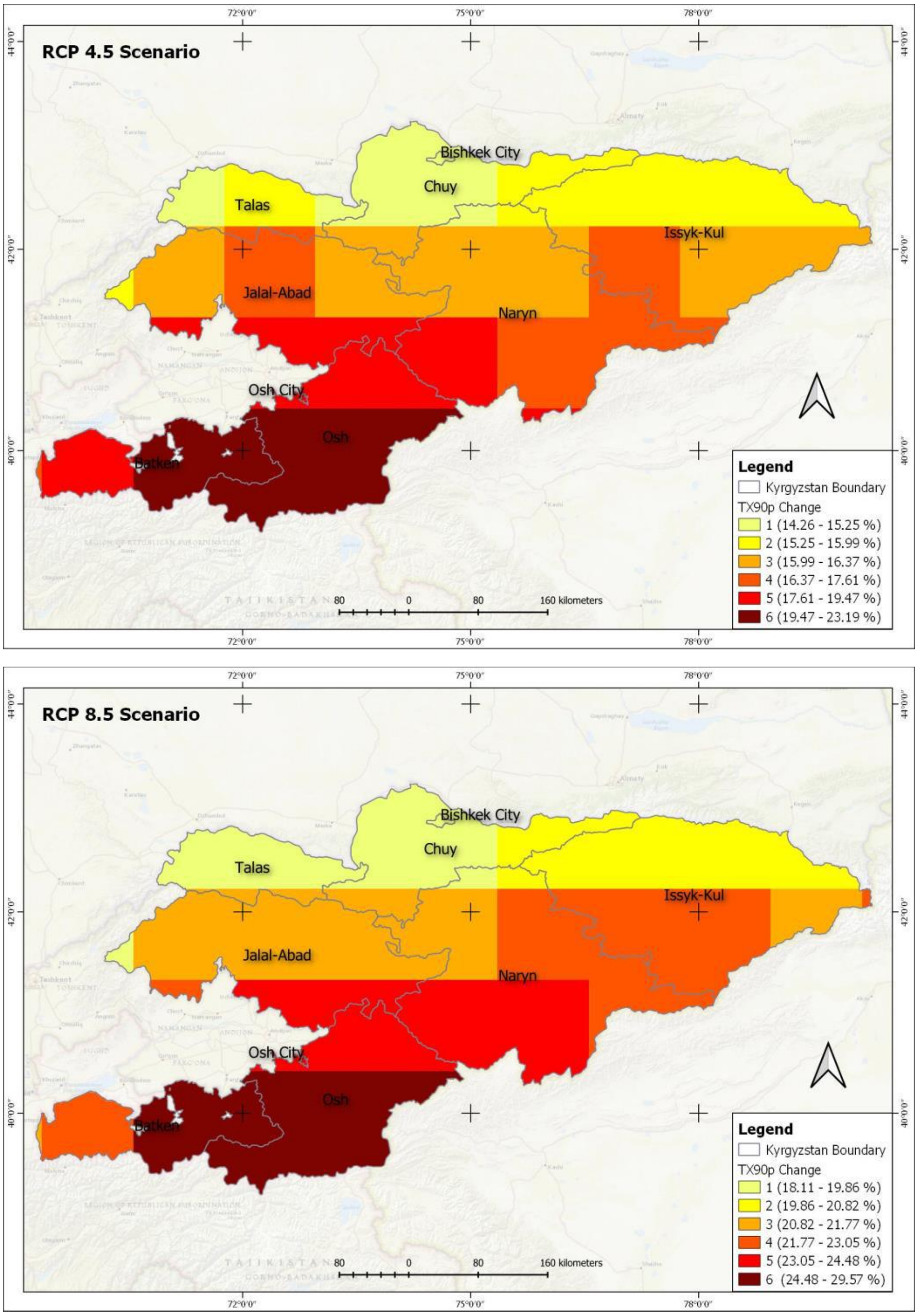


Figure 33: Projected Change in Percentage of warm daytime > 90% (TX90p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. TX90p represents % of days when the daily maximum temperature > 90th percentile.

7.2.3 Change in Total Precipitation (PrcpTOT)

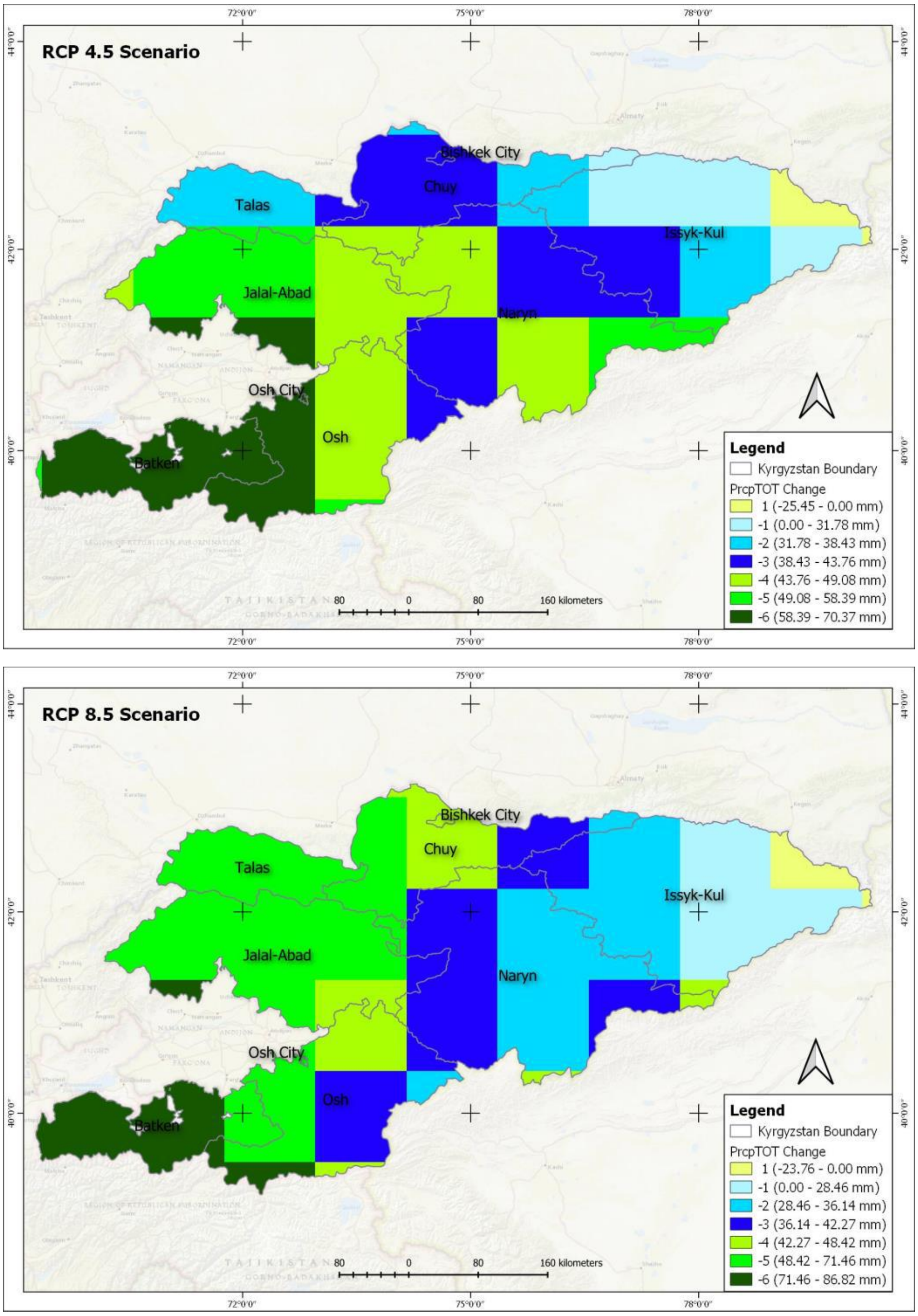


Figure 34:Projected Change in Total Precipitation by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Total Precipitation represents annual precipitation in wet days.

7.2.4 Heavy Precipitation (Rx95p)

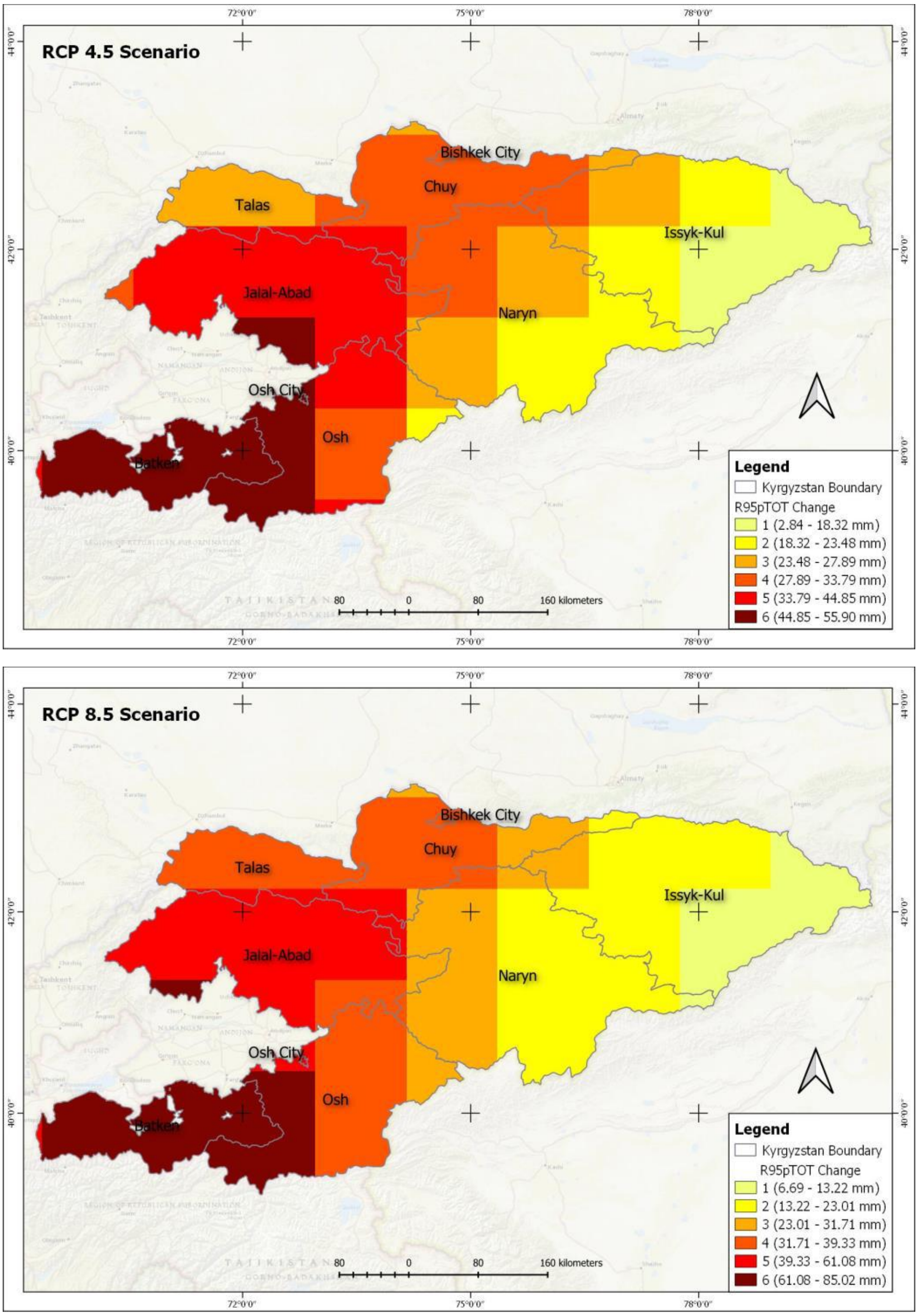


Figure 35: Projected Change in Precipitation on very wet days >95% (R95p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. R95p represents annual total precipitation when daily precipitation is > 95th percentile.

7.2.5 Extreme Precipitation (Rx99p)

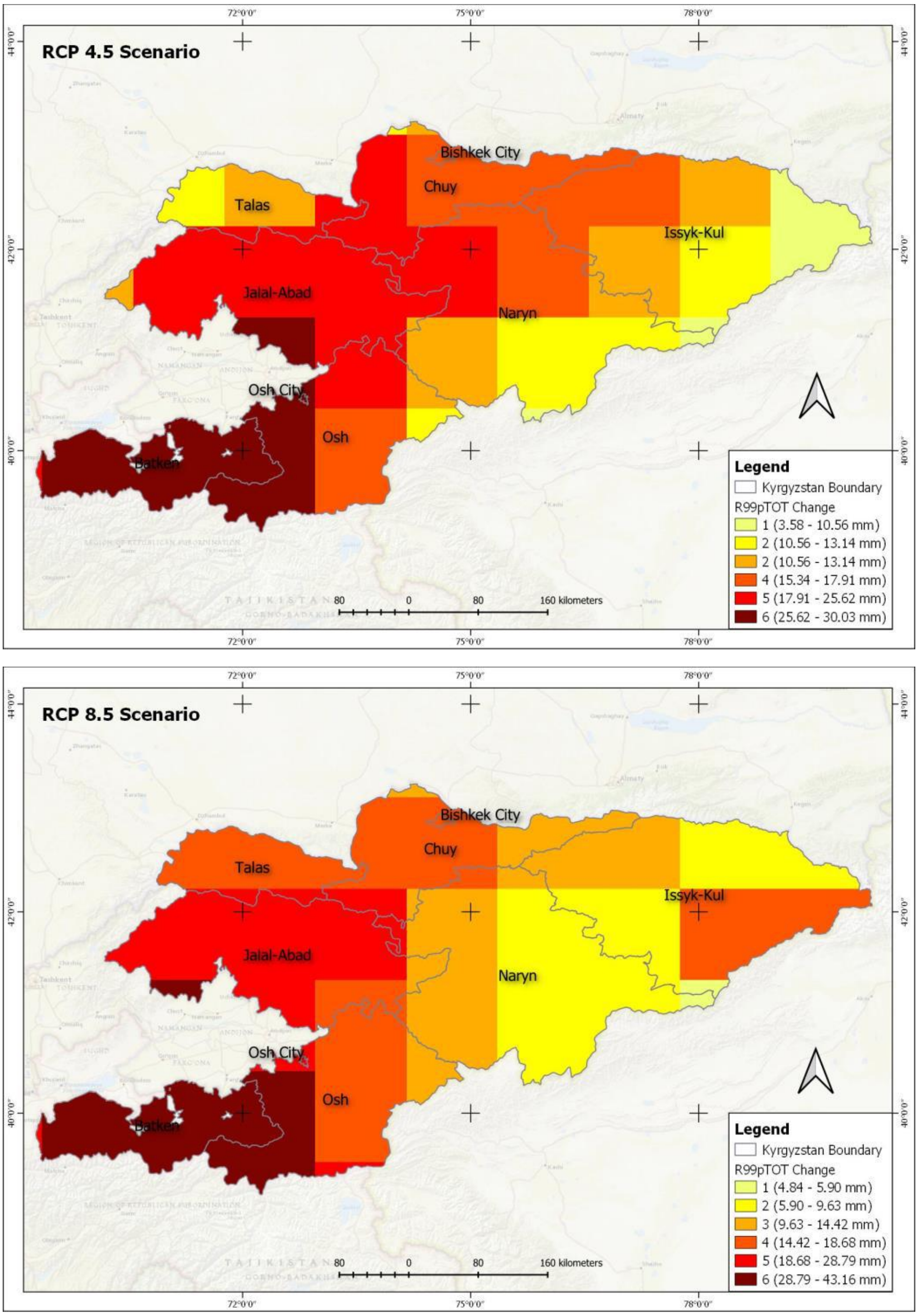


Figure 36: Projected Change in Precipitation on extremely wet days >99% (R99p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. R99p represents annual total precipitation when daily precipitation is > 99th percentile.

7.2.6 Day Maximum Precipitation (Rx1-day)

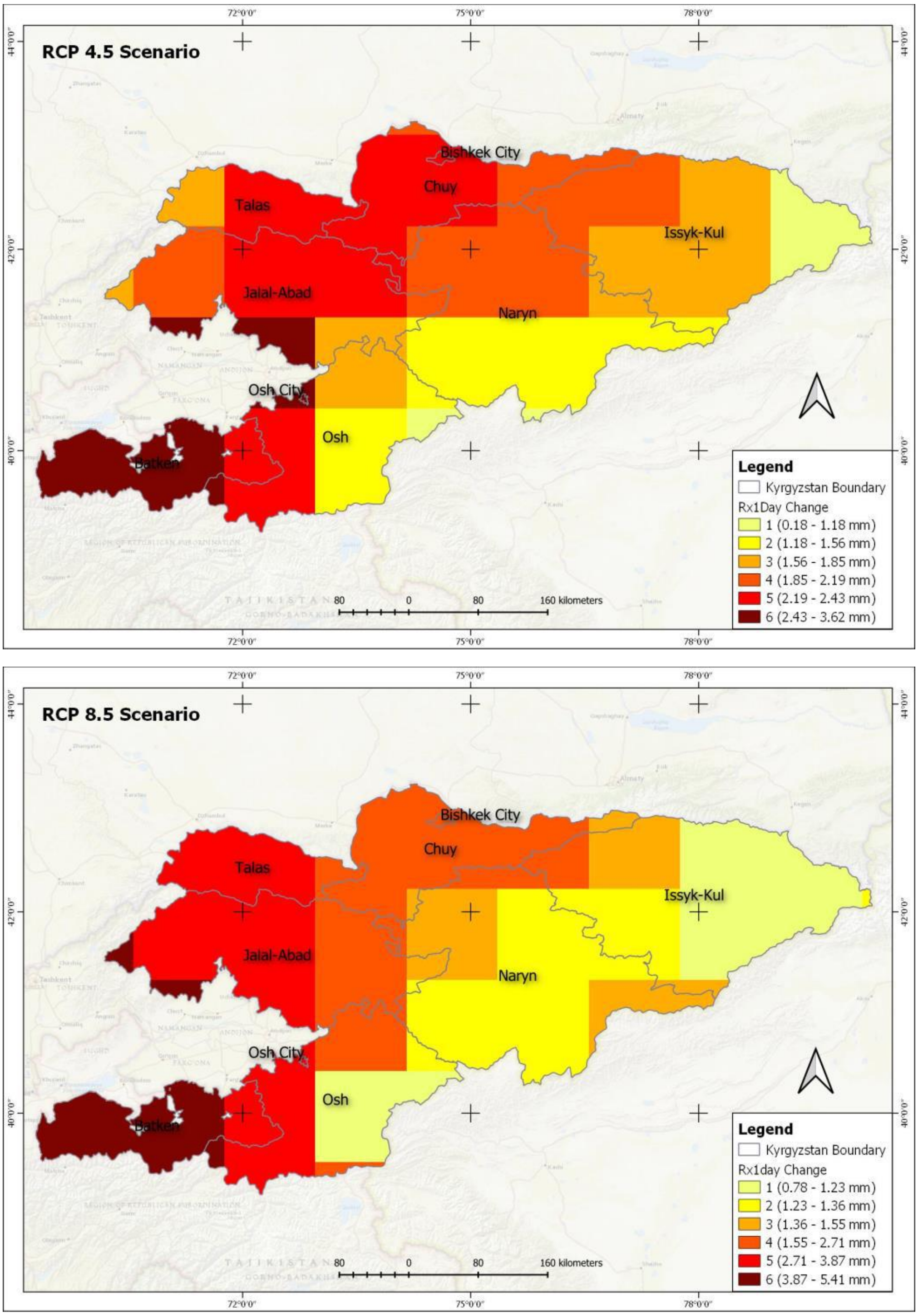


Figure 37: Projected Change in Highest 1-day precipitation per year (R1-day) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Rx1day represents annual maximum 1-day precipitation.

7.2.7 Drought Period Duration (CDD)

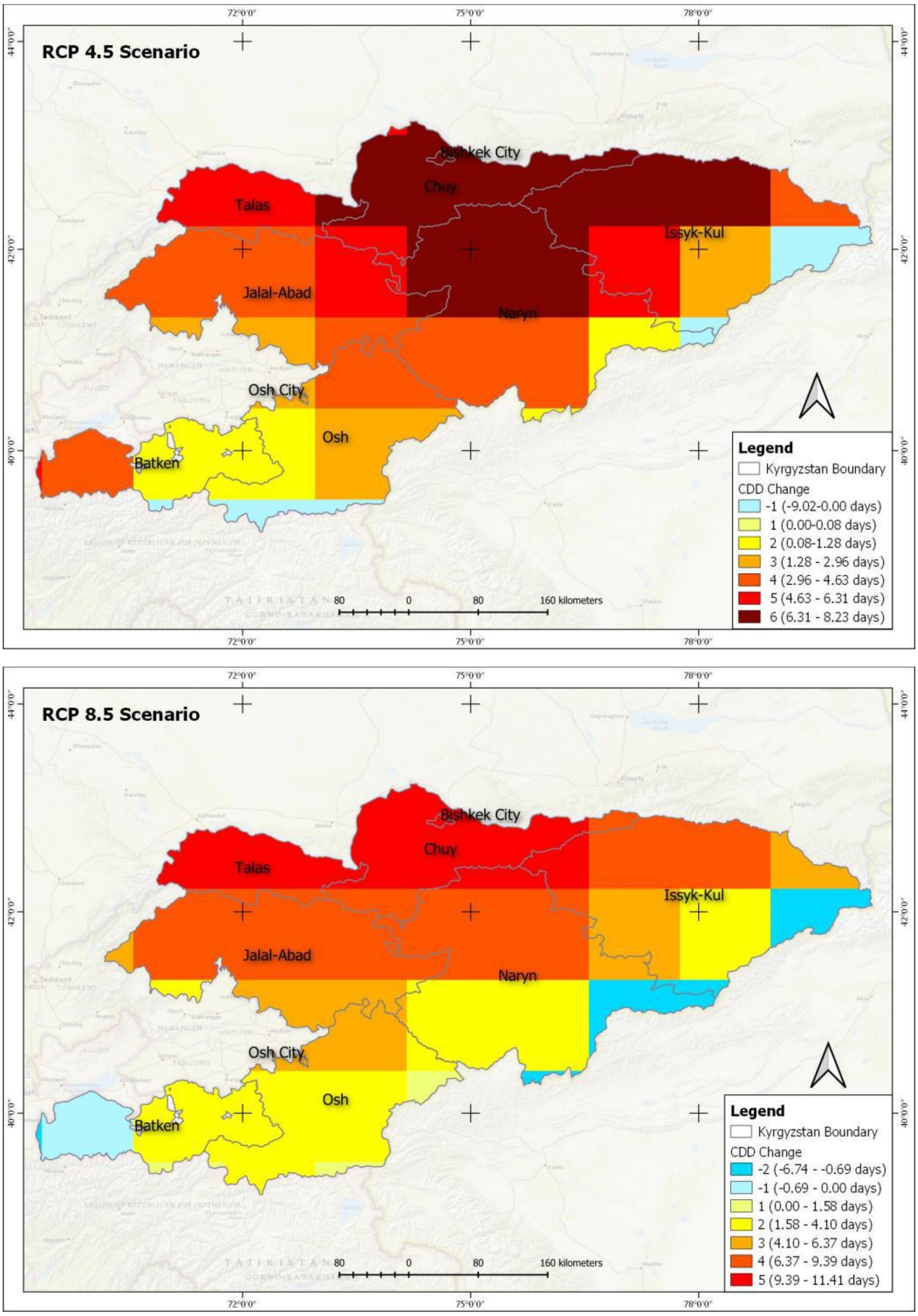


Figure 38: Projected Change in Maximum duration of drought period (CDD) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. CDD is maximum number of consecutive days with daily precipitation less than 1mm.

7.2.8 Combined Climate Exposure

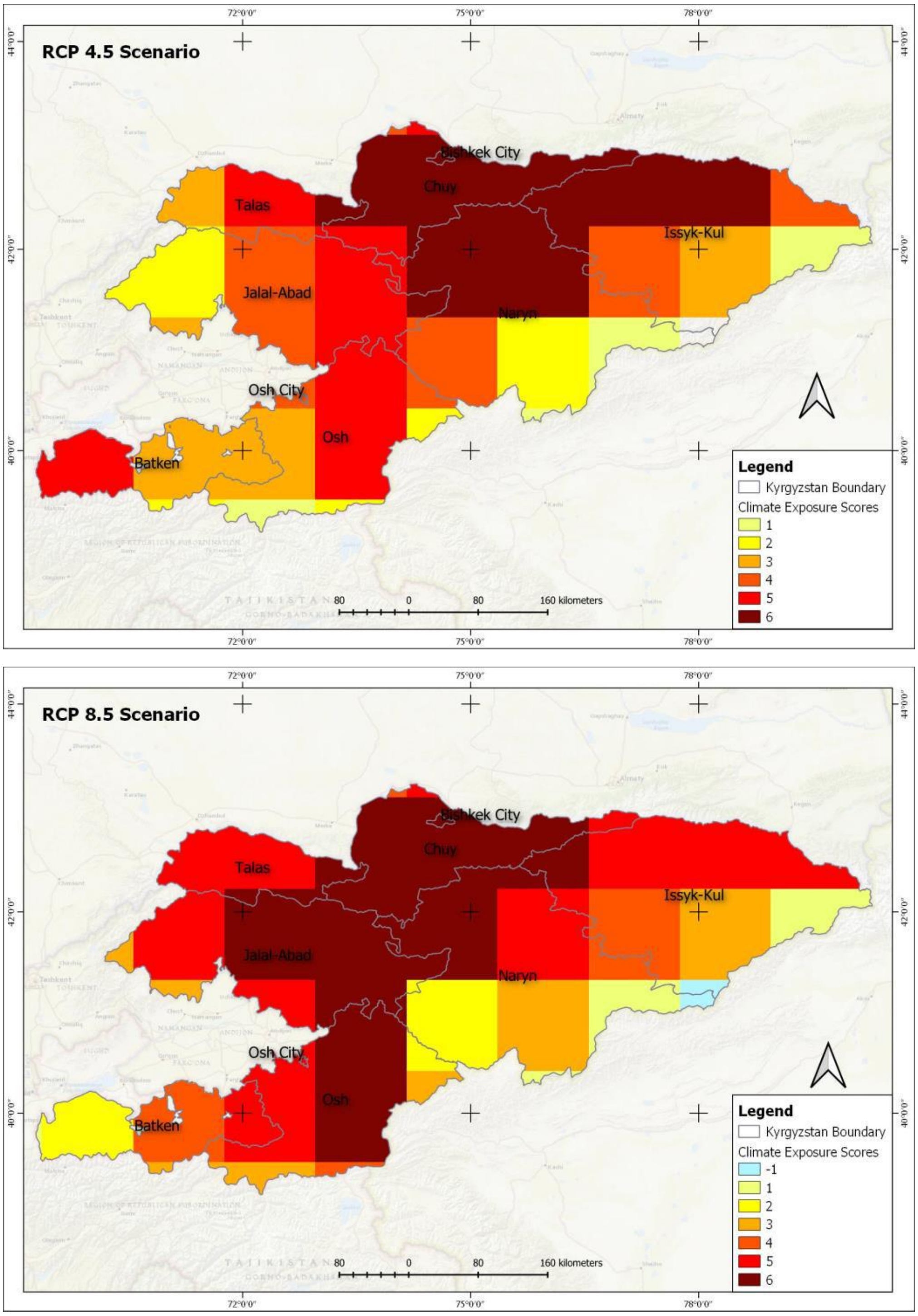


Figure 39: Total climate exposure as summary of scores of the classified climate maps for heat / total precipitation / share of heavy precipitation / drought duration by 2050. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios.

7.3 Climate Change Related Geographical Sensitivity

7.3.1 Water Stress

7.3.1.1 Water Stress (percentage of water resources used)

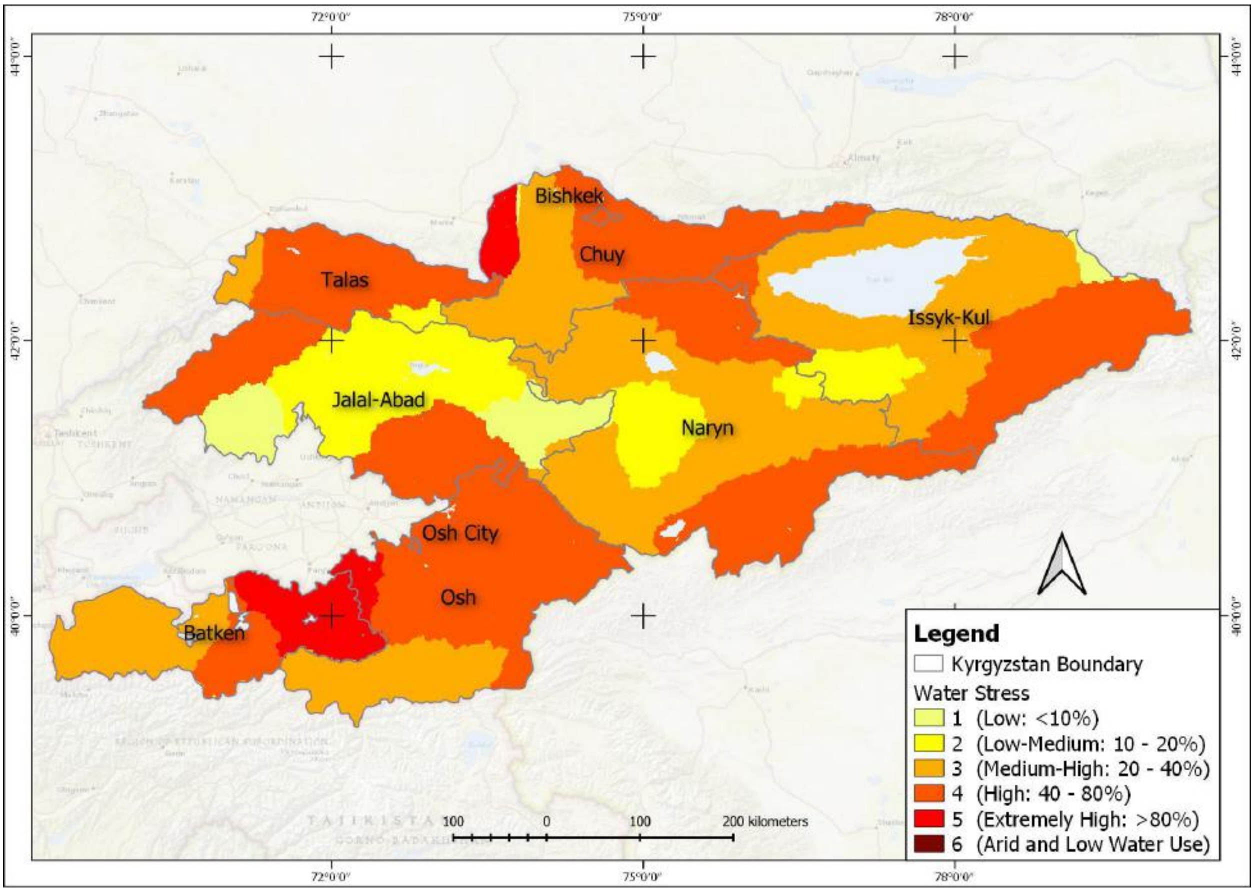


Figure 40: Annual Baseline (1960-2014) water stress. From Aqueduct 3.0, World Resources Institute. Baseline water stress measures the ratio of sectoral water request to water availability, which is then, expressed in percentage.

7.3.1.2 Drought Risk (population, chance, % water use)

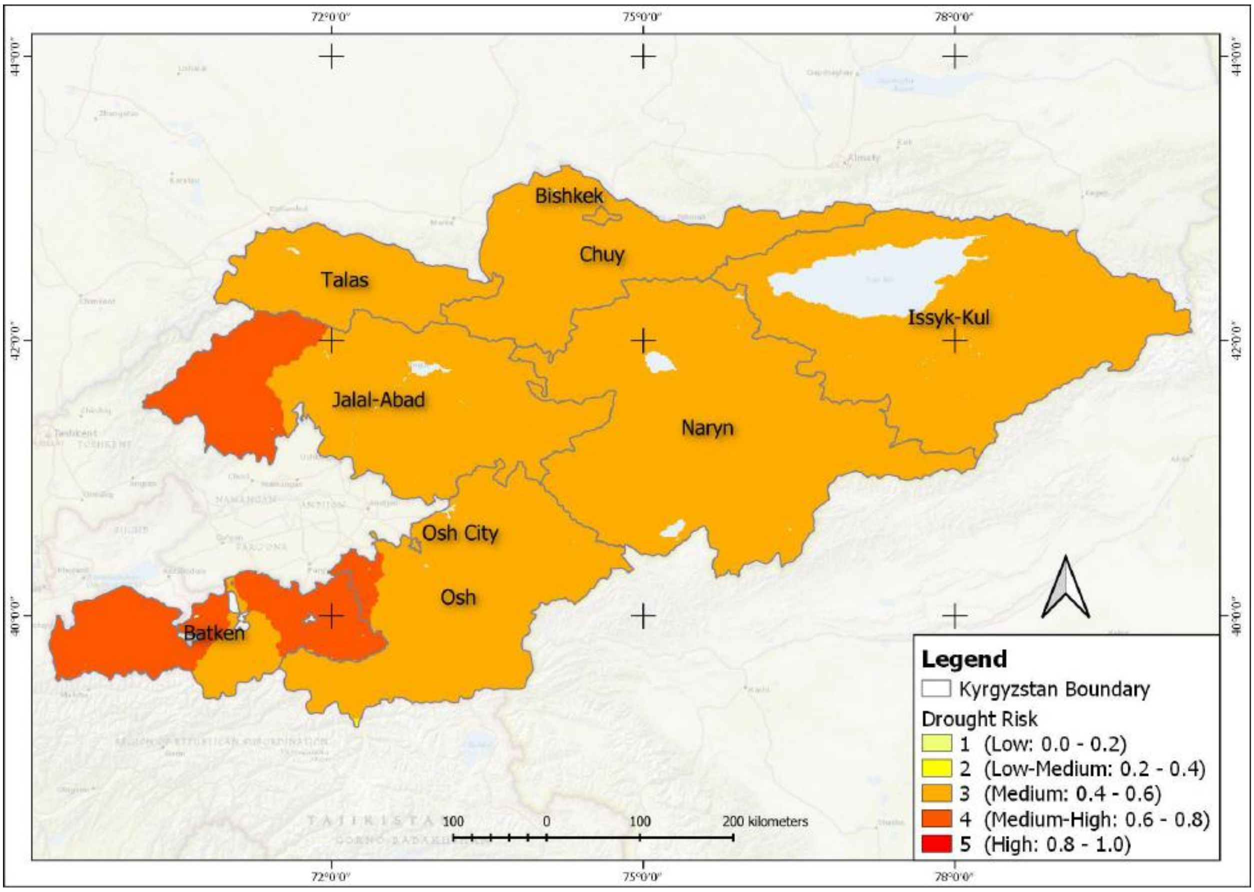


Figure 41: Annual Baseline (2000-2014) Droughts risk. From Aqueduct 3.0, World Resources Institute. Droughts risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects.

7.3.2 Land Productivity

7.3.2.1 Change in Soil cover 2000-2020 (NDVI analyses)

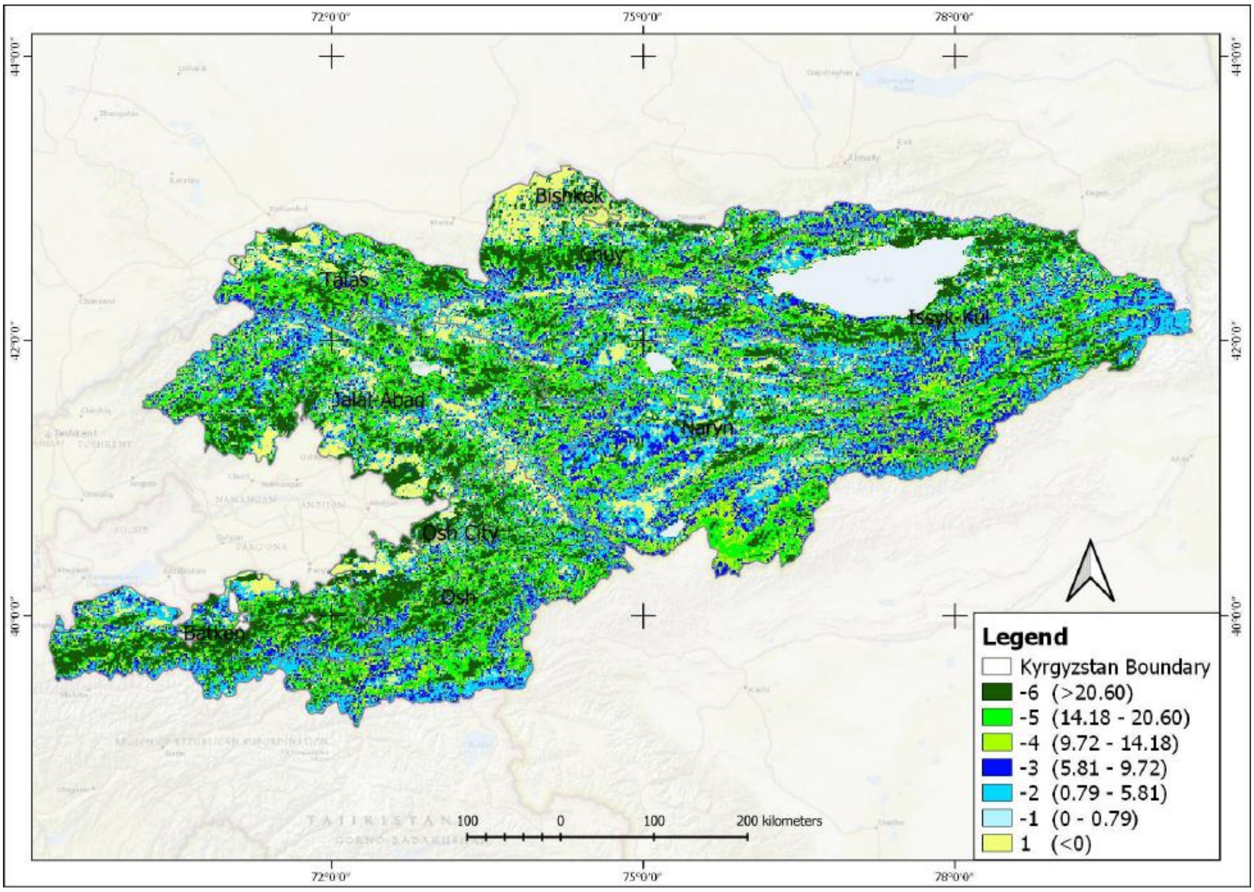


Figure 42: Change in NDVI as indicator for soil productivity from 2000-2020. Data from NASA LP DAAC at the USGSEROS Center. The MODIS NDVI is computed from atmospherically correlated bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols, and cloudy shadows.

In large regions of Kyrgyzstan the soil productivity has been increased over the last 20 years. Northern Chuy province, but also large areas in Jalal-Abad province, show a decrease of soil productivity. This phenomena is partially due to climate change as land degradation due to poor pasture management practives may play a multifolding role in the decrease of land productivity.

7.3.2.2 Combined Geographic Sensitivity to Climate Change

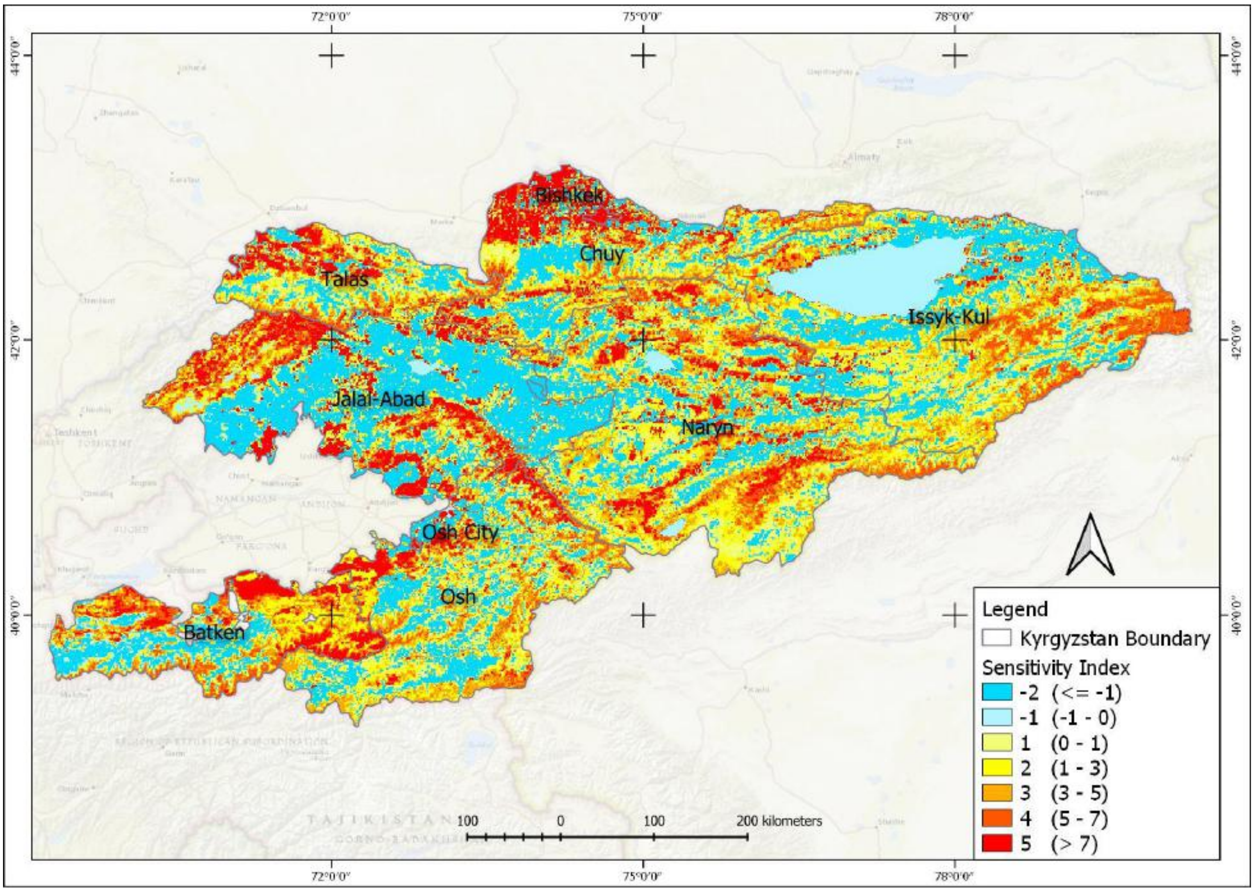


Figure 43: Combined geographic sensitivity to climate change. From NASA LP DAAC at the USGSEROS Center; EU Copernicus Space Agency (ESA); Aqueduct 3.0, World Resources Institute. The combined geographic sensitivity map is obtained using the equation: 2 * NDV Trend + 2 * Baseline Water Stress + Baseline Droughts Risk.

7.4 Climate Change Related Socio-Economic Sensitivity / Adaptive Capacity

7.4.1 Gross National Income (GNI) per Capita (Poverty)

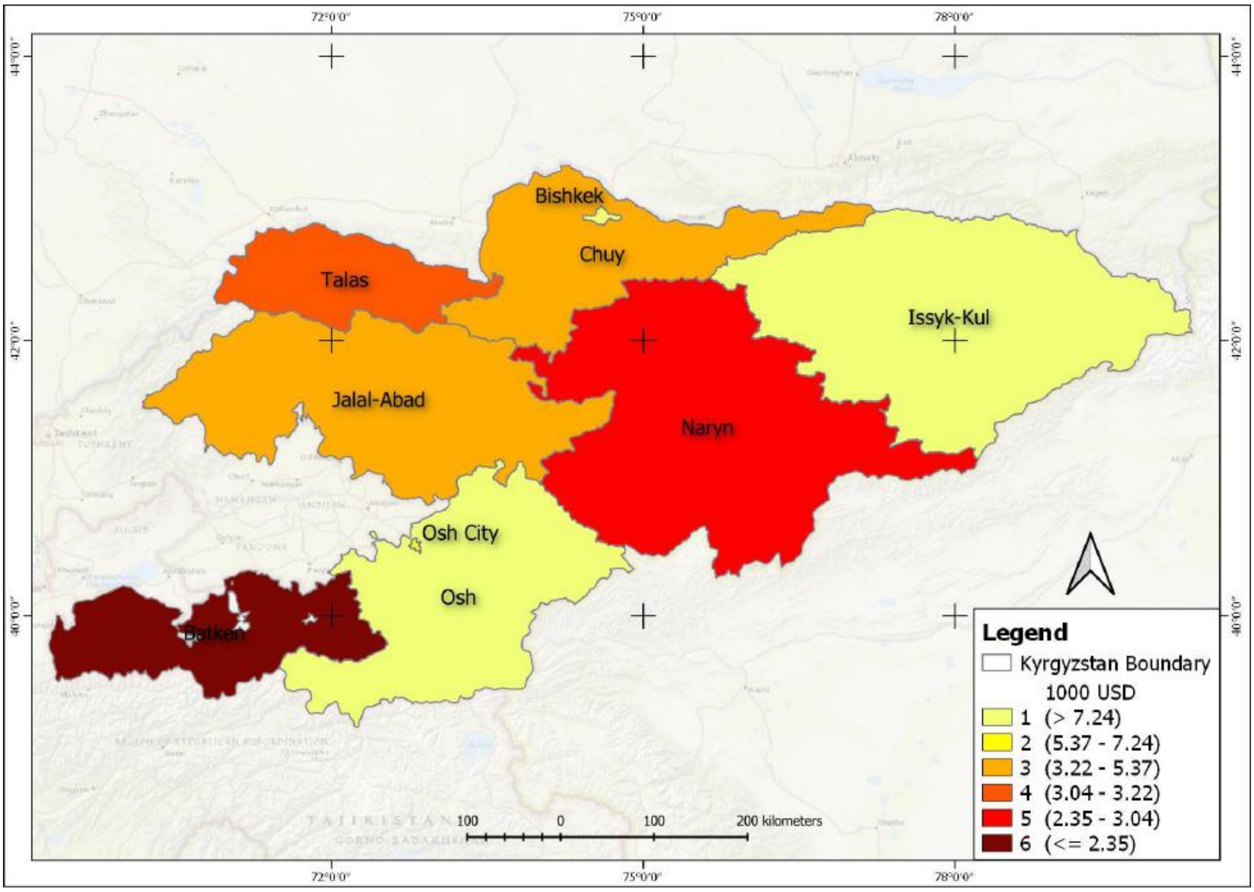


Figure 44: Level of Gross National Income per capita 2018 (GNI PPP). Data from National Statistics Bureau of Kyrgyzstan. GNI per capita PPP is gross national income in purchasing power parity (PPP) divided by middle year population.

7.4.2 Human Development Index (HDI): Life Expectancy + Education + Health

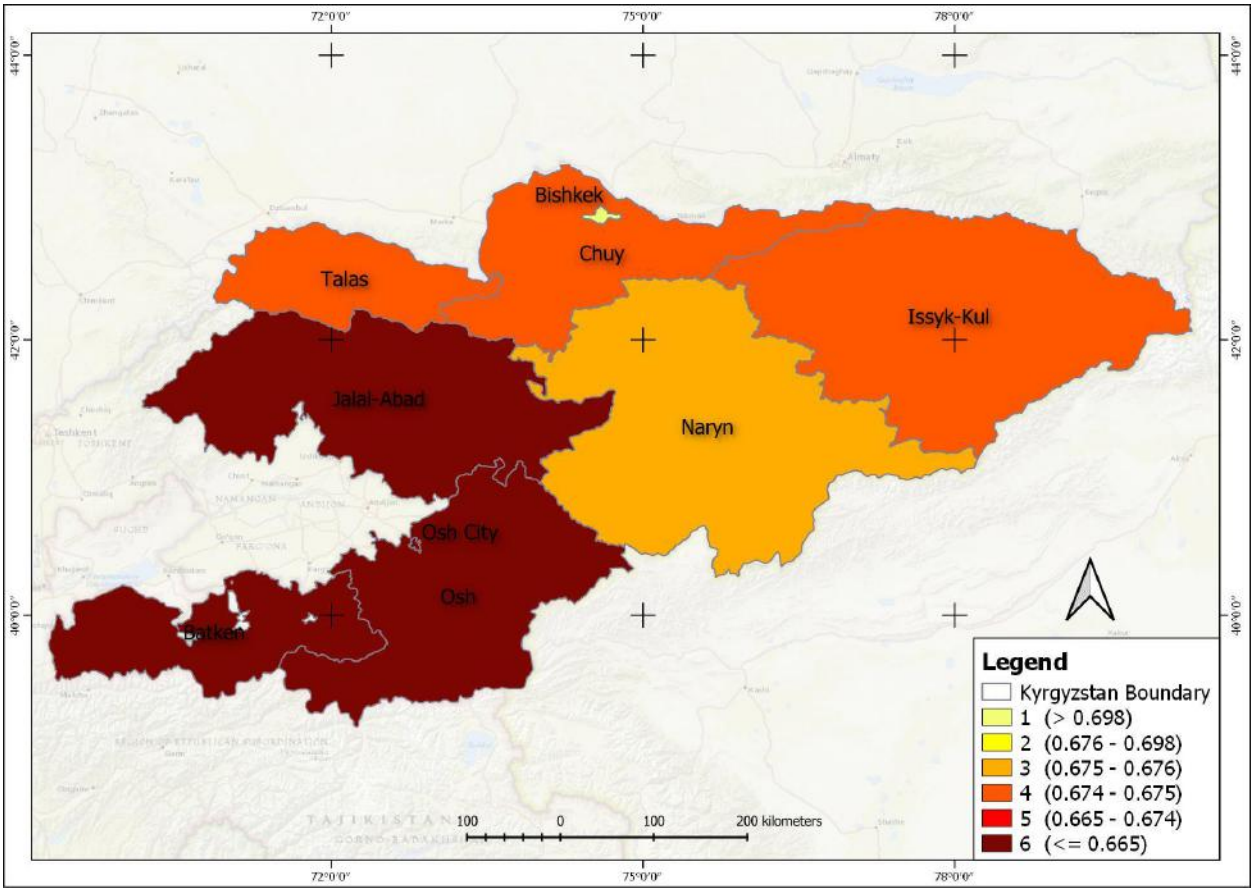


Figure 45: Level of Human Development Index 2018 (HDI). Data from Global Data Lab (GDL). HDI is used to measure a country's overall achievement in its social and economic dimensions like the health of people, their level of education attainment and their standard of living.

7.4.3 Distance to Markets

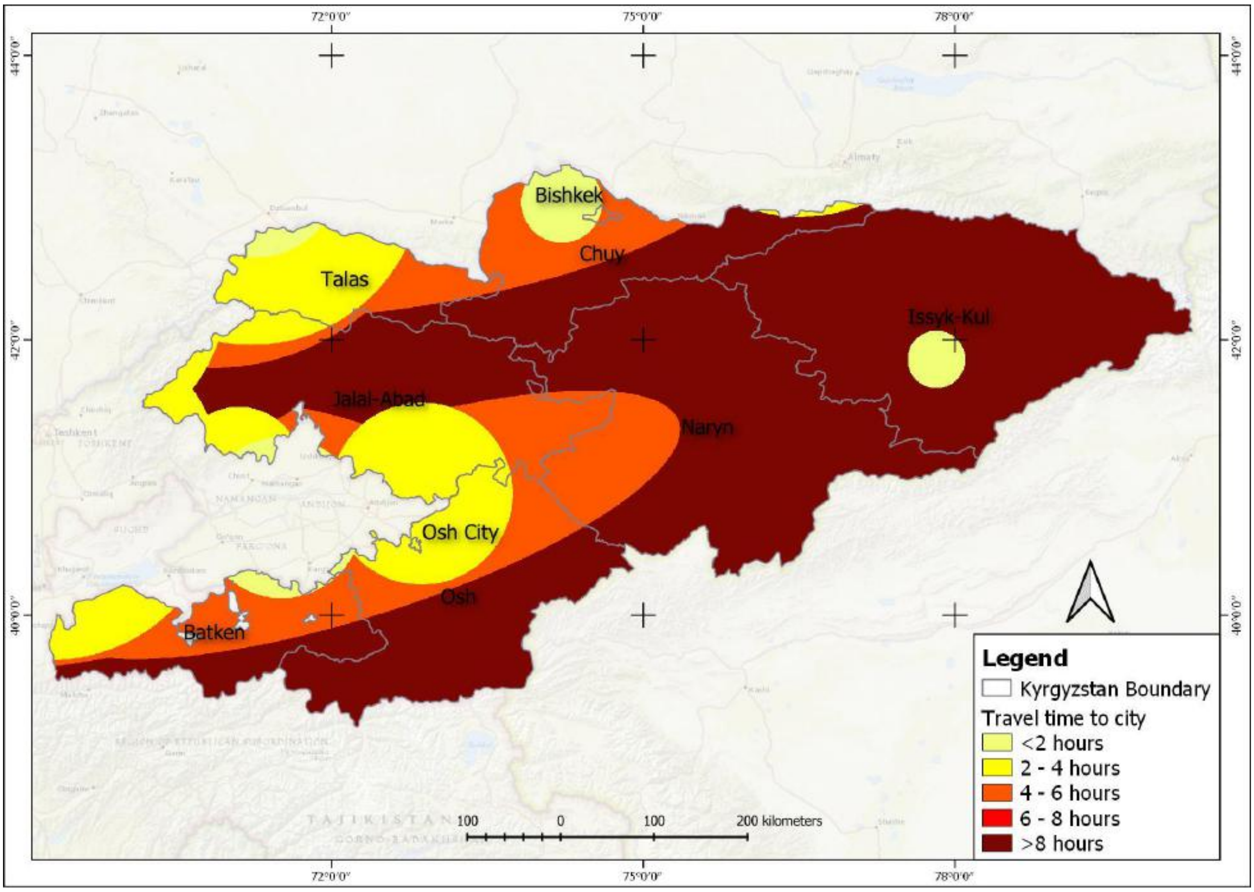


Figure 46: Accessibility to markets. Data from Geoinformatics Solutions for Integrated Agro-Ecosystems Research, ICARDA. This map shows travel time to cities with at least 50.000 inhabitants as an indicator of accessibility to markets.

7.4.4 Combined Socio-Economic Sensitivity to Climate Change

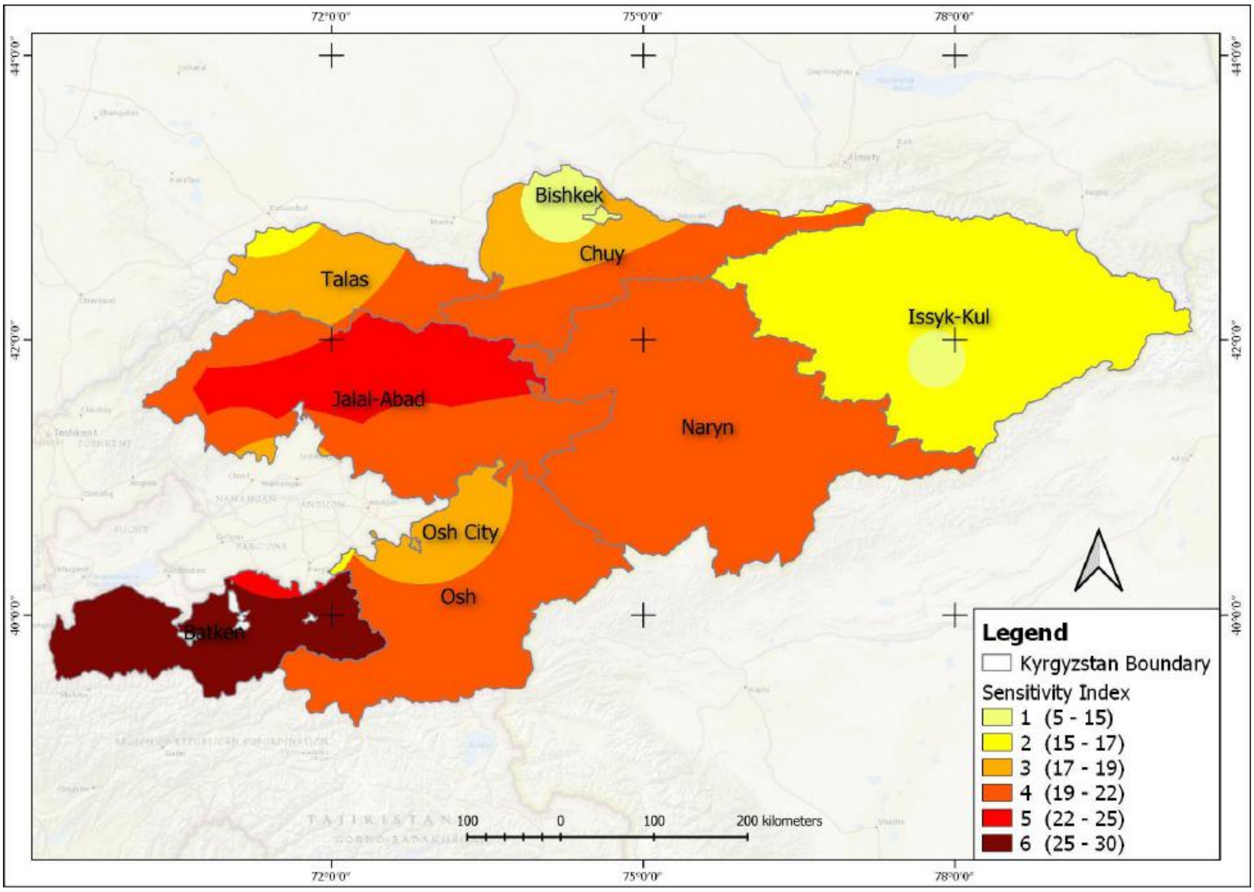


Figure 47: Combined Socio-Economic Sensitivity to Climate Change Map. Data from Global Data Lab (GDL); National National Statistics Bureau of Kyrgyzstan; Geoinformatics Solutions for Integrated Agro-Ecosystems Research, ICARDA. The combined socio-economic sensitivity map is obtained from the equation: 2 * HDI + 2 * GNI PPP + Accessibility to markets.

7.5 Climate Change Vulnerability Map

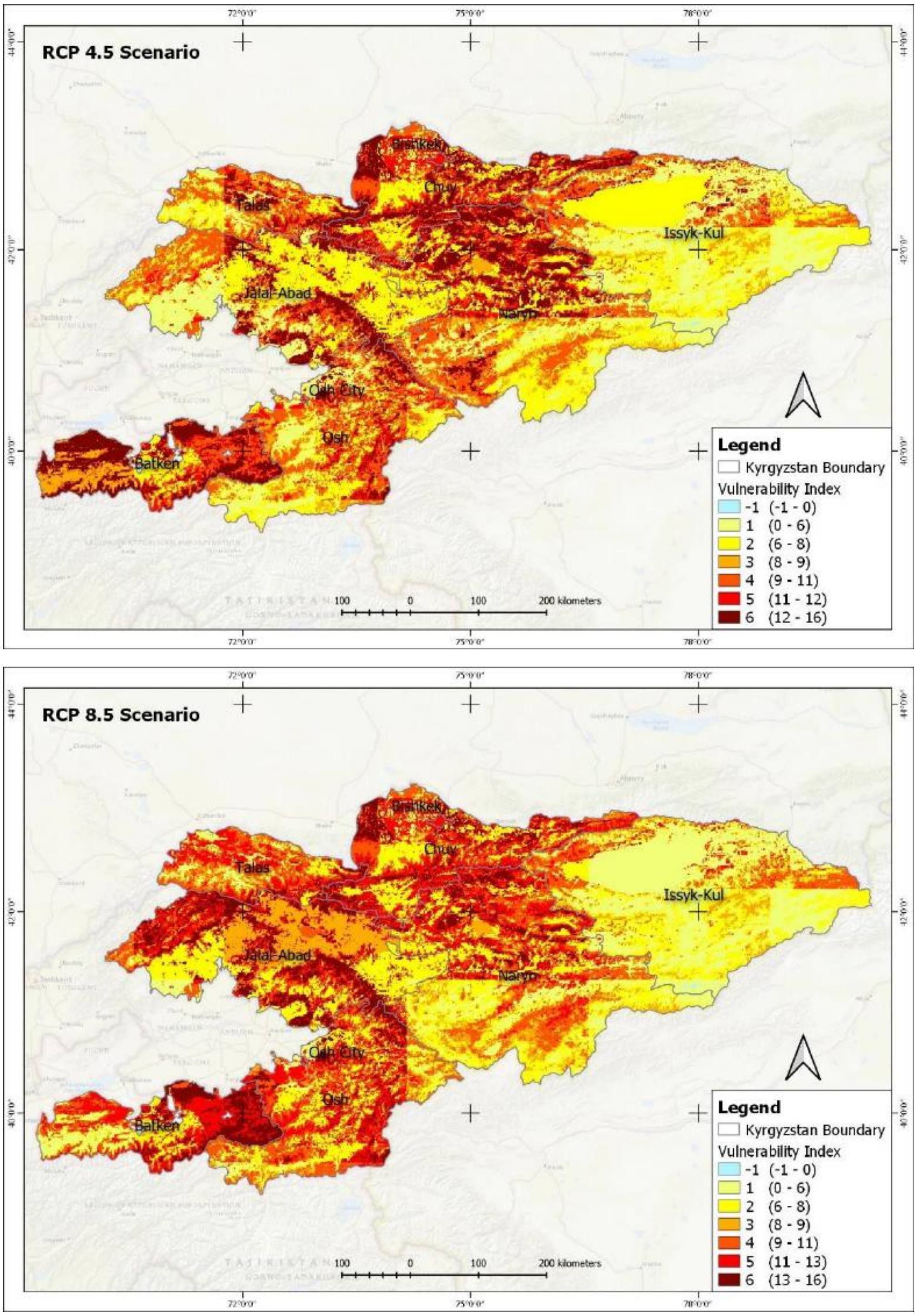


Figure 48: Climate Change Vulnerability Map based on Climate Exposure, Geographic and Socio-Economic Sensitivity. The climate change vulnerability map is obtained using the equation: Climate Exposure + Geographic Sensitivity + Socio-Economical Sensitivity.

7.6 Thematic Maps

In addition to the maps that are most critical for the development of the CRVA, the following additional maps were prepared as they provide further insights on the impact of climate change to Kyrgyzstan, its vulnerability and the options that might arise for adaptation.

7.6.1 Agriculture

A number of additional maps have been prepared to further assist in the assessment of the agriculture sector. The list of maps, and some key findings are listed as follows:

- **Land Use Map** which was developed to help identify specific climate and geographic sensitivities for certain land uses.
- **Elevation Map** which was developed to identify slope risk
- **Soil Moisture Map** which was developed to identify in combination with soil productivity land degradation
- **Soil Cover Change Minus Soil Moisture Change Map** which was developed as a possible indicator for human induced changes in land productivity (land degradation / regeneration, de/reforestation). This phenomena is especially found in Chuy and Jalal-Abad province. This can only partly be linked to climate change. Normally soil moisture in growing season is expected to be related to soil productivity. In these provinces land degradation due pasture management may also be a serious contributing factor.
- **Climate Exposure on arable Map** which was obtained combining the Land Use Map with the Rainfed Agriculture and the Climate Exposure Map. Both set of maps on climate exposure for rainfed and irrigated arable farming indicate more clearly where the impact on arable farming can be expected.,namely in the Chuy, Talas and the Issyk Kul province.
- **Change in Growing Season Length Map:** In general, the growing season is lengthening. North Kyrgyzstan profits the most from it, as in the other parts later in the season drought and heat are the limiting factors.
- **Change in Soil cover 1999-2019 (arable land) Map:** Assessing soil cover (land productivity) against agricultural land use, indicates that Atyrau, west Kyrgyzstan, Aktobe and to less extent Kostanay are most sensitive for climate change

7.6.1.1 Change in Growing season Length

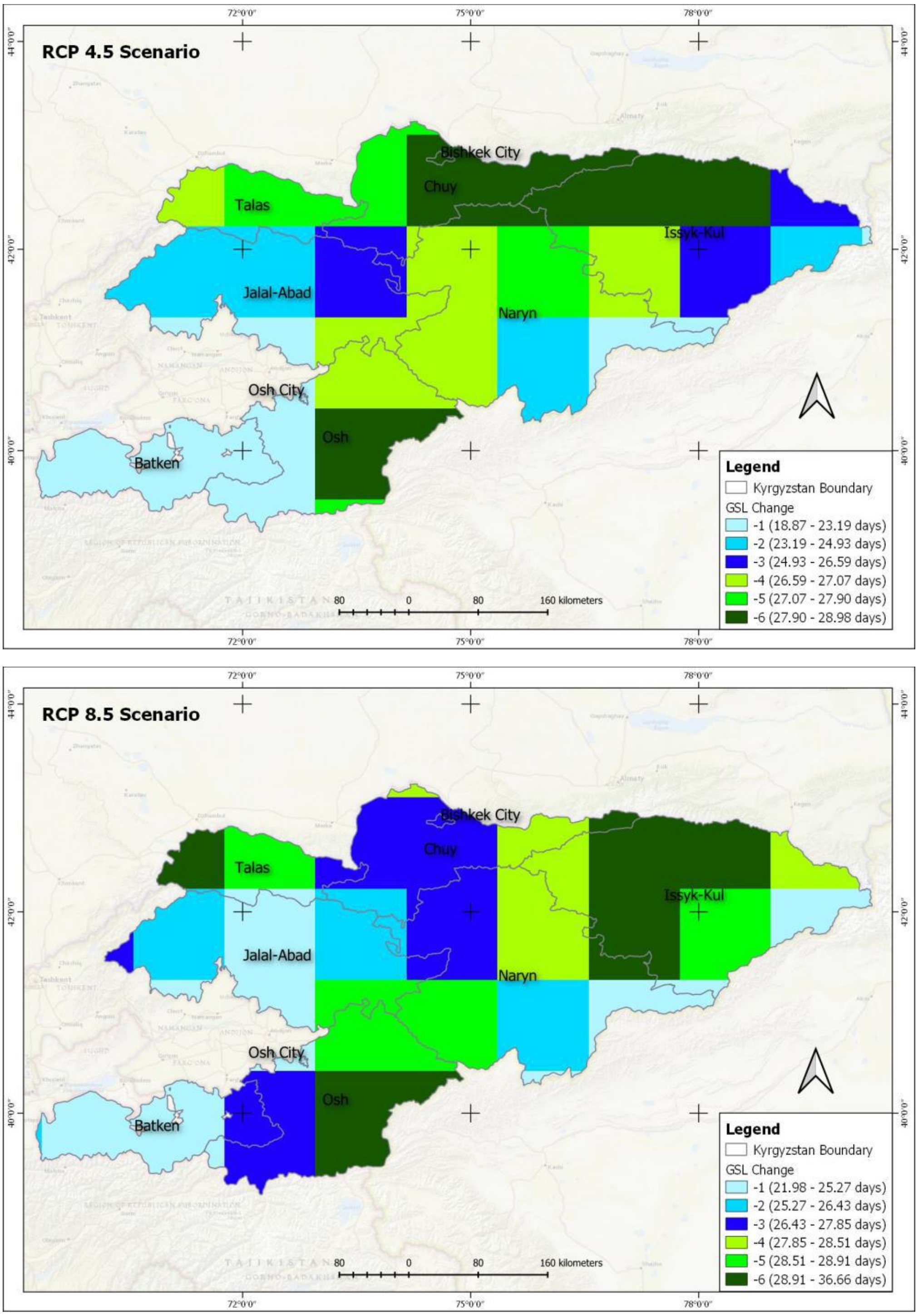


Figure 49: Projected Change in Length of growing season (GSL) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. GSL is growing season length and is dependent on daily mean temperature.

7.6.1.2 Land Use Map

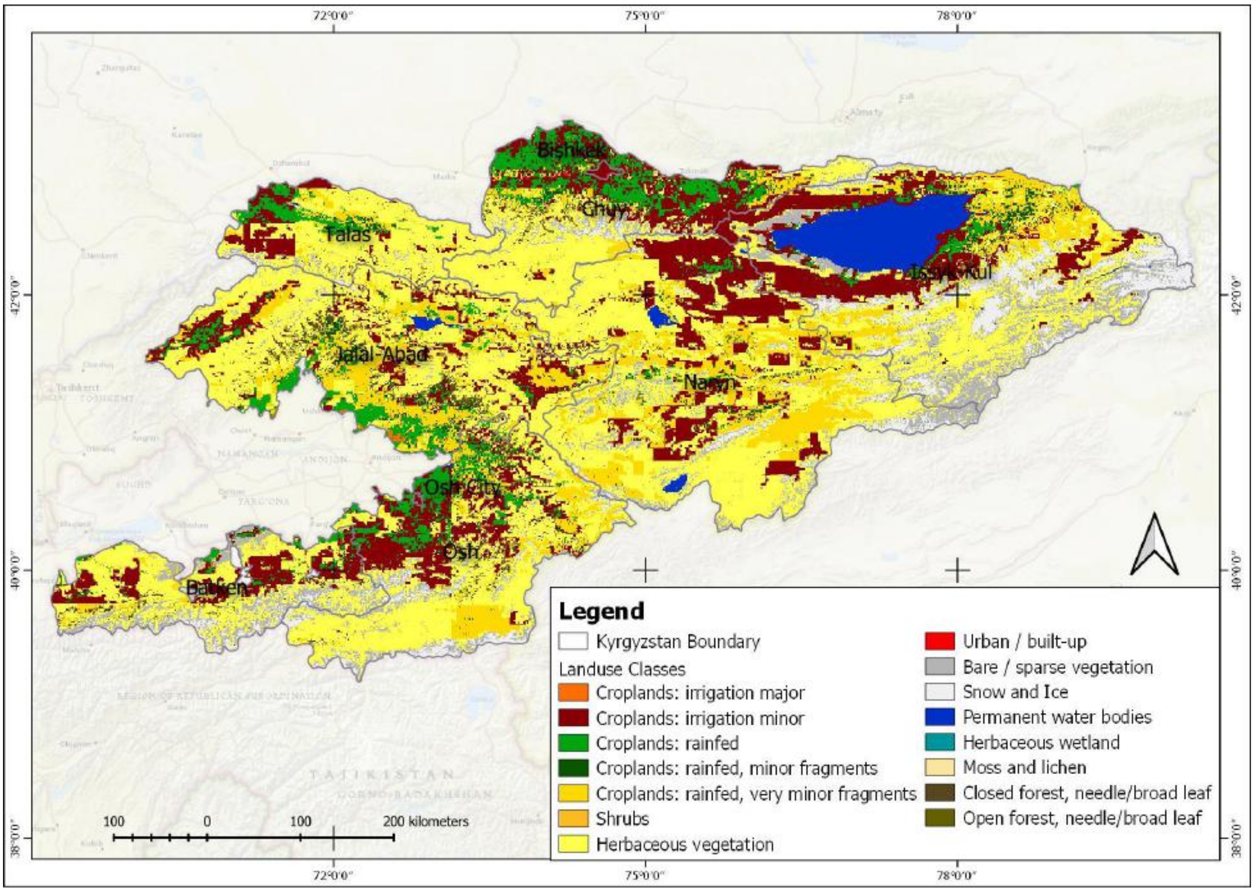


Figure 50: Global Land cover and Cropland Extent map. Data from EU Copernicus and USGS. Land cover map represents spatial information on different classes of physical coverage on the Earth's surface, e.g. forests, grasslands, croplands, lakes, wetlands. The cropland extent product provides the spatial distribution of a disaggregated five-class global cropland extent map and irrigated versus rainfed cropping.

7.6.1.3 Change in Soil Moisture for the period 1999-2019 Map

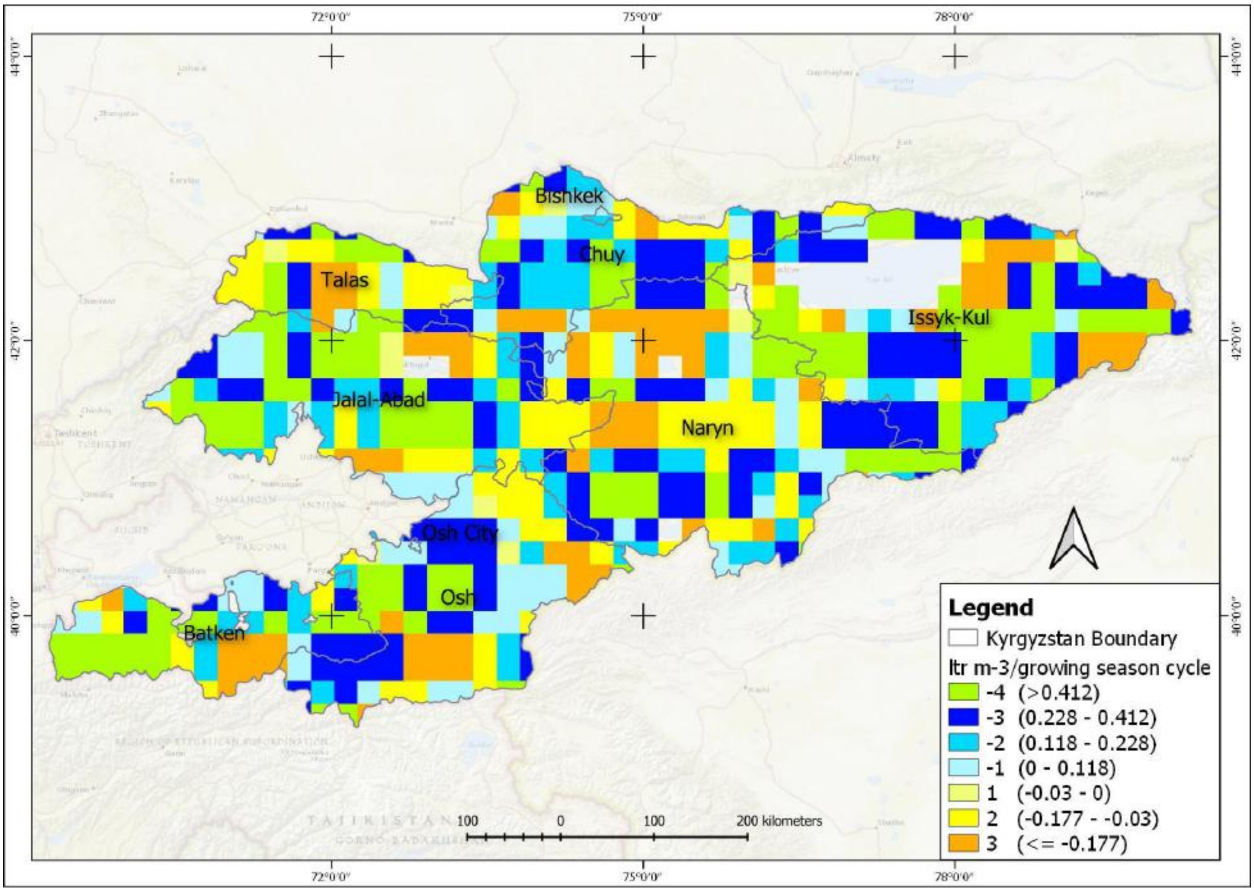


Figure 51: Change in Volumetric Surface Soil Moisture 1999-2019 for Kyrgyzstan. Data from EU Copernicus and USGS. The Soil Moisture dataset is created as part of the European Space Agency's (ESA) Soil Moisture Essential Climate Variable (ECV) Climate Change Initiative (CCI) project.

7.6.1.4 Change in Soil Cover Minus Soil Moisture Map

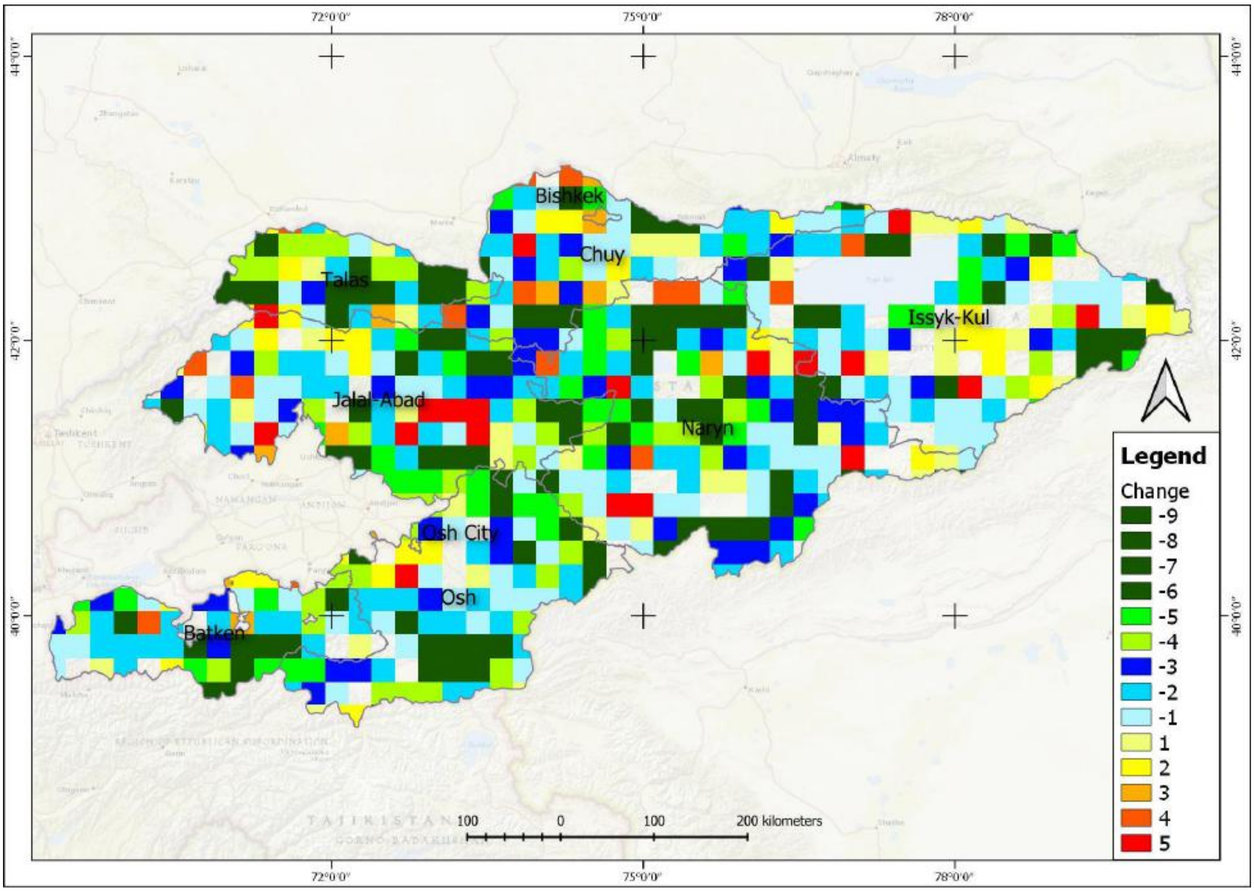
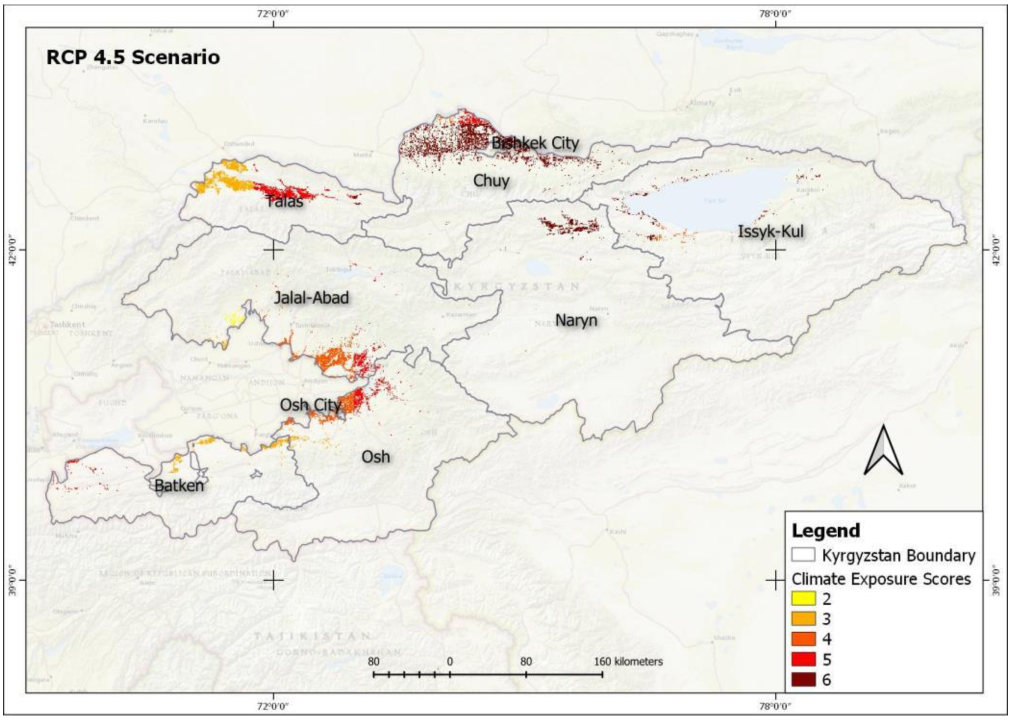


Figure 52: NDVI Trend – Growing Season Soil Moisture Trend of Kyrgyzstan. Data from MODIS/NASA and EU Copernicus/ESA. The growing season soil moisture trend classified map was obtained from the NDIV trend classified map to obtain the map shown above

7.6.1.5 Climate Exposure on Arable Land



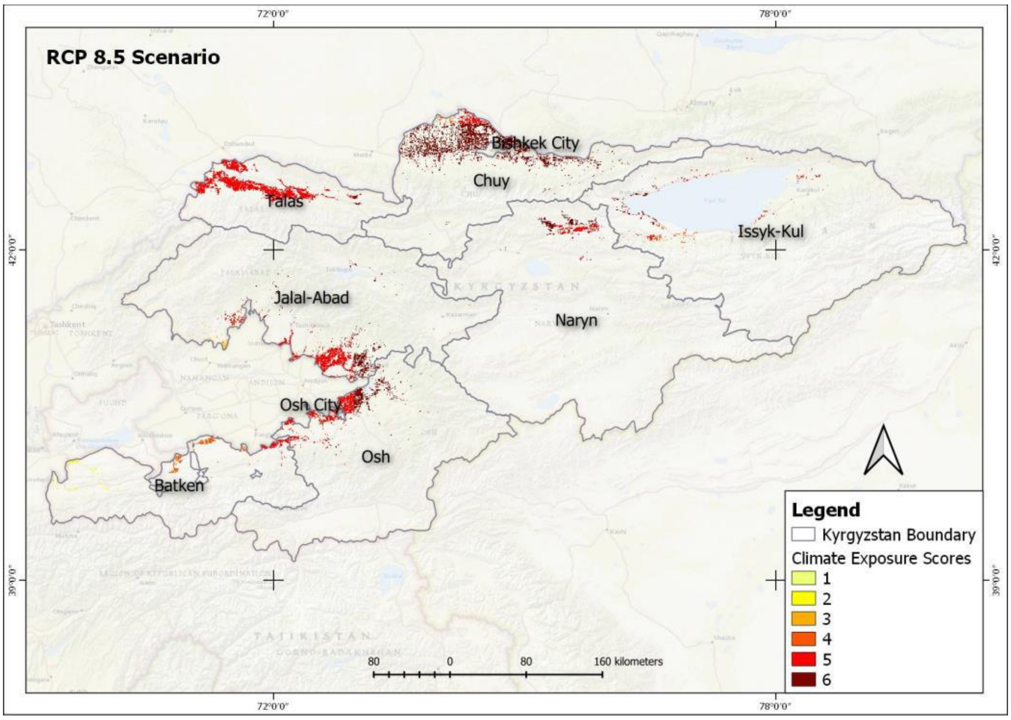


Figure 53: Total climate exposure as summary of scores of the classified climate maps for heat / total precipitation / share of heavy precipitation / drought duration by 2050 in arable land area. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Climate score is obtained using the equation: (TXx*0.5+TX90p*0.5+CDD*1+PrcpTOT*0.5+Rx1day*0.33+R95p*0.33+R99p*0.33). 1 is the lowest exposure and 6 is the highest exposure.

7.6.1.6 Change in Soil cover 2000-2020 – arable land

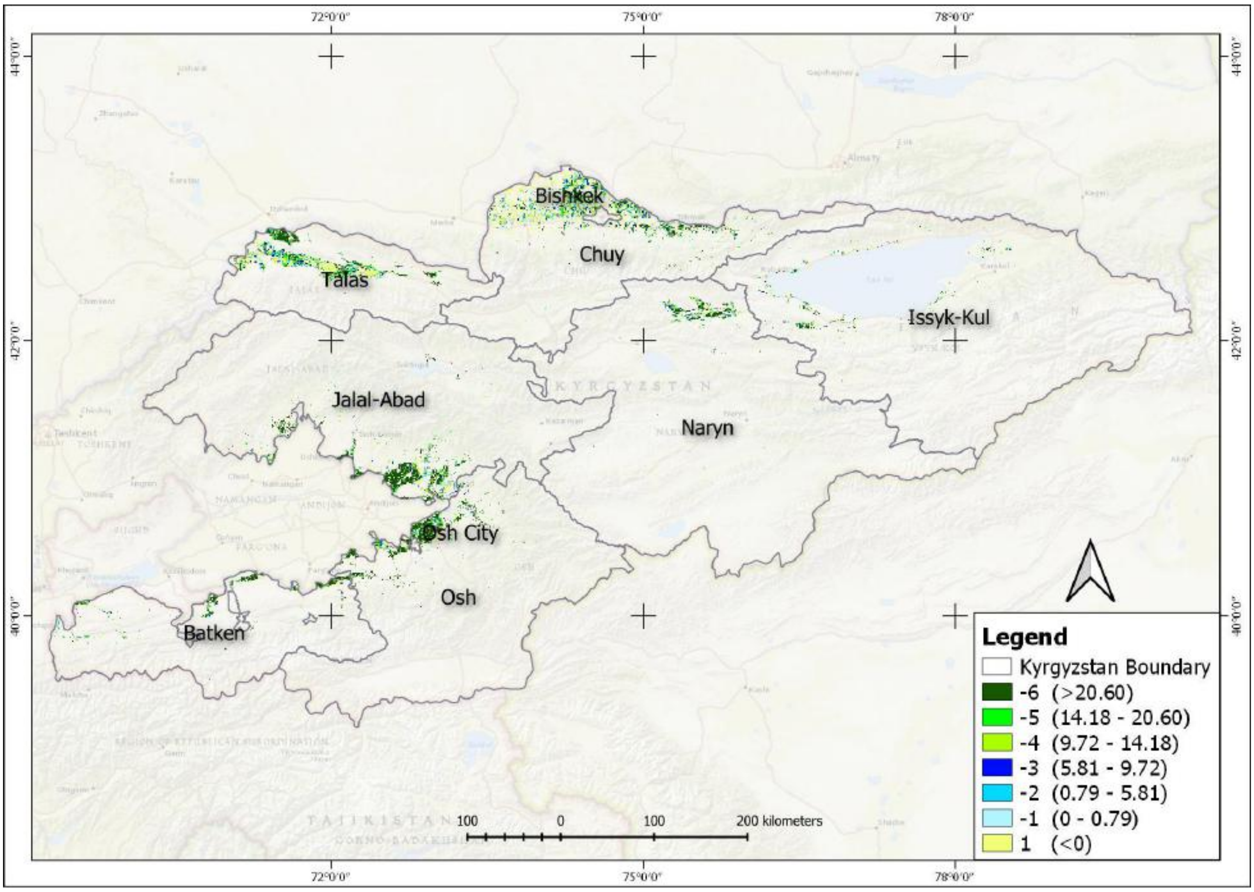


Figure 54: Change in NDVI as indicator for soil productivity in arable land. Data from NASA LP DAAC at the USGSEROS Center. The MODIS NDVI is computed from atmospherically correlated bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols, and cloudy shadows.

7.6.2 Water Management

Water management is severely impacted by extreme precipitation, especially the 5-day maximum precipitation. Therefore, two indicative maps where prepared on flood risk of reservoir and river flood risk. The last map of WRI indicates the flood risk, not taking into account the state of river dikes, but the elevation of the floodplains above the river water level.

- **5-day maximum precipitation change (Rx5-day)(as indication for flood risk).** The 5-day maximum precipitation change (Rx5-day) is seen as a good indicator for the risk of extreme discharge. Extreme discharge is most experienced in mountain areas and up to around 150 km downstream of mountain regions. In these zones it might be necessary to re-assess the modelling of the river discharge and the related management of water reservoirs.
- **Climate Change Related Changes in River Water Flood risk 2050 in Comparison with 2010.** The risk for flooding differs from basin to basin. For The Syr Darya Basin the risk is expected to decrease. But this does not count for the upper basins like Naryn river. Also for southern Issyk Kul an increased risk is expected.

7.6.2.1 5-day maximum precipitation change (Rx5-day)(as indication for flood risk)

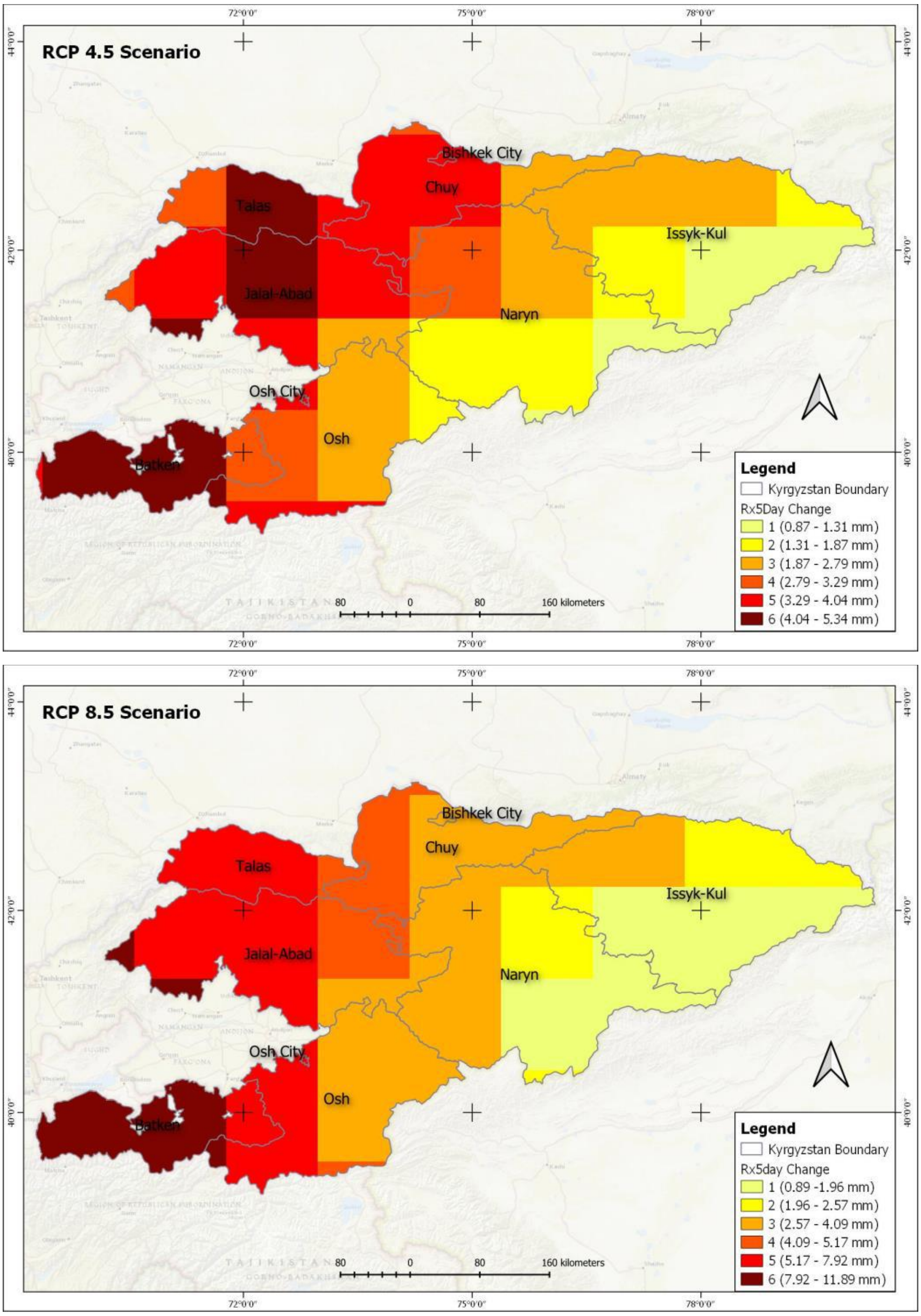


Figure 55: Flood risk zone based on change in 5-days precipitation and slope by 2050. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. The higher scores indicate more risk while lower scores indicate less risk.

7.6.2.2 Climate Change Related Changes in River Water Flood risk 2050 in Comparison with 2010

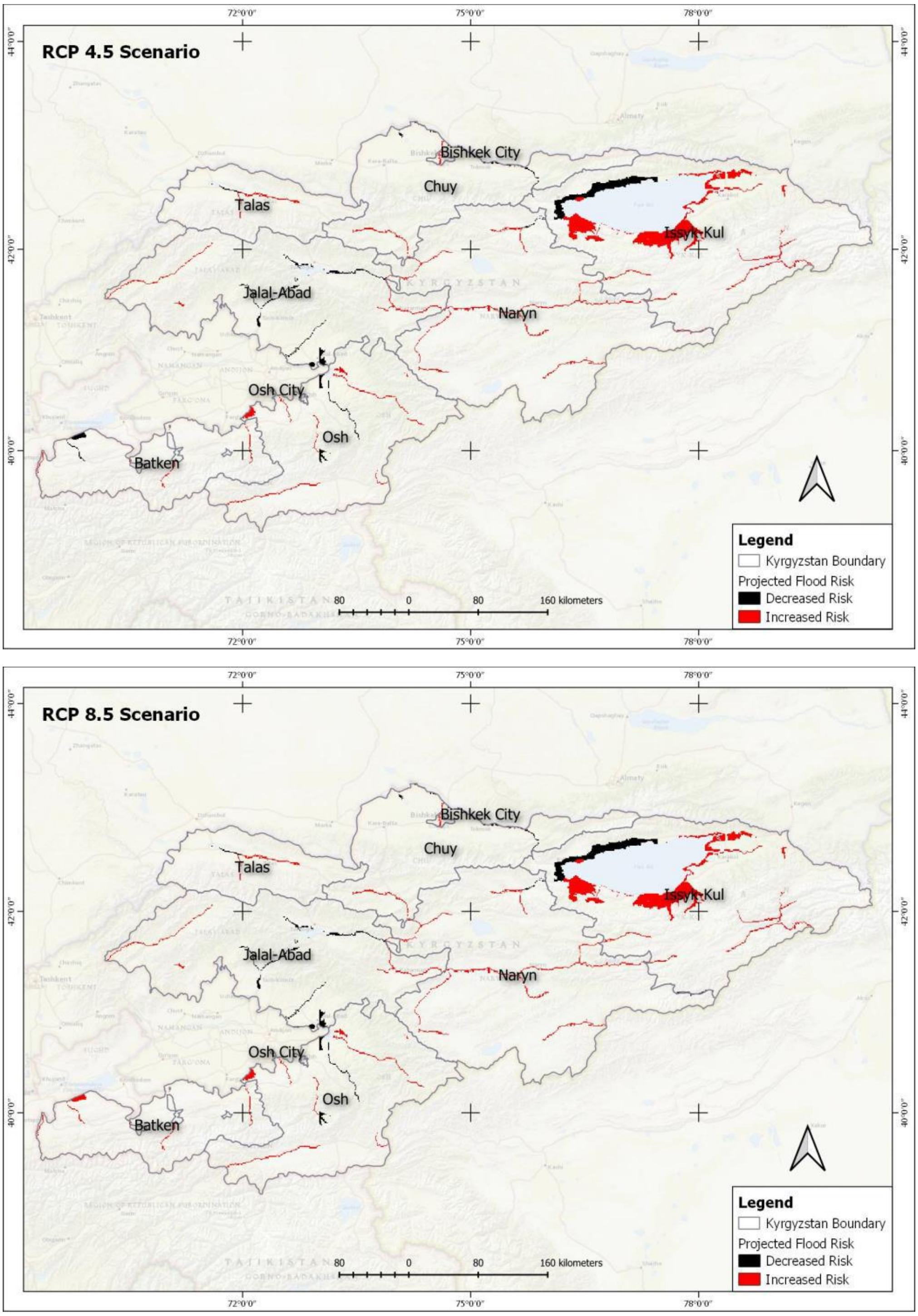


Figure 56: Projected Change in Flood risk by 2050 with return period of 50 years. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Flood map is obtained by taking difference between RCP flood map and historic flood map.

8 WAY FORWARD

The Climate Risk and Vulnerability Assessment provides the bridge between Climate Change and the measures that we, as a society, can implement to manage the risks posed by the changing climate and adapt.

The road to achieve adaptation moves through five pathways (Figure 57):

- The identification of the Climate **Exposures** (to heat, droughts, extreme precipitations, etc.);
- The definition of the possible **measures** we might be able to resort to in dealing with climate change (i.e. risk reduction and impact prevention)
- The **understanding** of the climate chain impact;
- Promotion of Preparedness to boost the **Adaptive Capacity** through, for example, information exchange, capacity development, knowledge generation and identification of the necessary funding;
- Promote the **use of natural resources** (i.e. regulate land and natural resources utilization)

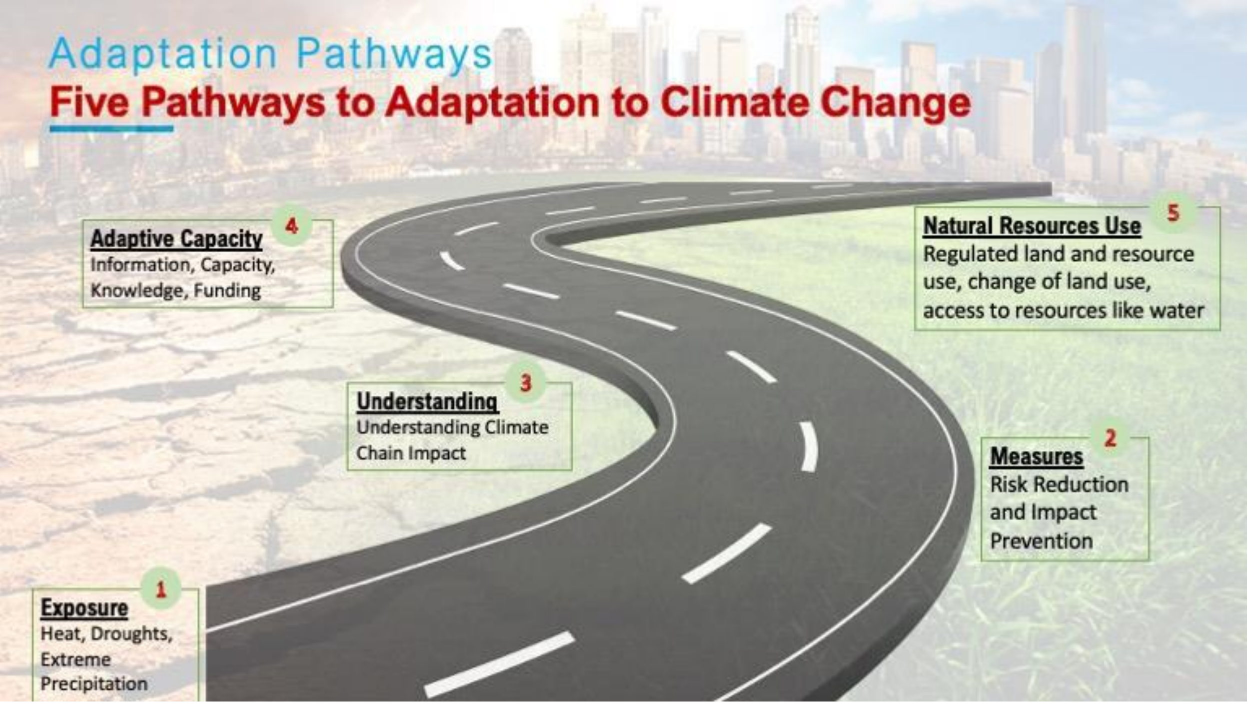


Figure 57: The five pathways to adaptation to climate change

These five pathways take different forms depending on whether they are dealt with at local, regional or national level as best illustrated in the following three artistic diagrams (Figure 58, Figure 59, Figure 60).

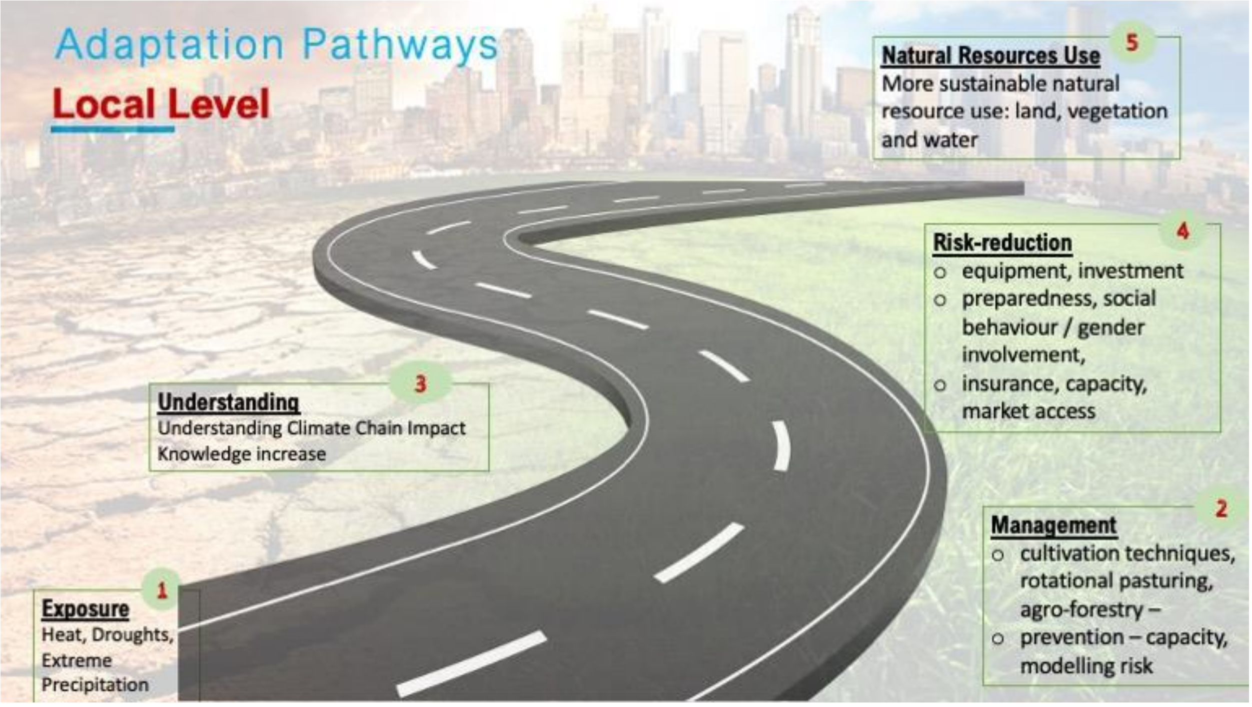


Figure 58: The ‘Local Level’ pathways to Adaptation to Climate Change

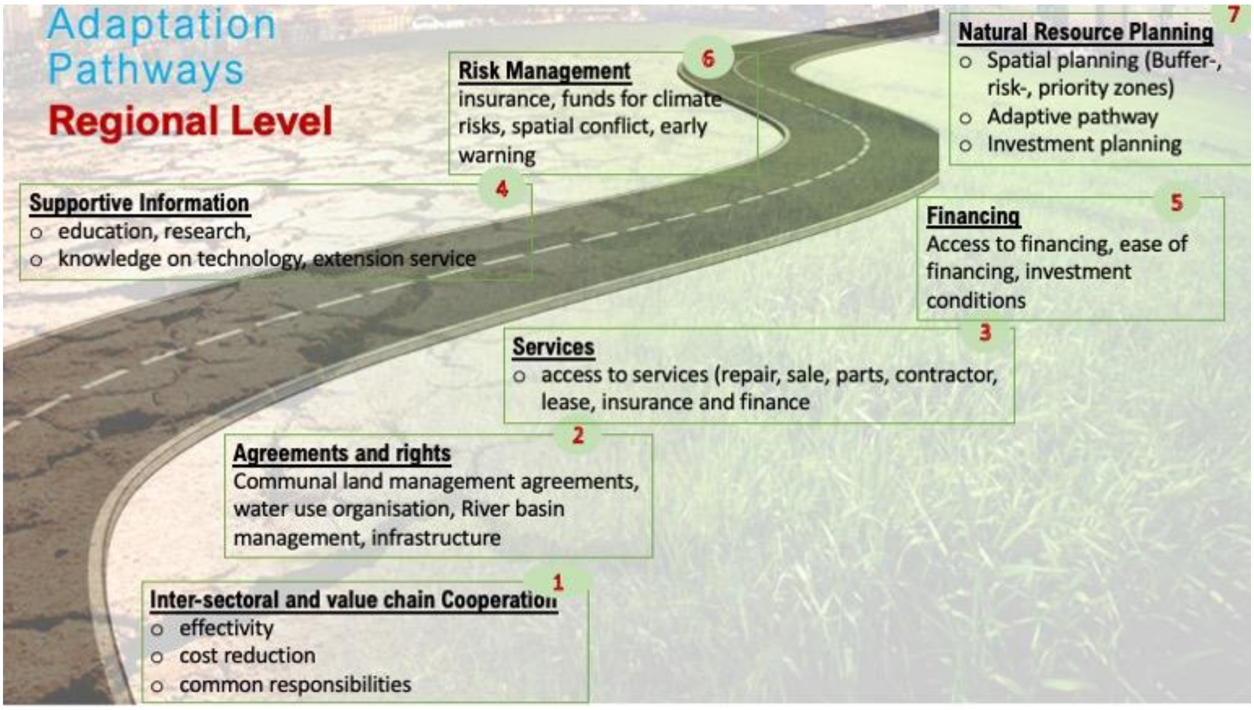


Figure 59: The ‘Regional Level’ pathways to Adaptation to Climate Change

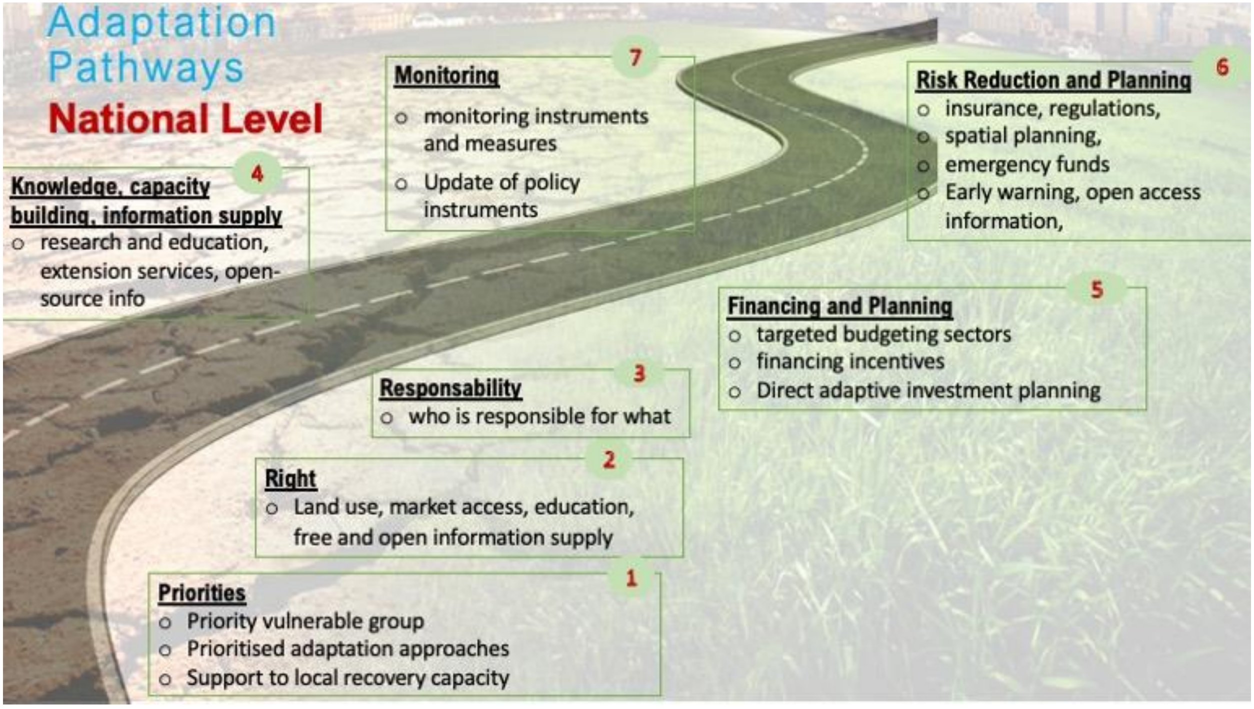


Figure 60: The 'National Level' pathways to Adaptation to Climate Change