Establishing a Water Pillar under CAREC

# Scoping study for the CAREC Water Pillar: climate resilience through regional cooperation

REPORT 240


CLIENT ADB

AUTHORS Johannes Hunink
Jeremy Bird



DATE March-2021

# Scoping study for the CAREC Water Pillar: climate resilience through regional cooperation

Establishing a Water Pillar under CAREC

**FutureWater report 240**

**Client**

ADB

**Authors**

Johannes Hunink

Jeremy Bird

**Date**

June-2021

ADDRESS
FutureWater B.V.
Costerweg 1V
6702 AA Wageningen
The Netherlands

TELEPHONE +31 317 460 050
WEBSITE www.futurewater.eu

# Summary

1. This report provides an overview of the climate change risks that affect the water resources situation for Central Asia and identifies opportunities for climate adaptation and regional cooperation. Material in this report contributes to the Scoping Study of the CAREC (Central Asia Regional Economic Cooperation) Water Pillar, which will include proposals for specific programmes and projects suitable for the Pillar.

2. The analysis describes how key climate variables affect water security in the region, which are (i) precipitation, (ii) evaporative demand, (iii) glaciers and snow cover, (iv) flow variability and (vi) groundwater. Afterwards, several projections on water demand are described based on different development scenarios. An overview of climate change risks to water security in the region is given and focus areas for adaptation measures are proposed. These will provide input in the further stakeholder consultations.

3. Trend analysis over the past 30 years shows that precipitation amounts have decreased slightly (-3%) over the entire region. Based on climate projections, future amounts may either increase or decrease slightly in the order of a few percent: projections do not agree among each other (see Figure 1). However, even though changes of a few percent may appear low, it should be noted that they are in the same order of magnitude as the water received by the Aral Sea, so they can have notable impacts.

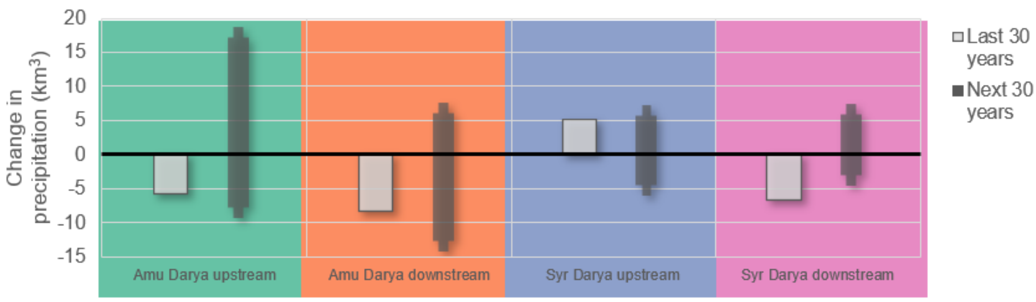



**Figure 1. Changes in mean annual precipitation per sub-region based over the last 30 years and the range projected for the next 30 years (km$^3$) – note the large uncertainty margins in predicted change.**

4. The evaporative demand in the region will increase up to 2050 in the same order of magnitude as the precipitation changes (around 5%). It is very likely that at least part of this increase will translate in increased consumptive use of water by natural vegetation and crops. Consequently, this will lead to lower runoff and river flows, most likely also in the same order of magnitude (a few percent).

5. Increased temperatures will generate additional glacial meltwater to become available over the next decades in some of the tributaries. However, at the regional level, this will most likely be offset by reductions in other tributaries where a change in snowfall fraction and increases in evaporative demand (reservoirs, soil and vegetation) and sublimation (snow surface) will lead to flow decreases. On the long-term, in the second half of this century, major impacts on total flows can be expected, especially in Syr Darya; but also potentially Amu Darya could face severe reductions.

6. The reduced capacity of the high-mountain regions to buffer water in the water towers will have three major impacts on the variability of flows: (i) dry years will become drier due to more pronounced inter-annual fluctuations of water stored as snow or ice, causing a reduction in water security in dry and hot years; (ii) a seasonal shift in water availability: peak flows will happen earlier in the season and ; (iii)

a less predictable or more variable seasonal regime, as the seasonal snow and glacial melt contribution will be smaller, which will make flows more depend on variable precipitation.

7. Groundwater as a resource is becoming more important for sustaining several water uses in the region (e.g., livestock, domestic water use, industries, and in some areas also irrigated agriculture), but has been under gradual increasing pressures in recent decades due to rapid population growth and economic development in the region. However, basic information and analytical assessments of groundwater are very limited. So far, pressures are mainly related to water quality in aquifers, but trends in the region (increased pumping and livestock) may cause quantity to become a regional issue as well soon.

8. On the demand side of the water balance: water demands will increase drastically in the near future across the region, following population growth, economic development and changing consumption patterns. Consequently, the gap between reliable water supply and demand will increase. This gap is an indicator of the amount of water stress a region experiences and can inform decision making for sustainable growth. Scenario projections on water supply and demand are thus useful to compare a situation where current practices continue and others where interventions reduce the gap.

9. From the analysis it is concluded that an important gap will occur under business-as-usual, if the region follows its current pace and without modernization and demand management investments in the water and agricultural sector. Water demand will increase by about 15%, which combined with increased variability and uncertainty for supply, will lead to a supply-demand gap of around 37% (meaning total demands are 37% higher than reliable supply). A moderate rehabilitation scenario suggests there is scope to reduce this gap, but a significant gap will still remain. Figure 12 shows both scenarios visually.

10. A more comprehensive climate resilient scenario will therefore be required to close the gap, which assumes a broad intervention portfolio of region-wide investments which could potentially reduce the gap to minimum, with a residual uncertainty related to climate change (Figure 12). Key elements of this scenario are: regional cooperation; a system- and basin-level approach to water resources interventions, water productivity technologies; demand management interventions and wide-spread adoption of risk management climate adaptation interventions.

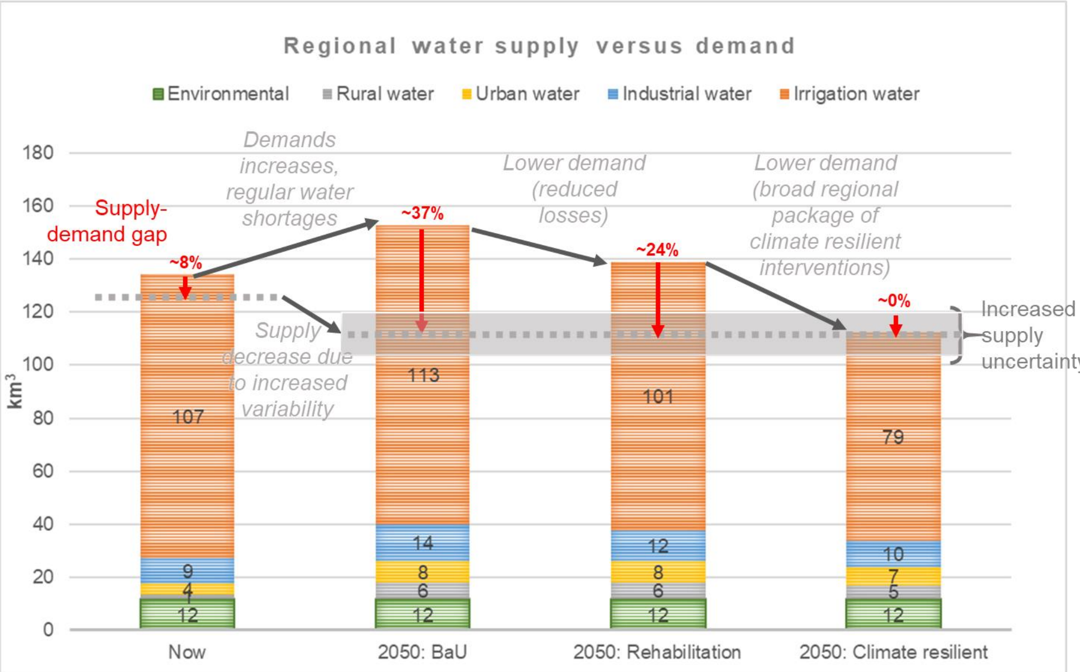



**Figure 2. Gap between regional water demand and reliable supply. The bars indicate the forecast demand for the five sectors; grey dotted line the projected supply**

11. Key to the climate resilient scenario is boosting water productivity across the region, while at the same time recognizing water needs for aquatic ecosystems. The water productivity gap is large in Central Asia: different data sources show that there is large variability between the performance across farms, irrigation districts and countries (up to at least a factor of five between low and well performing regions). This will be further aggravated by climate change impacts as yields may drop considerably if no action is taken. Different technologies can help to assess and boost water productivity in the region. There is huge potential to use remote sensing data to monitor performance, adjust water allocations, evaluate interventions and practices, and also to monitor environmental assets in the region.

12. Reduction of demand through water saving technologies and other measures will be key to achieve a sustainable situation. When implementing water saving technologies for irrigation, it is increasingly recognized that not only possible local irrigation efficiency gains should be considered but also other positive or negative impacts, related to return flows, water quality and energy costs. Projects can have a positive impact if they reduce the salinity of the river that receives saline return flows, but can at the same time have a negative impact if these return flows are for example essential to sustain the ecosystem of the Aral Sea. These complex linkages are especially relevant in the Central Asian region with internal uncoordinated reuse, high salinization, high leaching requirements and return flows, and under-performing irrigation equipment. Projects investing in rehabilitating and modernizing infrastructure should thus assess potential water savings at the site- or farm level, but also look beyond and assess win-wins at the basin-level. These could be related to water quality, reduced withdrawals and thus additional water for downstream use, reduced energy costs and $CO_2$ emissions.

13. To illustrate the relevance of looking beyond reducing water losses only, Figure 3 illustrates two scenarios: one business-as-usual scenario that could represent the flows of typical large farm or irrigation district in Central Asia nowadays, in which there are relatively high evaporative losses from soil and weeds, high return flows through percolation and drainage, and high saline return flows that become non-recoverable due to high salinity levels. On the right side of the figure, a scenario for the system is represented in which water withdrawals from the main distribution system are reduced considerably, in response to more efficient water use at farm level, thereby releasing water for downstream use. The system becomes more productive through reduction of non-beneficial consumption, and there are reduced non-recoverable return flows.

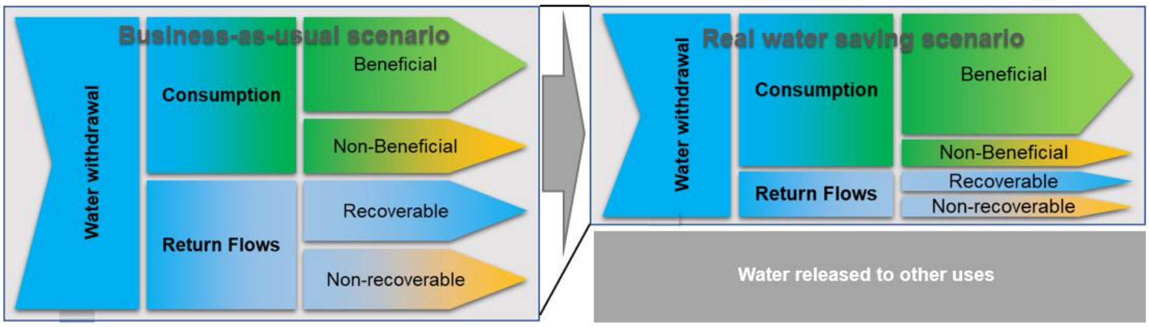



**Figure 3. Conceptual representation of "real" water savings interventions on the water flows at the irrigation district-level, illustrated using the FAO Follow the Water concept**

14. Overall: the water resources system in Central Asia is highly complex and interlinked. The changing climate will have many effects over the next decades on the water-dependent economic and environmental systems in the region. Already on the short-term (horizon 2050), impacts will be notable mainly due to increased variability of flows, and changes in demands, while on the long-term (second

half of this century) major impacts can be expected on total and seasonal flows due to the reduced glacial and snow melt.

15. To prepare for these impacts, a wide range of climate adaptation measures are needed. Several focus areas are identified and will be further discussed during following-up stakeholder meetings. So far, based on the national consultations a critical issue that was raised is that the current status of national systems is limited and the level of regional information sharing these large and complex river basins is not consistent with the desire for more effective management of the resources.

16. Key climate adaptation focus areas that are put forward in the report are centred around the water-energy nexus, regional water information systems that link national systems and integrate advanced remote sensing technologies, improved planning of water allocations, conjunctive water use, knowledge exchange on climate adaptation and finance, climate resilient water resources infrastructure and nature-based solutions, among others. Many, if not all, of the activities in these focus areas can be considered "no regrets": they that generate net social, economic or environmental benefits irrespective of whether or not climate change occurs. Further stakeholder consultation workshops will be used to shape this initial list of areas and activities, as reflected in the scoping report.

# Content

# Tables



# Figures

# 1 Introduction

## 1.1 Background

1. This work is part of a ADB´s technical assistance to develop the scope of the CAREC (Central Asia Regional Economic Cooperation) Water Pillar as a contribution to improving water resources management in the Central Asian region. The scoping study has an emphasis climate resilience and economic aspects of water resources management. This scoping study focuses on the five Central Asian republics which largely share the water resources in the Amu Darya and Syr Darya river basins.

2. This report is part of the scoping study report (as Annex). Other thematic papers that are annexed to the scoping study are on economic aspects, and legal aspects. Work presented here is based on extensive stakeholder consultations and literature review, as well as some generic analysis of available data, including climate change projections.

3. This report presents the status, trends and an outlook on the future supply and demand for water resources in the Central Asia region up to 2050. The assessment is based on primary and secondary data to assess the region's water resources status, and the likely impacts of climate change (based on climate change projections) on various water users across the region. Besides, this report identifies opportunities for climate adaptation and mitigation activities with a regional dimension, potentially part of the Water Pillar. These proposals and ideas are consolidated and harmonized with other proposals in the main scoping study report.

4. Stakeholder consultations have been taking place and several more will follow. Outputs of these consultations are integrated in this report, especially concerning specific opportunities which can be scaled up to basin wide interventions or the broader CAREC region.

## 1.2 Objective

5. The objective of the work presented here is to

i. Define key climate variables for the Central Asia region and performance and consider prior climate projections already prepared under other studies and research;

ii. Review climate projection data in the context of population growth and changing demands for water resources and consider its impact on the region up to 2050;

iii. Identify climate change risks and assessing the impacts for the region

iv. Assess implications for the Water Pillar and identify potential focus areas for climate adaptation and mitigation and make recommendations on potential interventions and actions;

11. The scoping report itself provides the policy and institutional framing for the Water Pillar and a proposed list of potential areas for investment and support. It delivers a basis for countries in Aral Sea Basin region to initiate cooperation on water under the umbrella of CAREC. Over time, this cooperation may expand to other CAREC States and involve the development of a CAREC Water Strategy in a process similar to that followed by other sectors of CAREC cooperation.

# 2 Methods and data

6. The analysis and information provided in this report relies on several data and information sources, mainly being:

a. Analysis and data in reports on climate change and water resources in Central Asian countries

b. Scientific literature on studies done on country-level or regional-level, on climate change and water resources

c. Data and modelled outputs available to the consultant from previous work since 2000, done in the region on climate change and water resources, for the World Bank and Asian Development Bank, both regional studies as well as project-specific climate risk assessment studies.

d. Data extracted from climate model projections from the ensemble NASA-NEX dataset (see Annex 1)

e. Extensive stakeholder consultations in the region that took place from Nov-2020 till Mar-2021, with key experts of the main water resources-actors in the region, like IWMI, IFAS, ICWC, and donors like GIZ, ADB, SDC, among others. Minutes of these meetings can be found as Annex in the main scoping study report.

# 3 Evolving trends in water supplies

7. Recent trends and future projections of water resources availability in the region are described here by focusing on the key climate variables that determine water security in the region. These are (i) precipitation, (ii) evaporative demand, (iii) glaciers and snow cover, (iv) flow variability and (vi) groundwater. The next Chapter 4 describes changes in water use and demand and how these affect the water resources situation in the region.

8. For describing the Amu Darya and Syr Darya basins in terms of water resources at the regional level, it is considered appropriate to divide the basins in **upstream and downstream** regions:

- The upstream region of the basins can be seen as the so-called "**water towers**": high-mountain regions that receive most of the precipitation and of which several tributaries include large man-made reservoirs that regulate water supply for downstream use and produce hydropower;
- The downstream region is where most **water use** occurs, is more extensive and receives less rainfall, while having favourable temperatures during part of the year to sustain agricultural production.

9. Figure 4 shows a map of the two river basins and the upstream and downstream regions. Note that the same colour styling is used for the figures in the succeeding sections.

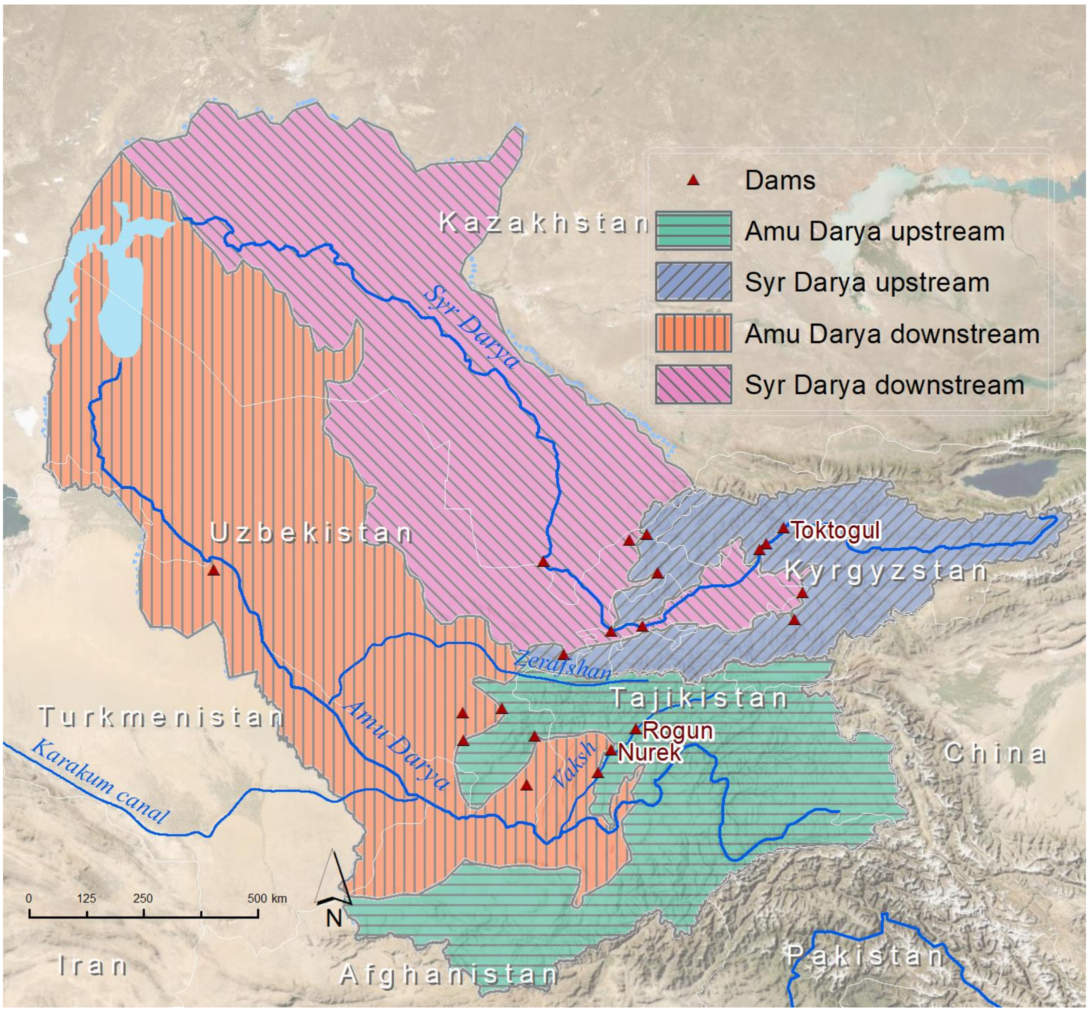



**Figure 4. Map showing the two river basins (Amu Darya and Syr Darya) and upstream versus downstream regions (source: author)**

## 3.1 Precipitation

10. The only natural input to any water resources system is precipitation. Precipitation can fall in the form of rain, snow or alike. In the high-mountain water tower regions, the vast majority falls as snow (Immerzeel et al., 2012). This resource is however of course highly variable, and subject to climate change. To assess recent historic regional trends of rainfall, data was extracted from the state-of-the-art reanalysis dataset ERA5 (ECMWF Reanalysis 5th Generation, latest release). For the four sub-regions as presented previously (two river basins, upstream and downstream), mean annual precipitation amounts were assessed based on data from the last 30 years. These were converted into a volumetric amount ($km^3$) to make them useful for water balance analysis.

11. Figure 5 shows the precipitation amounts each sub-region receives on average each year, based on data of the last 20 years. As can be seen, in total the two river basins receive 465 $km^3$ each year on average. The data shows, that in a very dry year the region receives in total about 15% less precipitation, while in a relatively wet year, it receives about 12% more. From Figure 5 it can also be clearly observed that the upstream regions ("water towers") receive most of the precipitation (64%).

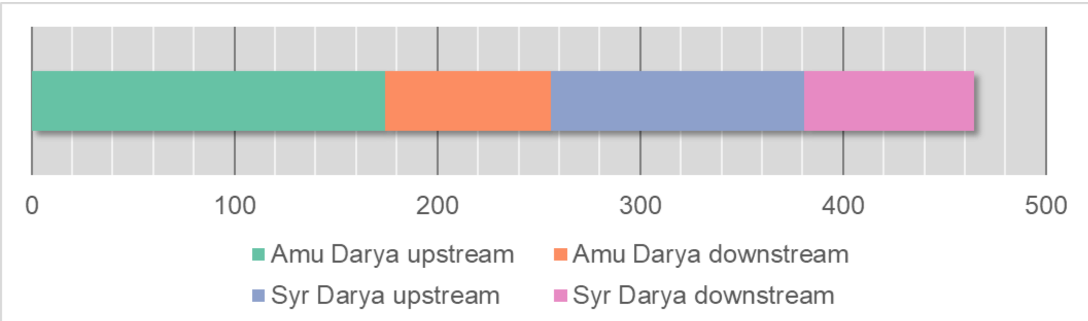



**Figure 5. Mean annual precipitation per sub-region (river basins and upstream-downstream) in volumetric units (km3).**

12. Based on timeseries for each of the regions over the period 1979-2018, a trend analysis was done. From this, a mean annual change was calculated for each of the regions. As, this scoping study looks 30 years ahead, these values were converted into a change value that corresponds to 30 years. The analysis indicated that nowadays the region receives **16 $km^3$ less** precipitation than 30 years ago – this is reduction of **3%**. Note though, that weather station data in high-mountain areas are limited in this region. This creates uncertainty for precipitation trend analysis.

13. Similarly, using climate model projection data (see Annex 1), an estimate was produced for each of the four sub regions for the likely change in precipitation over the next 30 years. Climate models in this region do **not show much agreement on the signal of change**: some models project increasing precipitation over the next 30 years, others a decrease. This is one of the reasons why studies that have selected a smaller subset of climate models, have come to different conclusions on the signal of change (e.g. Reyer et al., 2017). In general, precipitation projections for Central Asia need to be taken with caution, as it has been documented that the present generation of GCMs is not capable of reproducing the observed seasonal cycle of precipitation in Central Asia (Bhend and Whetton, 2013).

14. These past and future rates of changes in the order of a few percent may appear insignificant but given the fact that all water in these basins is allocated, changes of this size can be very relevant for the two river basins. For example, the Aral Sea received an annual average of 5 $km^3$ flow over the last decade: this is in the same order of magnitude as these trends in precipitation projections.

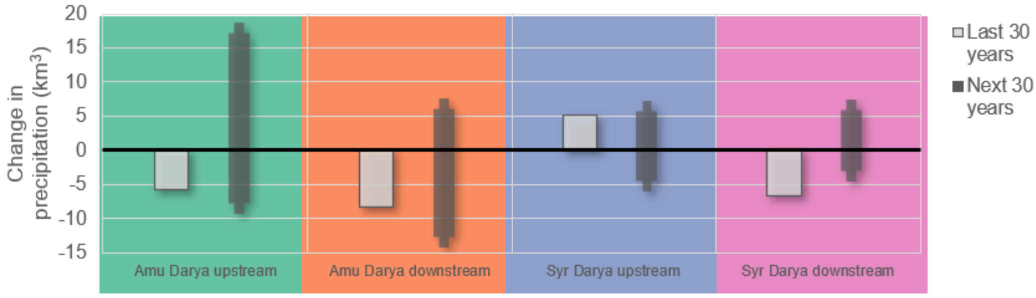



**Figure 6. Changes in mean annual precipitation per sub-region based over the last 30 years and the range projected for the next 30 years (km$^3$) – note the large uncertainty margins in predicted change.**

## 3.2 Evaporative demand

15. While projected precipitation changes in the region towards 2050 are quite uncertain as was shown in the previous section, climate models converge much more on temperature changes (see Figure 7). Analysis for this scoping study, based also on the ERA5 reanalysis dataset, show that temperatures will increase in the region to around 1.5ºC by 2050 compared to current temperatures (see Annex 1 for details).

16. Moreover, most previous studies focusing on Central Asia agree that the warming trend in mean annual temperatures is less pronounced in the high altitudes than in the lower elevation plains and protected intramontane valleys (Unger-Shayesteh et al., 2013). For the winter months, a stronger warming trend can be detected at higher elevations of the Tien Shan Mountains (Mannig et al., 2018). As such, it is not clear how elevation-dependent warming (greater surface warming occurring at higher altitudes) affects the region; for example for the Tibetan Plateau this effect was not observed (Gao et al., 2018).

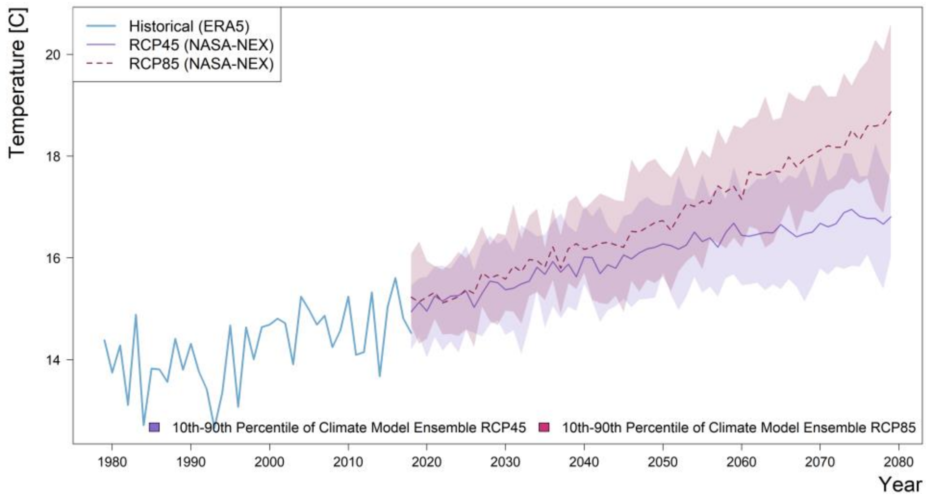



**Figure 7. Mean annual temperature trend and climate change projections for the Amu Darya downstream sub-region**

17. For water resources, increases in temperature have different direct and indirect impacts. A direct impact is the change in evaporative demand: from water surface bodies (reservoirs and lakes) and by vegetation and crops. The relationship between climate variables and evaporative demand is rather complex (and is best described using the Penman Monteith relationship which requires many data

inputs). For the purpose of this scoping study, a more practical relationship (Hargreaves) was used to obtain an approximate regional estimation of the expected change.

18. Based on this approach, it is estimated that the evaporative demand in the region will increase by about 5-7%. This increased evaporative demand does not necessarily convert in a similar increase in water consumption (= actual evapotranspiration), as this will primarily depend on the changes in the soil water balance. It is very likely though that at least part of this increase will translate in **increased consumptive use of water** by vegetation and crops. Consequently, this will lead to lower runoff and river flows, most likely also in the same order of magnitude (a few percent). Changes in this order of magnitude are highly relevant to downstream water uses. For example, the aquatic ecosystems of the Aral Sea currently rely on about 5% of the total water resources available in the river basins, thus changes of a few percent are relevant.

## 3.3 Glaciers and snow cover

19. Central Asian glaciers can be considered as the so-called water towers of the region and are mostly found in the Kyrgyz Republic (Tien Shan) and Tajikistan (Pamir). Some glaciers also exist in Kazakhstan and Uzbekistan. These water towers of both river basins have experienced notable changes over the last decades, due to changes in climate, glaciers and snow dynamics. Scientists indicate that climate warming in Central Asia is likely to exceed the global average. Already, this has caused the snowline to rise (about 150 m for every degree of warming) and water stored in glaciers to reduce: a trend which will further progress in the near and distant future (see Figure 8).

20. Additionally, the warming trend in CA is thought to be reinforced through the reduction in the snow albedo feedback (Unger-Shayesteh et al., 2013). Also, scientists recently confirmed a significant decline in snowfall fraction, which means that relatively more precipitation falls in the form or rain (Li et al., 2020).

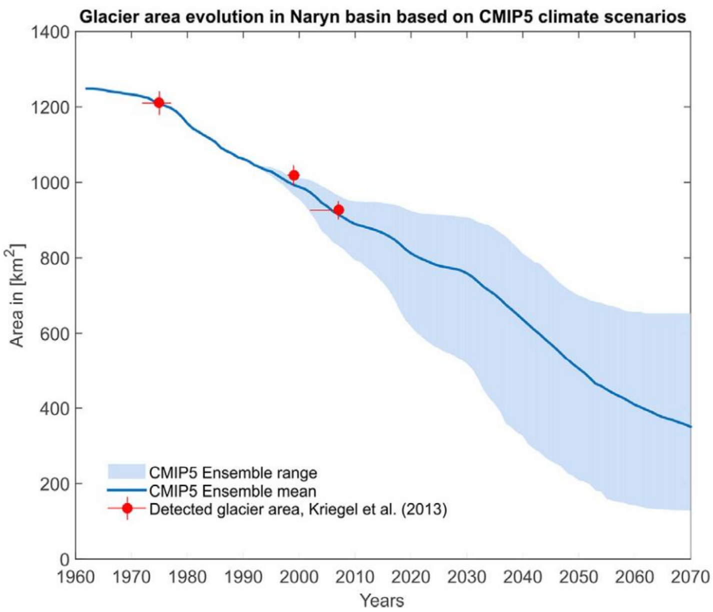



**Figure 8. Projected changes of glaciated area and mean monthly runoff in the Naryn river basin (main tributary of Syr Darya)** (Mannig et al., 2018)

21. The impact of changes in climate and cryosphere (glaciers and snow) on river runoff is a very complex and dynamic process. Several processes act simultaneously and can have either a positive or negative effect. For example, the loss of glaciers over the next decades can lead to an increase in flows

as more meltwater becomes available. It is acknowledged that even in tributaries with a glacierised fraction of less than 5%, glacier melt water can be an important contributor to irrigation in the summer to compensate for scarce precipitation, thus even small changes can have important impacts.

22. At the same time, a reduction in snowfall leads to changes in the seasonality of flow (see next section), and could possibly also reduce the annual streamflow due to changes in evapotranspiration, as has been observed already in the region in several smaller rivers (Li et al., 2020). Glacio-hydrological modelling assessments confirm that temperature change on its own (so without accounting for precipitation change) can have drastic impacts on water resources availability (Khanal et al., 2021).

23. Glacier mass decrease results in more meltwater to be released by the glaciers over the next decades. However, this will happen only up to a certain point when the glacial mass has shrunk to such a degree that run-off will start to decline. This moment is sometimes called *peak water* and can be considered a tipping point in the region beyond which impacts on water resources will be more severe. Some of the smaller tributaries have already passed this tipping point (e.g. Jia et al., 2020).

24. Calculations on the different flow components done for Syr Darya and Amu Darya show that the net effect on total river run-off in the region are likely to be minor up to around 2050. Figure 9 shows figures from a recently published scientific publication on climate change and hydrological response in the high mountain areas of Asia (Khanal et al., 2021). For Syr Darya, the results show that around half of the century, the glacier component will go down drastically. For Amu Darya, total contribution of snowmelt will go down considerably in all scenarios (Huss and Hock, 2018; Khanal et al., 2021)..

25. How these changes play out for total runoff in the second half of the century will depend on precipitation change to a large extent, as Figure 9 demonstrates. Table 1 shows results for a number of categorized scenarios (combinations of high or low precipitation change versus high or low temperature change), extracted from Khanal et al, (2021). Results suggest that for the end of this century, total runoff for Syr Darya may be even up to half of what it is now (percentages changes range between 0% and -49%). For Amu Darya, there is more uncertainty around the signal of change: total runoff may either increase or decrease.

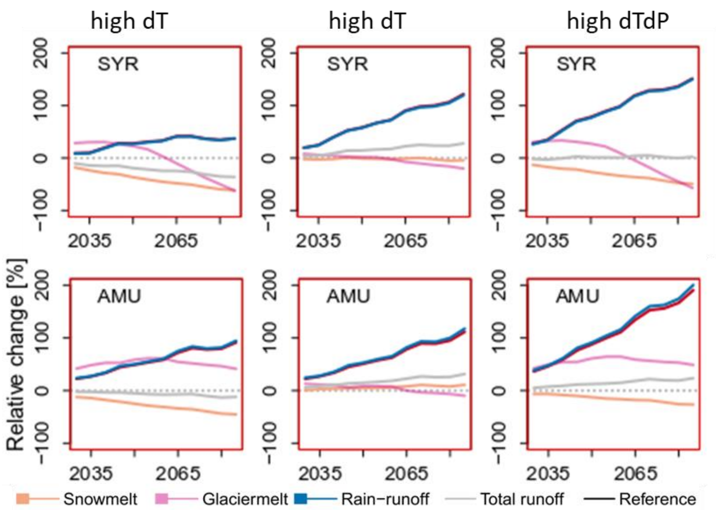



**Figure 9. Hydrological response to climate change for Syr Darya (SYR) and Amu Darya (AMU) flows at decadal time scales for three different future scenarios, that is, high temperature change (dT), high positive precipitation change (dP), and combination of both (dTdP). The lines in decadal plots represent the transient 30-year running mean relative changes in annual sums of rainfall-runoff, glacier melt, snowmelt, and total runoff. (source: Khanal et al., 2021)**

**Table 1. Relative changes in the magnitude (%) for Mean Annual Total Runoff for end of century (2071-2100) as compared to reference period (1985-2014), for various categorized scenarios. Source: Khanal et al., 2021.**

| Water demand | Warm-wet | Cold-wet | Warm-dry | Cold-dry |
|---|---|---|---|---|
| Amu Darya | 20 | 24 | -27 | -23 |
| Syr Darya | 0 | 15 | -49 | -38 |

26. Then up to 2050, there is not yet a good picture of how much additional meltwater will be released, due to a lack of observational data and regional cryosphere studies. Flow observations show over the last decades of the 20th century a minor increase for inflow to the Nurek (Amu Darya) inflow, but in the first decade of the 21st century again a decrease in flows (see Figure 10). Certainly, some tributaries that provide water to Nurek will have increased flows, but that positive effect may be compensated by tributaries where the effect of reduced snowfall fraction and increased evaporation wins. Data for inflow into Nurek reservoir (largest reservoir in Amu Darya basin) showed a slight increasing trend in the last three decades of the last century, then a slight decrease again in the first decade of the 21st century (data after 2010 was not available for analysis). More data for more points and longer time period are needed for a reliable trend analysis.

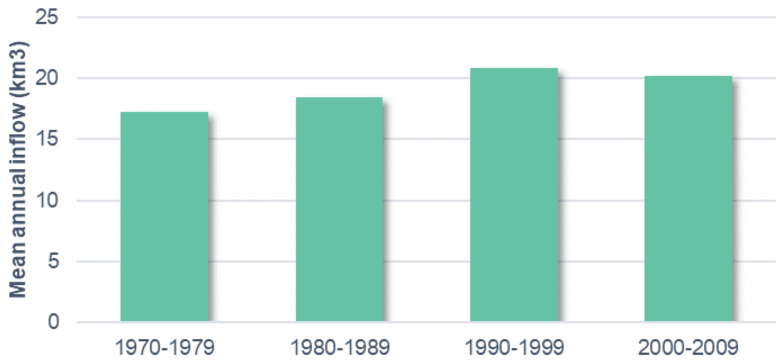



**Figure 10. Mean annual inflow per decade (1970-2010) into Nurek reservoir (Vaksh tributary of Amu Darya) (Source data: BWO "Amudarya")**

27. In summary, it is likely that the additional meltwater to become available over the next decades in some of the tributaries will be offset by other tributaries where a change in snowfall fraction and increases in evaporative demand (reservoirs, soil and vegetation) and sublimation (snow surface) will lead to decreases. Thus, it would be optimistic to count on additional water resources over the next decades for water use downstream. Some upstream tributaries may experience small increases in flows, especially in spring, but other tributaries will experience decreases. Also, increased evaporative demand upstream will likely counterbalance any net increase in water resources availability.

28. Beyond 2050, model predictions converge more and project that the contribution of snow and glacial melt to river flow in the mountainous areas of Central Asia are very likely to decline substantially leading to a considerable decrease in the water volume of the Syr Darya and substantial increases in flow variability in the Amu Darya River (Khanal et al. 2021). Measures to address this longer-term reduction in water availability and greater variability need to be considered soon as they involve complex decisions related to the future role of irrigated agriculture and land resources in the economy.

## 3.4 Climate impacts on flow variability

29. As already mentioned previously, the variability of flows is to a large extent driven by the glacier and snow dynamics in the high-mountain regions. The water towers store the precipitation that falls in

winter in the form of snow and releases it during spring and summer. However, reductions in snowfall fraction, increases in temperature and melt rates, and reductions in glacier mass will reduce this buffering capacity. This reduced capacity to buffer water in the water towers will have three major impacts on the flow regime:

1. **dry years will become drier** due to more pronounced inter-annual fluctuations in water stored in the high-mountain regions, leading to less water security in dry and hot years

2. a **seasonal shift** in water availability: peak flows happening earlier in the season due to higher temperatures

3. overall a **less predictable** and **more variable seasonal regime**, as the flow component that is relatively stable (snow and glacial melt) will be smaller, and the runoff coming from direct more uncertain rainfall will become larger.

30. The first two impacts will likely be noticeable already over the next decades (flow data are already showing first signs of these changes). The impact on predictability due to reduced glacier melt is most likely to become important in the second half of the century. These impacts have important implications for water resources planning, which needs to adapt to increased variability and uncertainty.

31. Figure 11 shows simulated runoff for the Naryn basin – a major tributary of the Syr Darya river, for an historic period and a future period (representative for 2050). This simulation shows that peak flows for this tributary will shift in the future from July to May-June, and that runoff (and thus reservoir inflow in this case of Toktogul) in July and August will likely be lower. Other studies predict an even much more drastic change in seasonality by the end of this century (Khanal et al, 2021).

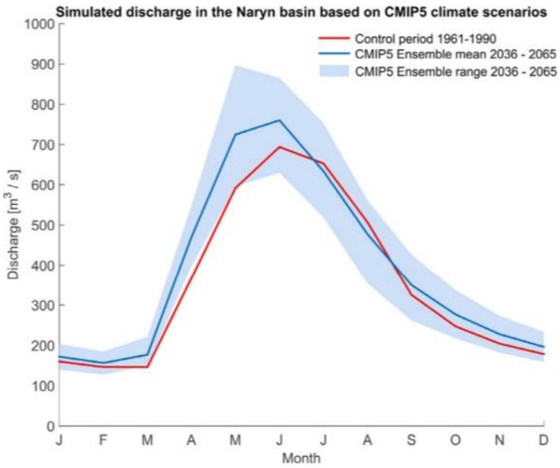



**Figure 11. Projected changes in mean monthly runoff in the Nary basin (main tributary of Syr Darya), as simulated using climate scenarios** (Mannig et al., 2018)**.**

32. To some extent, large reservoirs have the potential to buffer some of the increased variability. The three major reservoirs Nurek, future Rogun and Toktogul sum around 27 km$^3$ of active storage capacity which is around 81% of annual inflows into these reservoirs. But there are physical limitations for these water reservoirs with limited over-year storage to compensate the natural storage capacity loss from reduced glaciers and snowpack. Also, there are many tributaries that do not have significant reservoir storage capacity to potentially mitigate this effect.

33. It has been reported that there is already a detectable increasing trend in the frequency and amplitude of extreme floods and water shortages (OECD, 2020). Last year and this year have been reported to be extremely dry. The drought that affected the region in 2000-2001 made institutions react and gain capacity to deal with disaster management planning. However, there is still a general lack of preparedness and coordination strategies as the main focus continues to be predominately on

emergency response and recovery. The water shortages during the summer of 2020 have led to restrictions in some parts of the region.[1]. Forecasts by the Minister of Water Resources of Uzbekistan predict water shortages for this summer of 2021, similar as those in 2008.[2]

34. More irregular water supplies also increases the risk for high peak flows entering reservoirs and consequent failure of infrastructure. The recent failure of the Sardoba dam in Uzbekistan illustrates the possible consequences. On May 1, 2020, after five days of severe storms, a dam wall at the Sardoba reservoir in Uzbekistan's Syr-Darya oblast collapsed and water poured through a breach onto cotton fields and villages. To reduce water pressure on the walls of the reservoir and prevent further collapse of dam walls, its gates were opened. It has been reported that the water spilled could exceed 500 million $m^3$. The event has sparked the debate around regional cooperation between Central Asia's countries on water security and safety issues.

35. Also, the potential for glacier lake outburst floods (GLOF) is expected to increase with rising temperatures as well as with a rising number and size of moraine-dammed lakes (Bolch et al., 2011; Daiyrov et al., 2020; Marzeion et al., 2012; Zheng et al., 2019). This is associated with an increased risk for water resources infrastructure but also other infrastructure as road transport networks which are of high importance in the landlocked CA countries.

36. In spite of work done so far, especially at the regional level, there are still important knowledge gaps in terms of the magnitude and the spatio-temporal patterns of changes in the Central Asian high-mountain regions, and thus the impacts on the water resources. These gaps are related principally to the scarcity of reliable and appropriate data sets of these regions and a consequent lack of full understanding of the impacts on the hydrological response changes in snow and glacier dynamics in the headwater catchments. This was also one of the main conclusions from the USAID-funded CHARIS project.[3] A few relevant projects are about to start on this topic in the region (with involvement of SDC and UNESCO-IHP, among others).

## 3.5 Groundwater trends

37. Groundwater as a resource is essential for sustaining several water uses in the region (e.g., livestock, domestic water use, industries, and in some areas also irrigated agriculture), but has been under gradual increasing pressures in recent decades due to rapid population growth and economic development in the region. However, basic information and analytical assessments of groundwater are very limited.

38. Recently, countries have started an inventory of their groundwater stock and its use (OECD, 2020). Also, some promising developments are currently taking place that have potential to be upscaled. For example, GIZ is supporting the implementation of a "water cadastre" which is already actively used in the UzHydromet and the State Committee for Geology and is expected to be adopted by the Ministry of Water Resources soon. This can be considered an important first step in improving groundwater usage.

39. Groundwater inventories so far have taken place at the national level only. Given the nature of aquifers, it seems likely the regional stock is overestimated due to double counting of storage and yields in transboundary aquifers (Liu et al., 2020).

40. Limited information is on recent trends in groundwater levels and storage. It is reported that there are a reduced number of springs in Fergana Valley than before, leading to some impact on local

[1] ICWC bulletin September 7-11, 2020
[2] https://kun.uz/ru/news/2021/02/21/v-etom-godu-yest-risk-uvelicheniya-defitsita-vody-do-kriticheskix-pokazateley-2008-goda-ministerstvo-vodnogo-xozyaystva
[3] http://nsidc.org/charis/

households. It can be expected though that groundwater status will change in the near future, given the trend in on-farm pumping for irrigation. Farmers have increasingly access to cheap fossil-fuelled pumps which they use to mitigate water shortages pumping water in some areas from more than 50 meters deep. Also trends in livestock (see next Chapter) may affect groundwater in areas where groundwater is used for pasture.

41. A more immediate concern is the deterioration of aquifer quality in the two major river basins, which result in a decrease in usable groundwater stock (OECD, 2020). This is the consequence of groundwater recharge occurring often with water of poor quality (saline, nutrients and pollution). Consulted experts for this study have confirmed that as of today, depletion of groundwater is mainly an issue because of quality issues, rather than quantity issues.

42. In the region, water resources used from groundwater sum up to approximately 10 $km^3$ (about 8% of total abstracted water resources) (OECD, 2020). Whether this exceeds the renewable groundwater availability is not clear, as hardly any studies have been done on this matter in the region. In any case, the renewable groundwater resources are likely very small, given the climate and physiographic conditions of the basins.

43. Consulted experts have highlighted the need for pilot projects on conjunctive surface and groundwater management: the coordinated use of both resources, combined with water saving techniques that are effective at the system-level (see section in the next Chapter on Water saving). Artificial groundwater recharge (water banking), which is already a practice used for domestic use by several decades in some areas of the region, could be part of such a pilot.

# 4 Evolving trends in water demands

44. As reported in the previous chapter, climate change will change the water resources available considerably for the different uses across the region, including the environment. However, changes in water demands are often at least as important on the water balance as climate change (Chen et al., 2020). For example, the shrinkage of the Aral Sea was shown to be mostly explained by changing water uses in the river basins (86%), rather than climate change impacts (14%) (Aus der Beek et al., 2011). This chapter reports on the trends and projections in water uses and demands for the region, and the most relevant impacts. More data and information on water demand-related trends can be found in the parallel thematic paper on economic analysis for scoping the Water Pillar.

## 4.1 Water demand projections

45. Increasing water demand follows population growth, economic development and changing consumption patterns. The population of Central Asia is expected to grow by around 30% by 2050 (see Appendix of the scoping study, on the economic value of water). Combined with rising incomes and expanding cities this will cause water demand to rise further in the future. Estimates on these water demand forecasts are based on projections of these societal factors and are thus uncertain (Wada et al., 2016), but are the best we have to plan towards a more sustainable future.

46. Increasing water demands do not necessarily lead to an increasing water withdrawals, in cases where water is already fully committed. Central Asia is a good example of this fact: total water withdrawals in the region have remained more or less stable over the last decades in the regions. The reason for this is that practically all available resources are already commited thus there is no margin for withdrawing more.

47. However, over the last decades demands have changed among sectors, and certainly the pressure on the resource has even further increased. This has led to shifts between uses (for example more water withdrawals for households and industry) and higher vulnerability to water shortages. For example, it is reported that in dry years the withdrawals can drop by about 20%, leading to significant drops in production and additional environmental impacts (OECD, 2020).

48. Although withdrawals have remained more or less stable, or even reduced slightly according to the FAO Aquastat database[1], consumptive water use has most likley increased in the recent decades, as suggested by the negative trend in Aral Sea inflow. This demonstrates that it is not sufficient to look only into data for withdrawals, but also obtain indicators on actual consumptive water uses. Consumptive water use typically increases when demands exceed supplies.

49. Several studies have performed water demand projections that are specific to the region. The two most relevant are: (i) a study comissioned by OECD in 2020 (OECD, 2020), (ii) (i) a study for the World Bank by COWI, not published or reviewed but of which the estimates were provided by the consultants (COWI, 2020),. Besides there are a number of studies and projects that generated demand projections for the region, but rather based on global public domain data instead of region-specific information (e.g. Straatsma et al., 2020).

50. Comparing the projected demands of the two cited studies it can be concluded that they are reasonably consistent between each other. Table 2 shows the sectoral demand estimates for 2050, for two scenario´s: a Business-as-Usual scenario that assumes little rehabilitation over the next decades,

[1] http://www.fao.org/aquastat/en/databases/

and an “adequate rehabilitation” projection, which mainly based on the assumption of a 10% drop in water demand due to reduced leaking and seepage in the water conveyance system.

**Table 2. Projections of Central Asia demands (unpublished estimates provided to the consultants) in km$^3$**

| Water demand | Now | Business-as-usual | Rehabilitation |
|---|---|---|---|
| Irrigation water | 107 | 108 | 97 |
| Rural water | 1 | 6 | 6 |
| Urban water | 4 | 8 | 8 |
| Industrial water | 9 | 23 | 23 |
| **Total water** | **123** | **145** | **134** |

51. As known, irrigation demand corresponds to the largest share of water demand. In fact, Central Asia has nowadays the highest pressure on water resources due to irrigation (withdrawals for irrigation relative to total renewable water) (FAO, 2011). The relative share of irrigation in the total demand will reduce though, as shows the Business-as-usual scenario in Table 2. This is mainly due to significant growth in industrial demand (between 2-4% annually according to these estimates).

52. Hydropower demand is typically not included in this sort of projections, as most of its demand is non-consumptive. It is important to note however that hydropower does consume water through evaporation from the water surfaces of the reservoir (about 2 km3/annually, which is about 2% of the water resources available). Also, water needed to fill the dead storage of new dams can generate a consumptive loss on the water balance (in case of the new Rogun dam that is about 3 km3, which is about 1% of the available water in case filling is spread out over three years).

53. There are two other demands that were not included in the demand projections of the COWI study: (i) environmental demands and (ii) livestock demands. The main environmental demand in these two river basins is of course the Aral Sea and its aquatic ecosystem. The OECD study estimates this demand to be 12 km3/year. However, environmental requirements in the region are not limited to the Aral Sea, but should include floodplain, riparian, and instream ecosystems in the full extent of the river basins. No comprehensive study has been done to assess this demand, neither it is included in any of the agreements and water laws.

54. Several consulted sources have highlighted the relevance of trends in livestock across the region and their possible impact on water resources. Increases in livestock in the region will lead to increased demand for pasture and fodder. During dry periods, pasture may require additional irrigation water, typically abstracted from groundwater. This can lead to reductions of baseflow (water entering the river through the sub-surface). Especially with changing precipitation patterns and increasing temperatures, growth and regeneration of pastures for livestock grazing could decline in upper mountain valleys of the river basins (Reyer et al., 2017). There may be positive indirect effects of climate change, such as in Uzbekistan, where the productivity of alfalfa and grasslands is expected to increase under warming conditions (Sutton et al., 2013).This could potentially counter-balance the negative direct heat stress effects of climate change, that alter the feed intake, mortality, growth, reproduction, maintenance, and production of animals (Sutton et al., 2013).

## 4.2 Water stress and demand versus supply

55. The gap between reliable water supply and demand is an indicator of the amount of water stress a region experiences or will experience. Water stress hinders economic growth, thus current and future projections on water stress can inform decision making for sustainable growth and stimulate action. Projecting water supply and demand is thus useful to compare a scenario in which current practices

continue (Business-as-Usual) or where interventions reduce water stress and the supply-demand gap (Straatsma et al., 2020).

56. Whether supply is considered reliable or not depends to a certain extent to local conditions and can be assessed using a combination of observations and modelling. For large-scale and scenario-studies, simple assumptions can be however sufficient to project water stress to the future. The box below summarizes the key assumptions used for this analysis.

**Box: assumptions on supply-demand gap analysis, for the next 30 years (2050).**

- Changes in runoff over the next 30 years are driven by changes in precipitation. Changes in evaporative demand upstream and changes in snowfall fraction counterbalance the net increase in glacial meltwater. The fraction of precipitation which becomes runoff remains unaltered.
- Reliable supply is here defined based on annual flows with 90% reliability, i.e. tolerating water shortage on average once every 10 years. Calculation was done based on drought occurrence over the last 20 years (OECD, 2020). In 2050, it was assumed that low-flow extremes are 10% more severe due to climate change effects, so reliable supply is 10% lower.
- No regional estimates are available on groundwater renewable resources, but these are likely to be low. For this analysis it is assumed that current extractions correspond to the renewable amount
- Changes in water use efficiency upstream will affect return flow and can thus potentially negatively affect water available to downstream users. For the climate resilient scenario, it is assumed that this is counterbalanced by a reduction of non-recoverable flows and a corresponding increase in recoverable flows, mainly due to reduced salinity.
- Environmental demand only consists of the Aral Sea demand, recognizing that this is an under-estimate, as it does not account for other possible riparian and instream ecosystems.
- It is assumed that the impact of livestock and hydropower (through evaporation from reservoirs) on water resources is already accounted for in the used runoff estimates (in any case they are likely to be in the order of a few percent)
- In the BaU scenario, irrigation demand is assumed to increase by 5% (as a result of increased evaporative demand, irrigation expansion and a business-as-usual rehabilitation). Industrial demand increases linearly by 1.5% annually, in a similar pace as the last decades. Urban and rural water demand projections are taken from the COWI study.
- For the rehabilitation scenario, irrigation water demand is assumed to be reduced by 10% (water saving measures and increased productivity) For the climate resilient scenario, a reduction of 30% is assumed, by means of real water savings-interventions, including improve salinity management reducing leaching requirements, increases in water productivity and a wide portfolio of climate resilient interventions (management, drought-insurance, etc)
- For the rehabilitation scenario, industrial water use efficiency is assumed to increase by 20% and for the climate resilient scenario by 40%, compared to BaU. For the rehabilitation and the climate resilient scenario, rural and urban water use efficiency is expected to increase by 20%.
- Note that the future water demand for irrigation in Afghanistan was not included in this water balance, given the scope of this work on the five Central Asia countries. However, Afghanistan is an upstream riparian of the Amu Darya river, and has shown an increased demand of water over recent years as the economic and security situation in the country has improved. In fact, the Amu Darya river basin holds almost 40 percent of the country's available internal water resources and the majority of its hydropower potential is in this basin. Water demand is estimated to grow to 7km$^3$. In other words, this demand has the potential to add significant additional pressure on the available water resources.

Table 3 shows the demand projections based on the assumptions listed above. Note that these numbers refer to supply and demands from the main river systems – as is typically done for regional water balances in Central Asia, for example in the ICWC bulletins, other regional studies and for the regional agreements in place. In other words, this is gross demand: it includes water that is reused through the main river system (i.e. return flows used by downstream users). These numbers are used to draw Figure 12 in which reliable supply with demand are compared. The figure shows current and future reliable supply – including its uncertainty originating from the spread in climate change projections.

**Table 3. Projections of Central Asia demands (unpublished estimates provided to the consultants)**

| Water demand | Now | 2050: Business-as-Usual | 2050: Rehabilitation | 2050: Climate resilient |
|---|---|---|---|---|
| Irrigation water | 107 | 113 | 101 | 79 |
| Rural water | 1 | 6 | 6 | 5 |
| Urban water | 4 | 8 | 8 | 7 |
| Industrial water | 9 | 14 | 12 | 10 |
| Environmental | 12 | 12 | 12 | 12 |
| **Total water** | 134 | 153 | 139 | 112 |

57. From Figure 12 it can be concluded that:

- An sizable gap of 37% will occur under business-as-usual, if the region follows its current pace and without rehabilitation and modernization investments in the water and agricultural sector
- The rehabilitation scenario shows there is scope to reduce this gap to 24%, but a significant gap will remain.
- The climate resilient scenario assumes a much broader package of region-wide investments and would reduce the gap to minimum, with a residual uncertainty related to climate change.

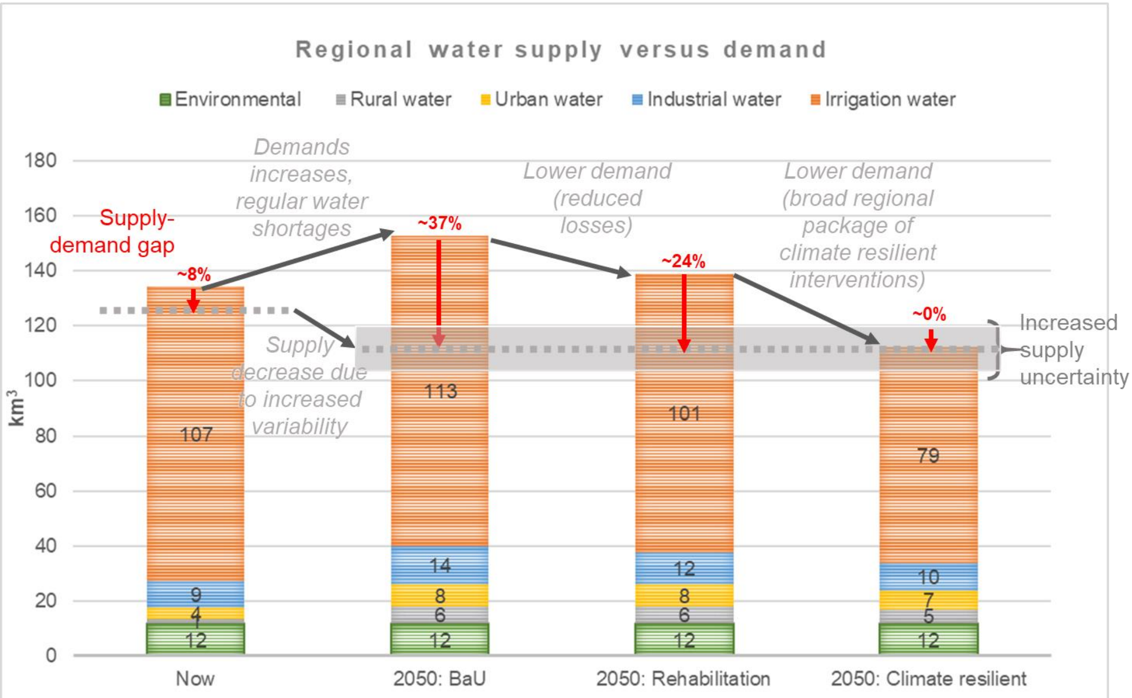



**Figure 12. Gap between regional water demand and reliable supply. The bars indicate the demand for the five sectors; grey dotted line the supply**

58. The climate resilient scenario is challenging: a broad, region-wide approach towards modernization of the sector, sustainable water resources management interventions, and climate adaptation measures are needed. A modeling study done in 2012 (Lutz et al., 2012) that assessed climate adaptation

strategies across the region, and  its cost-effectivness, indicated that closing the gap in this order of magnitude (around 30 km3) is feasible, but requires a combination of demand-side, supply-side and water productivity interventions.

59. Obviously, regional cooperation is of paramount importance to make this effective. Regional cooperation is critical in several areas to make a climate resilient approach effective in closing the gap between supply and demand. Critical areas are (i) energy-water nexus issues, like hydropower developments and energy trade, (ii) water-food nexus issues like irrigation modernization and water productivity, and (iii) disaster-risk-reduction measures. Section 5.2 identifies several areas and projects where CAREC could be involved in for this to become effective.

The gap between supply and demand differs according to region, basin and sub-basin. For example, it has been estimated that about one third of the gap between demand and supply corresponds to the Syr Darya, and two thirds to the Amu Darya basin (Lutz et al., 2012). To assess the spatial differences of water stress, another commonly water stress indicators can be used based on freshwater withdrawal as a proportion of available freshwater resources (more specifically: the ratio between total freshwater withdrawn by major economic sectors and total renewable freshwater resources, after taking into account environmental water requirements). This indicator is also known as water withdrawal intensity, or “level of water stress” and will measure progress towards SDG Target 6.4. Figure 13 shows a map of this indicator that was extracted from a global assessment on this indicator by WWF. As can be seen, especially the downstream areas in Amu Darya have the most reddish colours, or the highest level of water stress according to this SDG indicator.

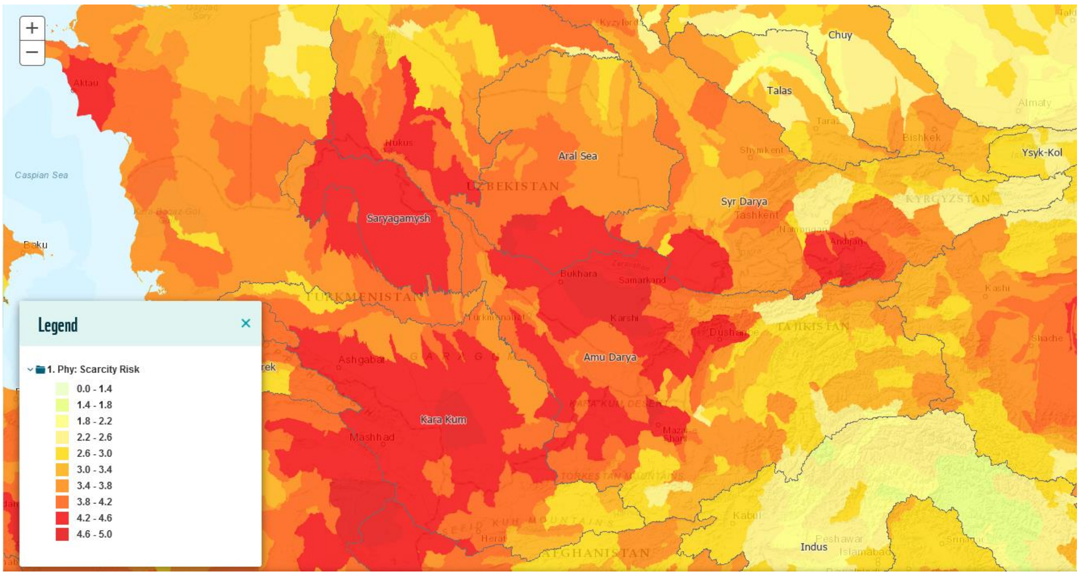


**Figure 13. Map of water scarcity risk (source: WWF Water Risk Filter)**

## 4.3 Water use impacts on flow variability

60. In the previous chapter, expected increased variability in flows and water supplies due to climate change has been discussed. Besides these climate change-effects, the future flow regime of the two river basins will also be influenced by changes in water use, reservoir operations and releases. Enhanced regional energy connectivity, changes in regional energy trade and future new dams will thus likely have an impact on the flow regime. The impacts may act on different temporal levels: (intra-)**daily**, monthly/**seasonal** and **annually**.

61. Since independence of the countries, hydropower releases have increasingly responded to peak domestic demand, which for the upstream countries occurs in winter. This causes a change in the

**seasonality** of the flows: peak flows downstream of the reservoirs shift from summer towards winter. Figure 14 shows for Toktogul (Syr Darya) and Nurek (Amu Darya) the mean inflows and releases based on data from 2000-2010, complemented with data from the latest ICWC Bulletin available of last year[1]. The seasonal shift is very clearly observed for Toktogul reservoir: inflows peak in summer, while releases peak in winter (Figure 14). Also it can be seen that the reservoir operations reduce the amplitude of the flows and flatten out the peaks (inflow peaks being higher than outflow peaks both for the high flows as well as the low flows), as can be seen for Nurek reservoir (Figure 14).

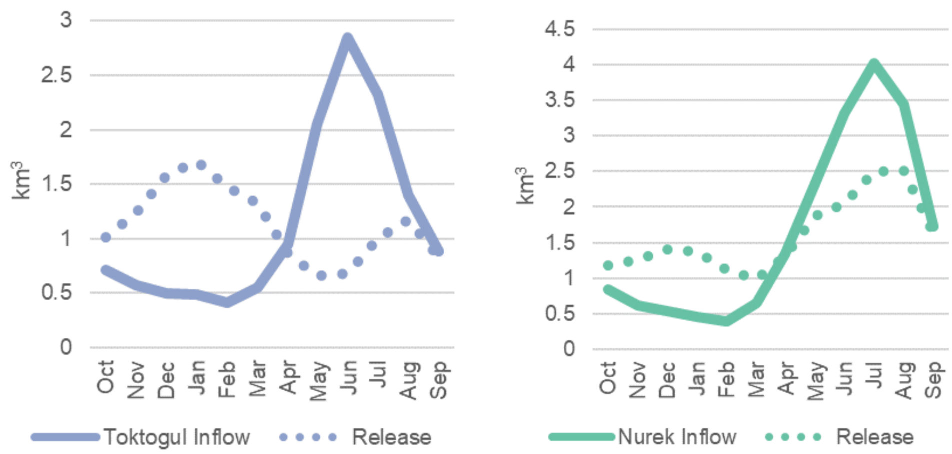



**Figure 14. Mean monthly inflows and releases from Toktogul (left) and Nurek (right) reservoir.**

62. Besides the seasonal variability, there is also significant annual variability in inflows, storage and releases. There is also considerable annual variability of reservoir inflows, storage and releases. Figure 15 shows the annual inflow for the period 2000-2010 for both reservoirs, and its deviation from the mean. As can be seen, inflows in some years go down up to -50% compared to the mean in the analyzed period, for Nurek (in case of Toktogul up to -19%). The annual releases provide some insight in how the reservoirs are actually buffering water in dry periods that have a duration of more than a year. In case of Nurek, similar negative anomalies are found for releases (not shown here) – so no a net over-year storage effect is observed. Data for Toktogul seems to suggest that negative anomalies are reduced by the effect of reservoir operations. Certainly, Toktogul has sufficient capacity to do so: live storage capacity is about the same as mean annual inflow (14 $km^3$). Nurek´s live storage capacity (4.5 $km^3$) is only around 25% of mean annual inflows into Nurek (20 $km^3$). Including the future Rogun dam upstream of Nurek, total live storage capacity of bother reservoirs (13 $km^3$) will be around 65% of total annual inflows into both reservoirs (approx. 20 $km^3$). The three major reservoirs Nurek, future Rogun and Toktogul sum around 27 $km^3$ of active storage capacity which is 81% of annual inflows into these reservoirs.

[1] http://www.icwc-aral.uz/icwc_bulletins.htm

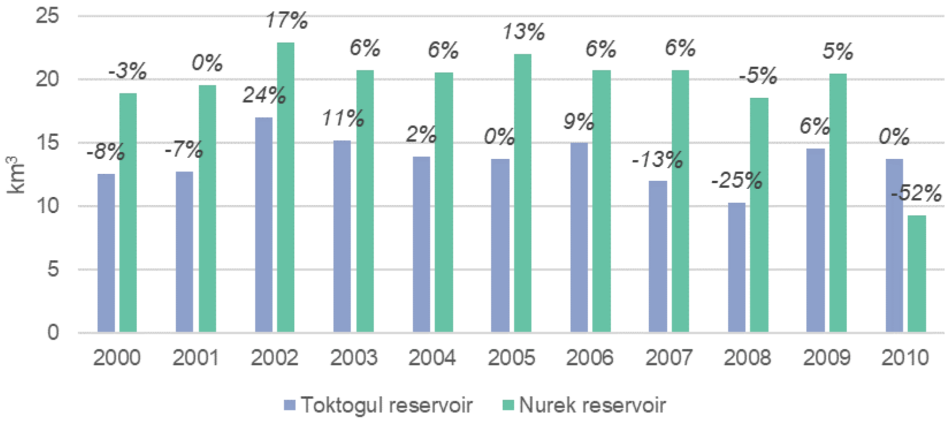



**Figure 15. Annual inflow for the main reservoirs and its deviation from the mean (%)**

63. Figure 16 shows how this plays out in storage capacity over a period from 1993-2020 (extracted from remote sensing data but with very good correlation with observed capacity, see Annex 2). The figure shows storage amounts in the first quarter of the year only, which is the most important period for downstream users. Clearly, there is huge variability, in spite of Toktogul´s carryover capacity. Climate change will change the seasonality of energy demand (e.g. less demand for heating in winter, more demand for cooling in summer) and will also change the seasonality of the reservoir inflows: especially on the long-term (i.e. beyond 2050) these changes will likely change the discussed dynamics significantly.

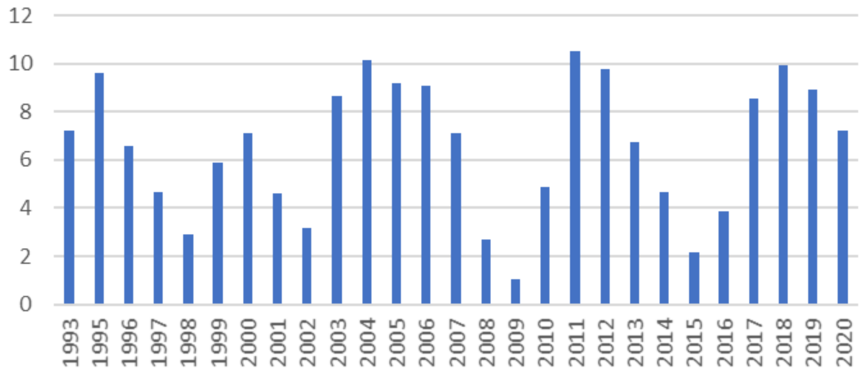



**Figure 16. Average reservoir active storage of Toktogul during the first quarter (Jan-Mar) in each year (source: analysis based on SDSS database) in km$^3$**

64. Reservoir operations may affect diurnal flow variability also. This diurnal variability may be flattened out to a certain extent if below the storage dams there is a cascade of runoff river dams (without storage). However, in several places in the river basins this is not the case (e.g. below Toktogul). Thus diurnal fluctuations as a result of intra-day reservoir operations (driven by intra-day demands) may become relevant. With hydropower becoming increasingly important for stabilizing the electricity grid once the proportion of intermittent renewables (solar, wind) in Central Asia increases, this diurnal variability will need to be looked into further.

## 4.4 Water productivity

65. In areas where a particular resource is scarce and limits productivity, it is useful to optimize the productivity by looking at the ratio between a unit of output (for example yield) and a unit of input of the resource (e.g. water). Water productivity (WP) is increasingly used to assess the productivity gap and the potential for interventions that improve productivity and finally the livelihoods that depend on it. It is used exclusively to denote the amount or value of product over volume or value of water depleted or diverted[1]. The value of the product might be expressed in different terms (biomass, grain, money). For example, the so-called 'crop per drop' approach focuses on the amount of product per unit of water.

66. Work done in the region shows that there is considerable variation in water productivity. Early performed in the Syr Darya basin showed that there is almost a factor two between the highest and lowest values (Abdullaev and Molden, 2004), only looking at best practice sites. Thus, the gap with areas without best practices can be expected to be much higher.

67. The latter is confirmed by recent studies using remote sensing. Water productivity (crop yield per unit of water depleted by evapotranspiration) can be estimated at the plot or regional level using remote sensing techniques. Recent work by IWMI covering two irrigation districts in Uzbekistan showed a large gap between well and low-performing areas: a factor five between the lowest and highest values (0.25 kg/m3 and 0.99 kg/m3) (IWMI, 2020). A potential explanation for this huge difference is differences in water reliability and access to inputs.

68. A remote sensing-based study on water productivity in the entire Syr Darya basin carried out by IrriWatch shows an even higher range in water productivity in the region (between 0.25 and 2.5 kg/m3 (based on dry matter production). Maps from this study show that typically areas at the tail end of irrigation systems and salinized areas are doing worse, while other areas perform reasonably well. Such spatial analysis can provide insight in which factors (drainage, capacity, extension service) explain the performance of these systems.

69. Those studies show that there is a potential scope to increase overall water productivity in the river basins by closing the gap between low and high values of water productivity through improved practices and technologies. Which measure may be most effective will depend on each location, ranging from improved drainage and salinity management to improved decisions support systems. It should be emphasised that those water productivity studies ignore mostly the wide-spread salinity problems in the region; comparing water productivity of saline lands with non-saline lands requires additional research. A second concern on simply comparing water productivity numbers is that different crops have by nature different water productivities.

70. FAO has developed a portal to assess water productivity on high resolution with updated maps for each location in Africa, called WaPOR. It is understood that the portal will soon be expanded to Asia.[2] An initiative for the region provided during some time information on water productivity, but does not appear to be updated recently (see Figure 18).[3] The data in this portal up to 2018 confirms there is a large water productivity gap in the region, showing that neighbouring districts can have water productivity values for cotton that on average differ by a factor of two.

[1] Note that there is an important difference between "depleted" and "diverted". Depleted means that water is actually consumed (by evapotranspiration) and cannot be reused by downstream users. Diverted means that a fraction will be consumed (depleted) and another fraction is potentially available to downstream users.

[2] wapor.apps.fao.org/

[3] https://wuemoca.geo.uni-halle.de/app/

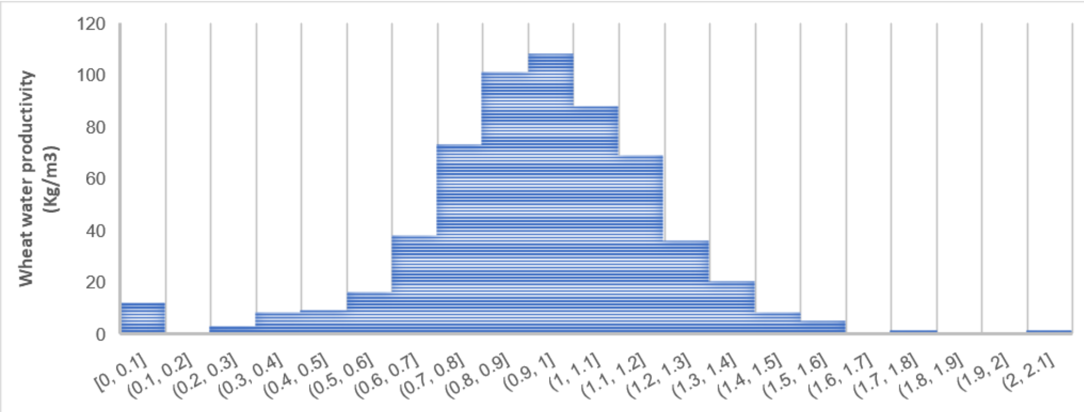
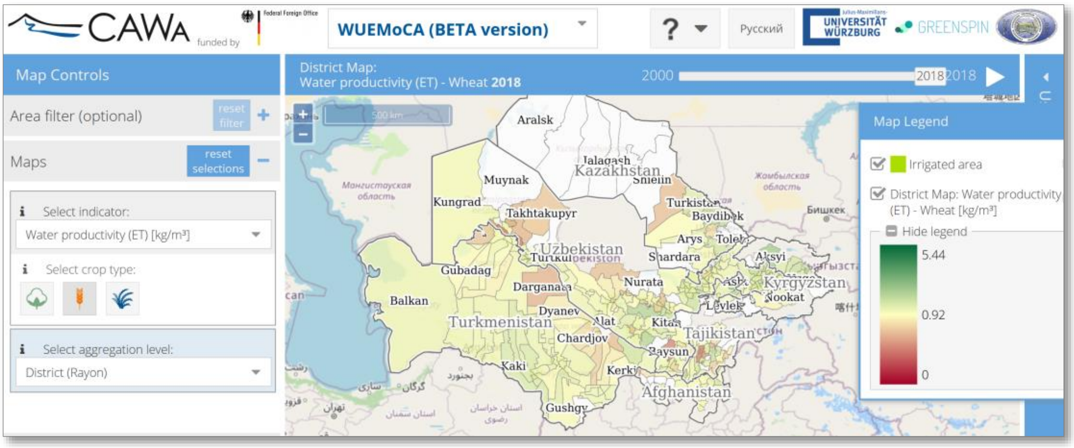



**Figure 17. Histogram showing a large spread in wheat water productivity based on data between years 2000-2018 and for 28 oblasts (source: http://wuemoca.net/app/)**

71. The water productivity gap will be further aggravated by climate change impacts. In Uzbekistan, without implementing adaptation measures and technological progress, yields for most crops are expected to drop by as much as 20–50 % (in comparison to the 2000–2009 baseline) by 2050 with 2 °C warming due to heat and water stress (Hunink and Droogers, 2011; Sutton et al., 2013). This study also finds that when including the effects of reduced water availability, yield decreases are much more pronounced.



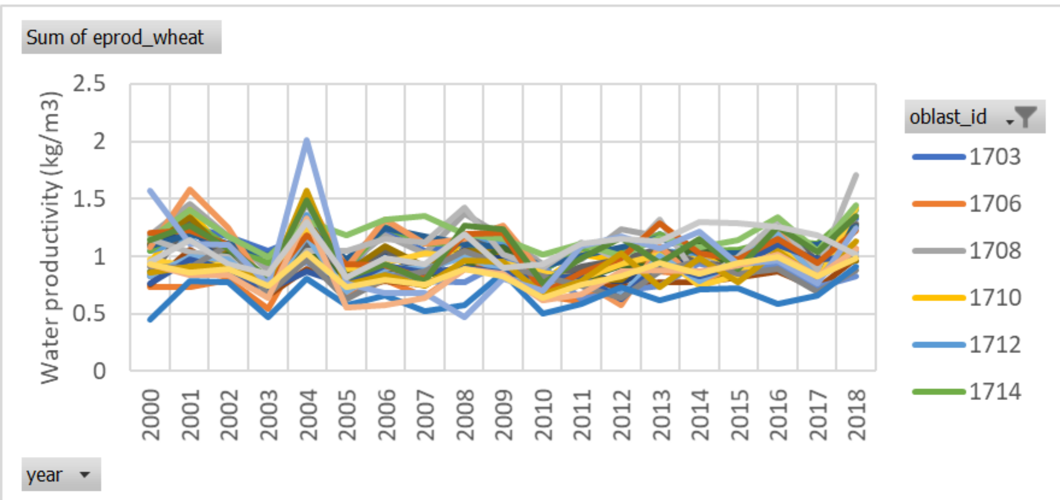



**Figure 18. Screenshot of the inactive portal for Central Asia with remote sensing-based data on water productivity; below: wheat water productivity for the period 2000-2018 for in total 28 oblasts (source: http://wuemoca.net/app/)**

72. Water productivity can also be expressed in economic terms, meaning that the numerator is expressed in monetary value of output minus monetary value of inputs used, both at market values (i.e. correcting for subsidies or distorted procurement prices). This measure is data-intensive and cannot be generated at scale by satellite, hence can only be used on a sample or project basis. However, it does pick up cases where high physical yields are due to uneconomically high inputs such as power for pumping, and conversely, where apparently low yields are offset by efficient use of other, non-water, inputs. Economic water productivity can be considered a refinement of physical water productivity and can be useful for policy guidance. The economic report prepared for the CAREC Water Pillar scoping study explains this concept and its usefulness in-depth.

## 4.5 Water savings and upstream-downstream issues

73. Irrigated agriculture is the largest consumer of freshwater withdrawals in Central Asia, responsible for around 90% of water consumption. Unsurprisingly, and as shown previously, water shortages are prevalent in the region. These shortages affect all water users in the basins differently, and also the irrigation sector faces direct impacts on farmer productivity and farmer livelihoods, and incomes. Therefore, options to reduce shortages by saving water tend to focus specifically on irrigation technologies and practices. Improved irrigation techniques (such as drip irrigation, sprinkler, pressurized systems) are promoted as optimal means of “saving water” for other uses (such as domestic use and the environment).

74. However, a growing body of evidence shows that in many cases, apparent water “savings” at field scale translate into an increase in water consumption when assessed at larger scales (for example the irrigation district), as these “savings” are often used for irrigation expansion or increased cropping intensities. This can lead to undesirable side-effects, as water saving interventions finally increase consumption and thus water stress elsewhere in the basin. This is well documented by a FAO report (Perry et al., 2017) and recently further refined by (Opstal et al., 2020). Also for example in Europe, a recent review of irrigation water use in Europe has revealed this fact (Gerveni et al., 2020).

75. In Central Asia, the reuse of water (mainly unplanned and not coordinated) is huge at different levels: at the basin-level but also within single irrigation districts (for example at tail end of systems relying on return flows from farmers higher in the system). For example, stakeholders consulted for this work have indicated that there are examples of situations in which farmers relying partially on return flows were negatively affected by canal lining activities and water that was supposedly saved, “disappeared”.

76. FAO has recently launched the concept of “Real Water Savings”. A distinction is made in “real” water savings in contrast to “apparent” water savings. Typically, projects and studies report on reduced “losses” only, while not considering that often these “recovered losses” are used for irrigation expansion or increased cropping cycles, so do no lead to any net saving. They fail to report on the impact on water consumption through evapotranspiration: often water consumption in fact goes up due to these interventions.

77. “Real” water savings however, report on reductions in water consumption, and on water released to other uses, by reducing non-beneficial consumptions and non-recoverable return flows. These concepts are illustrated by the FAO “Follow the Water” concept. According to this concept, the water flows of an irrigation system can be divided into the following components (see Figure 19):

78. The consumed fraction (essentially ET), comprising:

79. beneficial consumption (for the purpose intended or other beneficial use such as environmental purposes);

80. non-beneficial consumption (such as weeds; evaporation from wetted surfaces; or capillary rise during a fallow period)

81. The non-consumed fraction, comprising:

82. recoverable flows (water flowing to drains and back into the river system for possible diversion downstream, and percolation to freshwater aquifers);

83. non-recoverable flows (percolations to saline aquifers, outflow to drains that have no downstream diversions or direct outflow to the sea). There is an economic dimension to this component: salinized or polluted water can be physically recoverable but can become too costly to recover for re-use.


**Figure 19. Simplified water accounting system referred to as the "Follow the Water" concept (see explanation in the text. dS is the change in water stored in soil or reservoirs within the system, if applicable, over the time period considered).**

84. It is increasingly recognized that any project investing in irrigation modernization should not only consider possible local irrigation efficiency gains, but also assess other positive or negative impacts, related to return flows, impact of water remaining in the system, water quality and energy costs – looking at the local versus the basin perspective. Projects can have a positive impact if they reduce the salinity of the river that receives saline return flows, but can at the same time have a negative impact if these return flows are for example essential to sustain the ecosystem of the Aral Sea. Even more important though is that this should be embedded in good governance and specific regulations and control. Promising developments in this aspect are for example the harmonization between the Ecological Code and Water Code in Uzbekistan.

85. Positive impacts of local efficiency gains can also be substantial if energy can be saved. In Central Asia many of the irrigation systems rely on extensive pumping schemes that bring water from the river to higher elevations. For instance, in Uzbekistan, electricity use for Irrigation and Drainage (I&D) pumps accounts for 16 percent of national electricity generation, costing close to US$350 million annually and accounting for 60 percent of the annual budget of the ministry responsible for irrigation. A World Bank study in 2017 looked at the energy "costs of irrigation inefficiency" for Tajikistan (World Bank, 2017). The study concludes that the tendency for more competition and connections on the regional energy market could provide an incentive to the Government of Tajikistan to pursue irrigation efficiency. Earnings from reduced pumping and selling excess energy to national or regional clients could be used to support the population whose livelihoods depend currently on pump irrigation.

86. For illustrating this real water savings concept further, two scenarios are presented here, in which the Follow the Water diagram is shown for flows at the **farm level (**Figure 20), and the **basin level (**Figure 21). The left scenario is the Business-as-Usual scenario, which could be representative for current conditions. The scenario on the right is a scenario where a wide range of real water savings-measures are implemented (the Climate Resilient Scenario).

87. A climate resilient intervention portfolio at the farm-level **(**Figure 20) in principle should aim to reduce non-beneficial consumption and increase beneficial (productive) consumption – while leaving total consumption constant (or at least no increase, preventing negative downstream externalities). Return flows (traditionally framed as "losses") can be reduced – both recoverable as well as non-recoverable, but water withdrawals are reduced so water is released (real savings) to other uses, for example the environment.

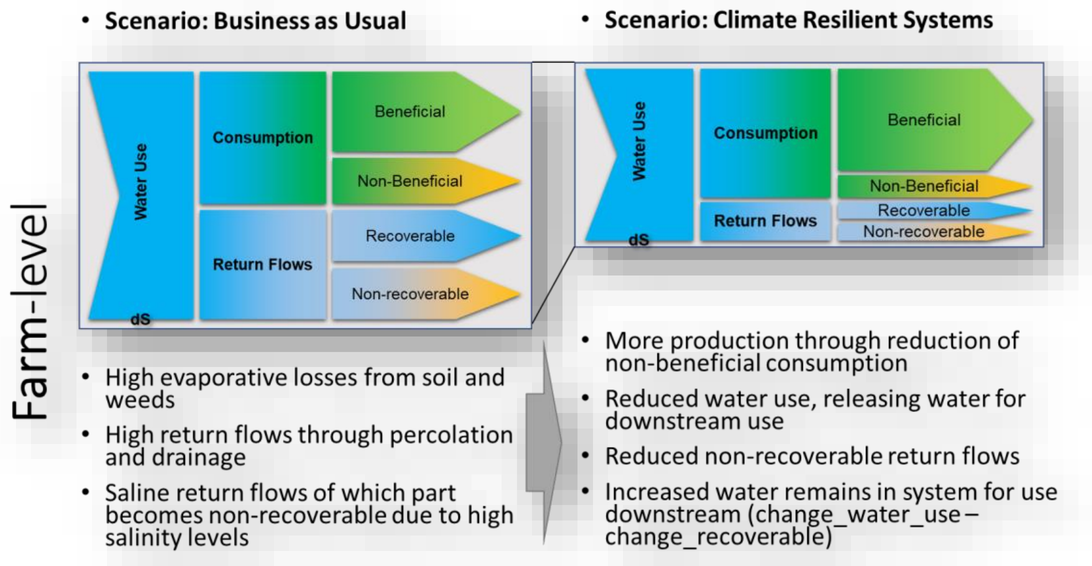



**Figure 20. Impacts of real water savings measures on the water flows at the farm-level, illustrated using the Follow the Water concept (Note: dS is zero in this example; Water Use = Water Withdrawals from the river or main distribution network)**

88. A climate resilient intervention portfolio at the basin-level (Figure 21) in principle should aim to reduced non-beneficial consumption, increase beneficial and productive consumption – possibly (but not necessarily) increasing total consumption. Such an intervention could also aim at reducing water withdrawals overall, leading to reduced return flows, and finally increased efficiency at the basin-level.

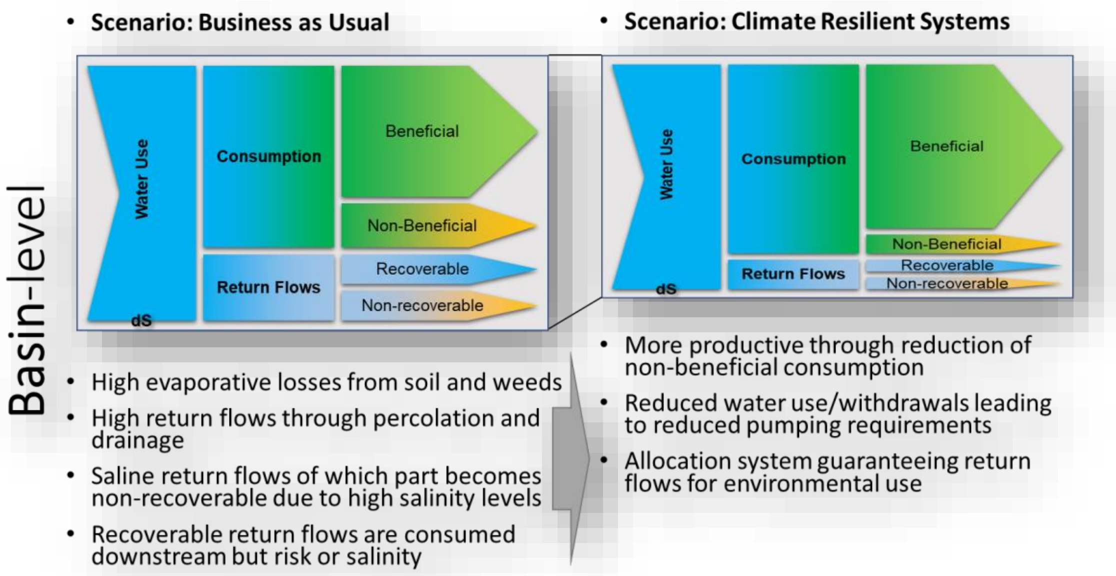



**Figure 21. Impacts of real water savings measures on the water flows at the farm-level, illustrated using the Follow the Water concept (Note: dS is zero in this example; Water Use = Water Withdrawals from the river or main distribution network)**

89. Another complexity to the water saving and upstream-downstream links is related to the high leaching requirements and the practice to use significant amounts of water during the non-vegetation (winter) period for leaching. This practice has significant costs (energy for pumping and evaporative water losses) but is needed to keep the lands productive. At the basin-scale, this practice has both negative as well as positive side effects. An obvious negative impact is that return flows are saline, which cause the rivers to become more saline, affecting downstream use. In some areas, a positive effect is a consequence of the water being effectively stored in the soil during winter and released during spring: increasing water availability during spring period for downstream users. Consulted experts indicated that the residence time of water in the soil can be about 3-5 months. This effect compensates to some extent the lack of a coordinated flow regime. probably does not outweigh the negative consequences of the lack of a coordinated (upstream-downstream) and conjunctive (surface and groundwater) water use in the region.

90. In summary, a system-wide approach is needed for irrigation investment planning in the region, that assesses how the investments can lead to real water savings, generating local benefits by reducing energy consumption and land productivity, and off-site benefits in terms of water availability and quality. Such a system-wide approach should be supported with a thorough assessment of these upstream-downstream linkages, and considering both the quantitative as well as the quality dimension of water resources. Also, the economic productivity dimension can be helpful to assess how for example a shift to higher (money) value crops, or a more efficient (e.g. less use of energy) irrigation regime can raise economic water productivity under a similar water use regime.

## 4.6 Sustainability considerations

### 4.6.1 Water quality trends

91. The Aral Sea basin faces several important challenges related to water quality. Over the last decades, there has been an increasing trend in salinization and pollution problems (Bekturganov et al., 2016). About 50% of the irrigated area in the Aral Sea basin are experiencing increased salinization,

affecting agricultural productivity. Bekturganov et al. (2016) provides a review of pollution issues in Central Asia and conclude that agricultural pollution is especially affecting downstream areas of Amu Darya and Syr Darya and that more than 70% of the area within the Amu Darya Basin in Uzbekistan has water quality levels that is dangerous to health and can lead to high algae and chlorophyll concentrations in surface water bodies (see . Copper, zinc, and chromium concentrations exceed maximum permissible concentration and more than 10% of the waters have been reported to suffer from extreme pollution levels (Bekturganov et al., 2016). Consulted experts have also highlighted that livestock is an increasing source of pollution for the region.

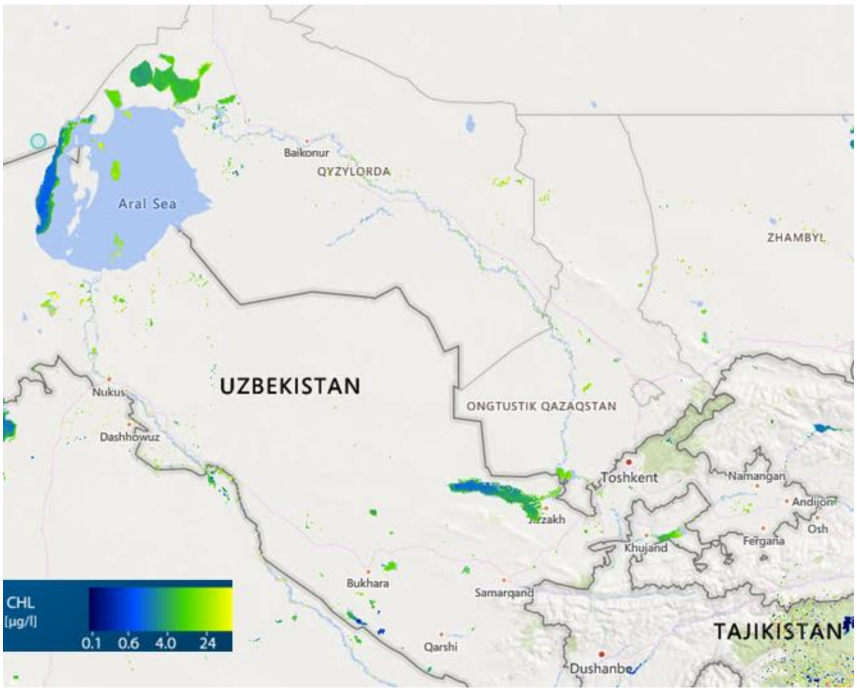


**Figure 22. Chlorophyll concentration in surface water bodies for part of the region, including Aral Sea, based on remote sensing-data (source: HTEP SDG Portal http://46.16.74.57/)**

92. The above issues urge for investments in the region in sanitation infrastructure and improved agricultural practices. Water supply and sanitation infrastructure is highly deteriorated, mostly constructed in 1970s. About 40-50% needs complete rehabilitation, in some cities even 70%.

93. So far, there is no regional dialogue on water quality issues. Some countries have openly shared concerns and their willingness to do so, but no concrete steps were taken so far. Consulted experts have also stressed the importance of building capacity and investments in water quality monitoring equipment, as currently hardly any water quality monitoring is done in the main river branches (OECD, 2020). Also harmonization of international standards would be highly beneficial on water quality monitoring.

94. The risk for water quality deterioration depends on the location in the river basin and on the local biophysical and socio-economic conditions. Regional differences are mapped in Figure 23 based on a global dataset on water quality provided by WWF, showing that the downstream areas of the Aral Sea basin suffer most from water quality issues (sink) although part of the pollutants come from upstream sources (irrigated areas, cities and industry in upstream regions).

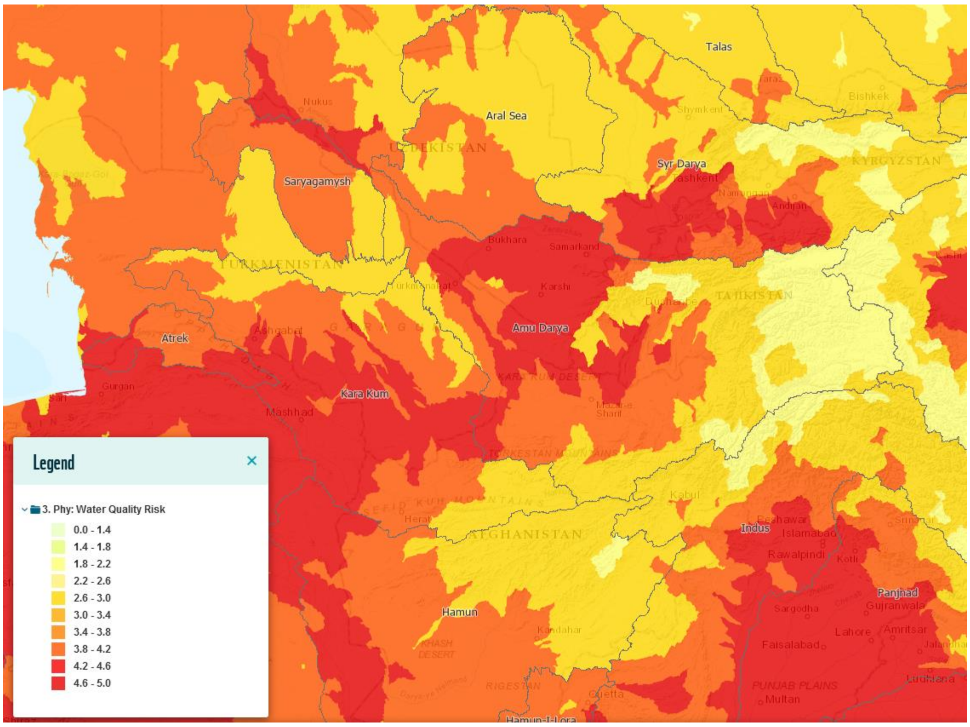



**Figure 23. Water quality risk for the region (source: WWF Water Risk Filter)**

### 4.6.2 Aquatic ecosystems

95. The water-related impacts of climate change are even more acute when environmental water requirements are taken into account. Natural ecosystems are often the residual claimant of water resources, receiving only as much water as is left over from agricultural and other human uses and much of this is polluted.

96. The Aral Sea, being at the tail end of the system, is receiving each year less water, which has caused the water body to loose the majority of its original surface, as can be assessed using remote sensing imagery (Figure 24). The environmental requirements for the Aral Sea have been estimated to be 12 km3/year (OECD, 2020). However, over the last decades, this volume has not been reached in most of the years as can be clearly observed from Figure 24, and there has been a decreasing trend in flow reaching the Aral Sea.

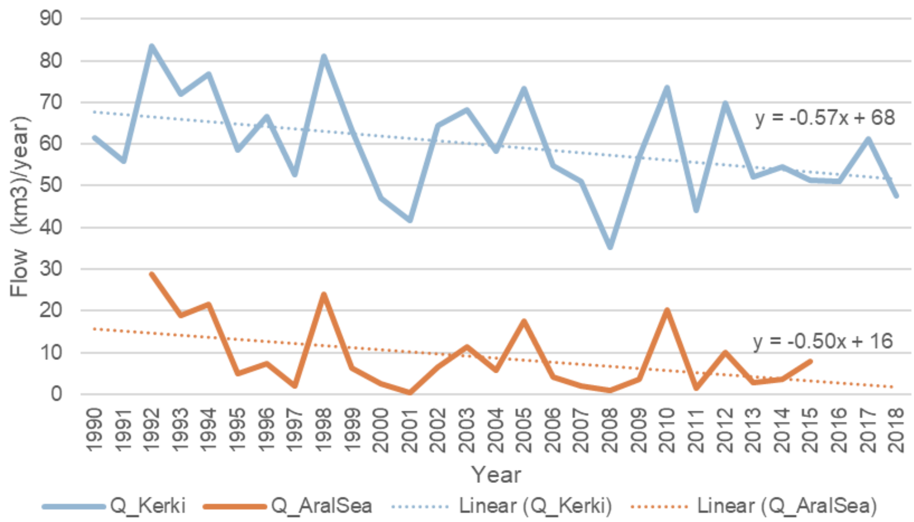



**Figure 24. Annual flow volumes for two points in the Amu Darya river (Kerki and inflow into Aral Sea)**

97. Assessing environmental water requirements is challenging, in any river basin, simply because of the lack of sufficient data. Each waterway has a distinctive flow regime with a similarly unique set of floodplain, riparian, and instream ecosystems that often vary considerably along the length of a waterway. For defining environmental water requirements, these functions need to be studied in a pristine condition: either in reality or by means of simulations. Thus, this is a complex and arduous process that includes modelling, experimental data collection, and habitat surveys along the length of the waterway. For Central Asia, to the author´s knowledge, very little work has been done on this subject so far (e.g. Schlüter et al., 2013).

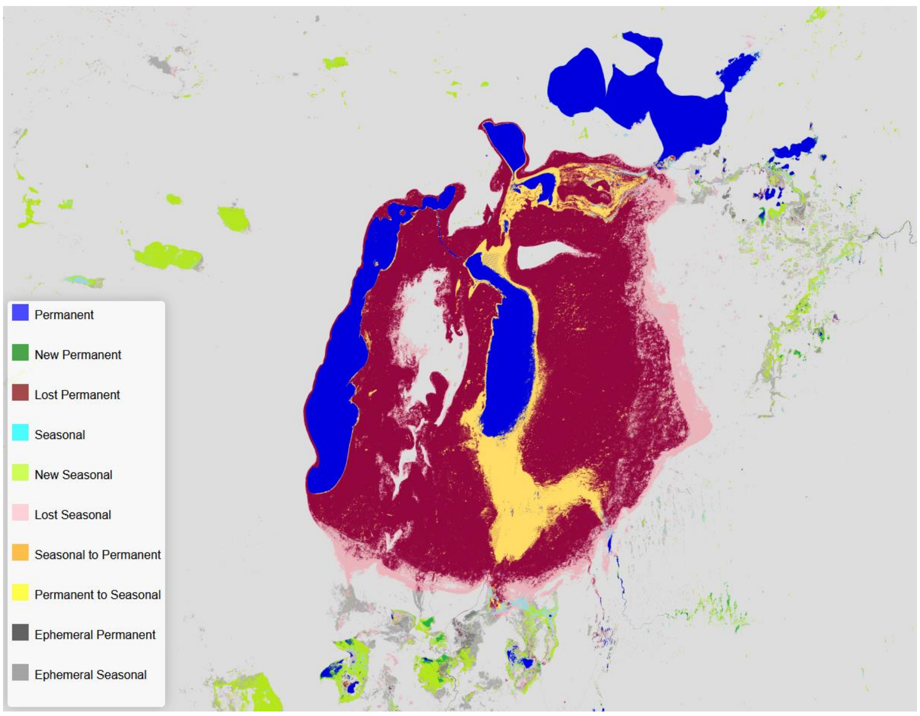



**Figure 25. Lost permanent water surface for the Aral Sea (reddish colours) and seasonal surface (yellow), based on remote sensing imagery. Source: https://spatialagent.org)**

### 4.6.3 Land degradation

98. Central Asia is subject to different land degradation processes, the major ones being (i) changes in vegetation state and biodiversity, (ii) wind and water erosion, (iii) desertification caused by human activities such as construction and quarrying and (iv) salinization of irrigated lands. Central Asia is a good example of how past achievements in terms of agricultural developments have been accompanied by negative side-effects or externalities on land and water resources, both on-farm and downstream. Part of this degradation has been caused by poorly adapted production systems, and part by deliberate choices or trade-offs to increase agricultural output at the expense of environmental degradation.

99. FAO has now adopted a new framework to assess land degradation in which its definition goes beyond simply soil erosion or loss of soil fertility, extending it to the deterioration of a balanced ecosystem and the loss of the services that ecosystem provides. Land degradation thus needs to be considered in an integrated way, taking into account all ecosystem goods and services – biophysical as well as socio-economic.

100. Tackling 'land degradation' thus goes beyond reducing soil erosion, risk for sedimentation of infrastructure (some reservoirs in the region are already out-of-service due to siltation) or water pollution costs. It includes the inter-related components of the ecosystem where several trade-offs exist between related to loss of biodiversity, for example, matched against improvements in economic services under intensive farming.

101. Increasingly, nature-based solutions are promoted worldwide to tackle some of the challenges related to land degradation. Some projects are currently active in the region that integrate and implement nature-based solutions (e.g. World Bank has commissioned a study in Kyrgyzstan on landscape restoration opportunities that assesses cost-benefits of nature-based solutions[1]).

102. Several other initiatives are active in the region around land degradation. Currently, several projects are going on in the Aral Sea Bed financed with GEF money, and based on the "land degradation neutrality" concept and aim at regreening the Aral Sea. The CAREC Institute and the Chinese Academy of Sciences are active in this field and organized recently an international symposium on "Ecological Restoration and Management of the Aral Sea" (Nov-2020). The UNCCD is currently commissioning a study to start in 2021, named "on Climate Change, Land Degradation and Migration nexus in Central Asia". The World Bank started to design a regional RESILAND CA+ Program (Uzbekistan, Kazakhstan, Tajikistan) building on the results of the Climate Adaptation and Mitigation Program for Aral Sea Basin project.

### 4.6.4 Carbon emissions

103. Central Asia is home to less than 1% of the global population and produces less than 0.5% of the world's GDP. Nonetheless, the region generates more than 120 million tons of carbon emissions or approximately 1.2% of the global carbon emissions (Wang et al., 2020). This fact clearly reflects the high energy and carbon intensity in Central Asia.

104. The water resources sector is responsible for part of the CO2 emissions of the region. Especially in the downstream region, many irrigation systems rely on water that is pumped from the river, significant lifting of water thus energy intensive. As per today mainly sourced from fossil fuels, thus responsible for CO2 emissions. Improved practices and irrigation technologies, if complemented with good governance and control of water allocations, can lead to water savings, energy savings, and thus also CO2 emission saving. Work by IWMI for example has shown that this can lead to emission savings of up to 30%

[1] More info: https://www.futurewater.eu/projects/baseline-assessment-for-the-identification-of-landscape-restoration-options-in-kyrgyzstan/

(Djumaboev et al., 2019). Also consulted experts have highlighted the potential of solar irrigation pumps (for Central Asia likely mostly on-grid rather than off-grid, given the scale of pumping) and floating solar for reservoirs that are used for hydropower, having the advantage that these locations are already connected to the grid. Floating solar can have also notable side-benefits in water savings by reducing evaporation if implemented at scale, and lead to improvements in water quality for shallow smaller (for example on-farm) reservoirs.

# 5 Implications for the CAREC Water Pillar

## 5.1 Climate change risks and regional water security

105. As the previous chapters have laid out, and as is widely acknowledged: (i) the water resources system in Central Asia is highly complex and interlinked, and (ii) a changing climate will have many effects, but some will be more dominant than others, (iii) there are many uncertainties around the projections (climate, economic growth, etc) that determine the trend and regional water resources situation over the next 30 years.

106. The key climate risks for the individual countries are well summarized in the respective National Communications to the UNFCCC. Rather than only listing and describing the key climate risks for the countries, this section attempts to bring together the key climate risks into one table, describing qualitatively their impacts on (i) water towers upstream, versus (ii) water uses downstream. As in Chapter 3, the water towers refer here to the high-mountain regions upstream of the larger storage reservoirs (mainly but not exclusively Tajikistan and Kyrgyzstan), while the water use-regions downstream correspond to the region downstream of these reservoirs where most water uses occur (mainly but not exclusively Uzbekistan, Turkmenistan and Kazakhstan). Figure 4 shows a map with the geographical split between both regions. Table 4 provides this overview of expected climate change effects on water resources across the two regions.

**Table 4. Overview of climate change effects and their impact on upstream and downstream water resources, horizon 2050**

| Expected future changes | Expected dominant impact on water tower region upstream | Expected dominant impact on water users downstream |
|---|---|---|
| Changes in precipitation amounts and extremes | ⊖⊕ Either positive or negative, depending on the region and climate scenario. Risks of extreme precipitation will likely be mitigated largely by reservoirs | ⊖○Even under a climate scenario with increasing rainfall amounts, increased extremes will likely have negative consequences |
| Increased evaporative demand due to increased temperatures | ⊖Reduced runoff and thus reduced flows and inflows into reservoirs | ⊖Less water supplies from upstream and increased water demands |
| Lower snowfall fraction | ⊖Reduced runoff | ⊖Reduced river flows and seasonality shifts in tributaries without reservoirs |
| Permafrost degradation | ⊖Infrastructure stability and permafrost-related hazards (landslides, etc) | ○None |
| Glacier shrinkage | ⊕Up to around 2050 likely more water from melt<br>⊖After 2050 significant decrease, especially for Amu Darya | ⊕Up to 2050 likely more water from melt<br>⊖Increased inter-annual flow variability, so more severe droughts |
| Increased cropping cycles due to increased temperatures | ⊕Up to 2050 likely more water from melt | ⊖Increased demands<br>⊕Increased agricultural production |

| Expected future changes | Expected dominant impact on water tower region upstream | Expected dominant impact on water users downstream |
|---|---|---|
| Earlier cropping cycles due to increased temperatures | ○ None | ⊕ Better in phase with peak flows and less potential for conflicting interests due to hydropower |
| Increased irrigated areas | ○ None | ⊖ Increased demands and pressure on environmental uses |
| Water use-driven changes | | |
| Increased hydropower installed capacity | ⊕ More regulation of resources and thus flexibility in hydropower generation | ⊕ If connected, more competitive energy market for water pumping |
| Increased connectivity and energy trading | ⊕ More potential buyers of hydropower | ⊕ Potential for better alignment: the peak energy demand of buyers coincide with downstream irrigation demands |
| Construction of new large storage dams upstream (e.g. Rogun) | ⊕ More regulation capacity<br>⊕ More hydropower generation capacity | ⊕ More capacity to buffer low-flow periods<br>○ Minor impact from increased evaporation<br>⊖ During first years of filling, foregone benefits as water is lost into dead storage<br>⊖ Environmental impacts |
| Changes in reservoir operations due to increased hydropower demands | ⊕ Complementarity with other renewables (grid stability) | ⊖ Increased diurnal variability of flows |
| Rehabilitation and modernization of irrigation schemes | ○ None | Depending on current and with-project water accounts:<br>⊖ Reduced recoverable return-flows<br>⊕ more water left in the river for other uses (e.g. environmental), if adequately regulated and controlled<br>⊕ Improved water quality and reduced energy |
| Increase in solar for energy provision of pumping of main distribution network | ○ None | ⊕ Reduced carbon emissions, less dependence on external energy |
| Floating solar on reservoirs | ○ None | ⊕ Reduced carbon emissions; more flexibility if combined with hydropower, so potentially reducing risk for high diurnal flow fluctations; reduced evaporation and improved |

| Expected future changes | Expected dominant impact on water tower region upstream | Expected dominant impact on water users downstream |
|---|---|---|
| | | water quality depending on site conditions |
| Increase in on-farm pumping for irrigation | ○None | ⊖Risk for overexploitation of groundwater and water quality risks<br>⊕More flexibility to mitigate water shortages |

## 5.2 Focus areas for climate adaptation

### 5.2.1 Current status of adaptation planning

107. All countries of the region are parties to the United Nations Framework Convention on Climate Change (UNFCCC) and were requested to publish their Intended Nationally Determined Contributions (INDC) in 2013. When the countries formally joined the Paris Agreement and look forward to implementation of these climate actions – the INDC is converted into a Nationally Determined Contribution (NDC). Some of the NDCs make mention of interventions in the water and energy sector (see Table 5 for an overview).

108. As can be observed from Table 6, the NDCs are rather generic. Some countries are updating their NDCs which are expected to be available by the end of 2021 and to include more details on water-related issues. More sector-specific and concrete information for some countries is available in strategies and documents that follow from the National Adaptation Plan (NAP) process that was promoted by the Conference of Parties (COP-17) to UNFCCC, to enhance country-led planning and preparedness for climate change adaptation (CCA) in the medium and long-term. The objectives of the NAPs are to reduce vulnerability to the impacts of climate change and to facilitate the integration of adaptation into all levels of development planning. The status across the region of the NAP process is as follows:

- In 2020, UNDP started through a specific project to support **Kazakhstan** in updating its NDCs by incorporating climate change adaptation policies
- The Government of the **Kyrgyz Republic** adopted in 2019 the Green Economy Development Program for 2019-2023. In 2020, GCF approved its support through UNDP for NAP preparation.
- **Tajikistan** adopted in 2019 the "2030 National Strategy for Adaptation to Climate Change of the Republic of Tajikistan". In 2020, it resubmitted a proposal to GCF for developing and implementing the NAP.
- In 2019, **Turkmenistan** has adopted a new edition of the National Climate Change Strategy. Adaptation priority measures include (a) identification of priority strategic actions for adaptation at the level of economic sectors and (b) enhancement of national legislation on climate change: Law “On Climate Change”
- **Uzbekistan** has started in 2020 with developing the NAP with support from UNDP and funded by GCF.

**Table 5. Overview of water resources and renewable-related adaptation interventions in NDCs**

| Kazakhstan | Kyrgyz Republic | Tajikistan | Turkmenistan | Uzbekistan |
|---|---|---|---|---|
| **Proposed interventions related to increased renewables** | | | | |
| General targets are defined including promotion of use of renewable energy sources | General targets are defined but no climate mitigation measures related to renewables are specified | Only a general statement that "the main efforts of the PPCR in the Republic of Tajikistan are focused on hydraulic power industry, development of other renewable sources of energy" | General targets are defined including increasing the share of renewable energy sources | - Mentions that "..it is planned to bring up the share of solar energy in the total energy balance of the country to 6% by 2030."<br>- Proposes "intensive construction of large solar photovoltaic power plants; creation of biogas plants; scaling up of wind power generation;"<br>- Besides several other energy efficiency interventions are proposed |
| **Proposed adaptation interventions in the water sector** | | | | |
| No adaptation goals are defined | Overall adaptation goals are mentioned but no specific adaptation measures are identified | Several adaptation focus areas are mentioned, including glacier and water resources-related ones. No specific interventions are proposed. | Mentions that National Action Plan on Adaptation will include adaptation measures on water. Construction of the "Golden Age" Lake is put forward as an adaptation measure. | - A list of interventions for agriculture, social sector, Aral Sea-related, ecosystems, and strategic infrastructure is included. As an example: "Improvement of the climate resilience of the agriculture through diversification of food crops production pattern; conservation of germplasm and indigenous plant species and agricultural crops resistant to droughts, pests and diseases; development of biotechnologies and breeding new crop varieties adopted to conditions of changing climate. |

109. GCF (Green Climate Fund) is funding currently several climate adaptation projects in the region. None of them are directly in the water sector, although some of them have a link with water-related risks. Table 6 provides an overview of the projects that are currently under implementation in the region (source: GCF website).

**Table 6. Active GCF-funded projects in the region with a relation to water resources (source: GCF website)**

| Status / Date Approved / Estimated Completion | Project objective |
|---|---|
| Under implementation / 30 Jun 2016 / 02 Jun 2026 | **Scaling up the Climate Adaptation and Mitigation Program for Aral Sea Basin (CAMP4ASB)** by providing support to adaptation activities in **Tajikistan** and **Uzbekistan**. Providing grants to the most vulnerable communities for climate resilient measures in priority areas, including to the poorest populations residing in risk-prone areas, and marginalized groups such as women. |
| Under implementation / 06 Apr 2017 / 11 Apr 2023 | **Protecting Tajikstan's hydropower from climate risks.** Best international practices will be adopted, and Tajik hydropower operators trained, to assess and manage climate risks. Institutional capacities and structures for effective transboundary management of hydropower cascades will be developed, within the context of transboundary cooperation and agreements in the region. Finally, climate resilience measures will be integrated into the hydropower facility, including structural rehabilitation to optimize its resilience to climate change. |
| Under implementation / 01 Mar 2018 / 07 Sep 2024 | **Building the adaptive capacity of vulnerable communities in Tajikistan affected by food insecurity.** This initiative will introduce adaption measures to address climate change effects leading to declines in agricultural yields, increases in food prices and reduced agricultural wages. It will focus on the most vulnerable and food insecure communities in the Rasht valley, Khatlon and Gorno-Badakhshan Autonomous Region (GBAO) regions. It will include an integrated approach to provide climate information services, capacity building, sustainable water management and resilient agriculture and forestry. |
| Under implementation / 20 Oct 2018 / 01 Sep 2022 | Climate services and diversification of climate sensitive livelihoods to empower food insecure and vulnerable communities in Kyrgyzstan. The project will support vulnerable rural communities to better manage climate risks, including increased weather variability. This will include enhanced provision of climate services, local-level adaptation planning, small-scale climate risk reduction infrastructure, and livelihood diversification, which strengthens the overall economic resilience of communities in the face of greater risks to the agricultural sector. |

110. The Pilot Program for Climate Resilience (PPCR), a multilateral target program of the Strategic Climate Fund (SCF), is providing some assistance in the region on integrating adaptation to climate change into the development planning process, including on water resources aspects. Some bilateral discussion has taken place within this context on lessons learned on climate finance. There is however an opportunity to strengthen those discussions, in order to exchange experiences and bring more climate finance to the region on projects that can generate regional benefits.

### 5.2.2 Proposed focus areas

111. Based on the presented analysis and extensive stakeholder consultations in the region, focus areas for climate adaptation where the CAREC Water Pillar could potentially serve a useful regional role are listed here below. Activities are a mix of (i) Knowledge and capacity building activities, and (ii) Technical assistance and preparation of investment projects. For some areas regional cooperation is specifically required or desirable – these are highlighted.

**1. Assessment of opportunities arising from the energy-water-nexus**

- *Summary*: Considering the regional energy-water nexus in any effort towards improving the regional water resources situation is critical, as was confirmed by many of the consultations done for the scoping study. Climate change brings additional challenges but also opportunities to improve this situation. Nowadays, an actual dialogue between key actors in the water sector and energy sector is practically non-existent, at least at the regional level, while there are clearly joint opportunities and shared benefits. These benefits need to be quantified to look for incentives to involve the energy sector in the existing water resources dialogue platforms.
- A good basis for these nexus discussions can be obtained from joint water-energy modelling that use the outputs from the regional energy master plan and grid stability studies. Key questions that need to be resolved are related to the potential of hydropower to regulate better seasonal variability creating joint benefits, potential impacts of increased diurnal variability in flows due to more intensive hydropower operations, including possible mitigation options. From this regional bottom-up modelling assessment, potential projects can be identified, for example for infrastructure and monitoring equipment that enables downstream water intakes to be more responsive to upstream releases and increased variability.
- *Type*: technical assistance, including identification of potential projects
- Regional cooperation: required

**2. Integrated regional water information systems including predictive modelling capacity**

- *Summary:* Currently, several countries have started working on improved national water information systems (for example Uzbekistan Water Cadastre and National Water Information System of Tajikistan). This is a good basis for the creation of a regional information system, building to the extent possible on existing regional initiatives (ICWC-SIC and a few donor-supported systems, see Annex 2). The Aral Sea Basin Program-4 (ASBP-4) identified two potential projects in this direction.
- This regional initiative can introduce SMART technology, remote sensing, cloud-based dashboards and other state-of-the-art technology. Lessons can be taken from other regional bodies, such as MRC and OMVS. Remote sensing-technology can be used to assess water consumption, flows and reservoir storage. To expand the predictive capacity even further, water resources modelling can be employed to: (i) generate information that cannot be accurately captured by ground-based and satellite-based measurements, for example on melting rates, and (ii) generate water resources forecasts, for example on reservoir inflow, or water demands downstream.
- In summary, this regional information system is fed with ground-based, remote sensing-based and model-based data, generates up-to-date information on water resources status, but also provides forecasts weeks or months ahead. Part of this information could be publicly available, other information could be available to water resources stakeholders in the region only. On an annual basis, regional water accounts can be built based on this information (i.e. harmonized synthesis of the water resources situation of the previous year) to serve as a basis for continuous improvement and discussions on water resources management.
- Besides data on water quantity, improvement and harmonization across the region on water quality monitoring is also highly needed and could be integrated in this project or implemented as a separate project. The Aral Sea Basin Program-4 includes a very similar proposal on water quality and international standards. In any case, an important first step is to look for ways to create a regional dialogue on water quality issues.
- Recent work has shown the scope for improving seasonal forecasts for the two river basins (Gerlitz et al., 2020), suggesting that with more advanced methods the forecasts can be done earlier in the

season than the ones used currently by SIC-ICWC, which would allow better anticipation and preparation for drought events.

- *Type:* technical assistance. Potentially this could be implemented first in a smaller transboundary watershed, as a pilot.
- Regional cooperation: required

**3. Improved planning of water allocations**

- Already in a few water resources systems in Central Asia, projects are being prepared to update water resources planning and allocations to a modern climate resilient approach, integrating aspects of sustainability, water savings, water quality and economic principles (for example the Climate Adaptive Water Resources Management in the Aral Sea Basin Project funded by ADB). There is an opportunity to upscale or transfer these experiences to other areas.
- To improve water allocation planning, the governments and water authorities need to promote improved measurements of diversions and consumptive use of water (ground-based and remote sensing-based). Regulatory instruments as caps on water diversions and flow requirements need to be reinforced. The Aral Sea Basin Program-4 (ASBP-4) has identified several potential projects that align with this proposal. Obviously, alignment with the national and/or regional information system developments is needed. CAREC can be involved in building capacity on different levels to improve measurement and control of diversions and consumptive water use, with special emphasis on environmental uses and climate change aspects.
- Part of this project can be to share lessons from the region (and neighbouring countries) and develop guidance on modernizing irrigation systems (main system and on-farm), including water saving and reuse technologies, ensuring real water savings (see resp. section in this report) and improvements in water quality and reclamation state of irrigated lands (aligned with proposed projects in Aral Sea Basin Program-4).
- This activity could include the development of updated design standards and irrigation norms, considering climate change impacts (“Introduce best practices to clarify crop irrigation regimes” in Aral Sea Basin Program-4).
- *Type*: technical assistance
- Regional cooperation: desirable

**4. Pilot project on climate resilient conjunctive surface and groundwater use**

- *Summary*: A pilot project, possibly in two distinct areas, for demonstrating and testing the potential conjunctive surface and groundwater management and various water saving technologies, considering an integrated system-approach to the water balance (consumptive, return flows - see section on real water savings) and pollution and salinity management. Possibly relation with trends in livestock could be integrated as well.
- *Type*: pilot implementation project with regional dissemination and knowledge transfer activities
- *Regional cooperation*: implementation in two countries, including knowledge exchange activities

**5. Reducing climate change vulnerability by boosting regional water productivity**

- *Summary*: Only recently, water productivity or irrigation systems can be assessed reliably from remote sensing-based information. There is a huge opportunity for Central Asia to generate information on water productivity, on a regular basis and accessible to stakeholders in the region.

This can be used to identify opportunities for closing the yield-gap, monitoring and evaluation of interventions and continuous improvement of water allocations where possible.

- This data on physical water productivity can be extended with economic data to generate useful information on the economic water productivity and serve as a basis for policy making. As a start, a regional working group could be established on this topic.
- *Type*: technical assistance
- Regional cooperation: desirable

**6. <u>Knowledge exchange on climate adaptation and green finance</u>**

- *Summary*: Several countries are involved in preparing National Adaptation Plans or similar. Typically, this is not in hands of Water Ministry, but hydromet and ministries of emergencies. Also, currently there is no exchange on experiences across the region. CAREC could promote dialogue between different institutions and countries. As a start, a regional working group could be established.
- This TA could include the exploration of scope for expanding green finance opportunities for climate mitigation and resilience in the water sector in Central Asia, including potential for renewable energy for water infrastructure
- This aligns with proposed projects in the Aral Sea Basin Program -4: Development of a regional action plan for adaptation to climate change and And Dissemination of best climate-adapted agricultural practices
- *Type*: technical assistance
- Regional cooperation: required

**7. <u>Climate resilient water resources infrastructure and services</u>**

- *Summary*: Currently many water resources infrastructure in the region are not adapted to current climate conditions due to lack of maintenance, and even less to more extreme future climate conditions. Several investment projects in the region already include climate resilience into design, however, there is so far a lack of knowledge sharing and guidance on these aspects, building on experiences from various countries, donors, and organizations and expertise within the region itself. Thus, there is an opportunity to

112. formulate guidance on building climate resilience into design and operationl management of water services (irrigation, water supply, sanitation and wastewater treatment)

113. prioritize critical water resources infrastructure for investment projects, for example those with increased risk for dam failures (currently several dam structures face imminent risks in the region). Several proposed projects in the Aral Sea Basin Program -4 align with this proposal, related to safety of dams and impact of siltation.

114. and managing the increasing variability of supply, including drought management planning. (TA – could lead to infrastructure investment).

- *Type*: TA with project identification/preparation
- Regional cooperation: desired

**8. Climate-proof regional agreements**

- *Summary:* The analysis on regional agreements and policies for this scoping study have revealed that the data and evidence these agreements were grounded on are outdated and need to be updated with the current realities, specifically climate change. CAREC could promote a study on how climate impacts will influence regional agreements and propose (adaptation) pathways to reach a sustainable 2050 scenario – as the climate resilient scenario framed earlier in this report.
- Type: TA
- Regional cooperation: required

**9. Nature-based solutions for the water sector**

- *Summary*: Nature-based Solutions (NbS) use or mimic natural processes to protect and suatainbly manage natural or modified ecosystems. In the water sector, NbS can improve wastewater treatment, drinking water provision, water storage, groundwater recharge, reduce flood risks in riverine areas and urban context, and agriculture.
- For example, NbS can improve water availability (e.g., soil moisture retention, groundwater recharge), improve water quality (e.g., natural and constructed wetlands, riparian buffer strips), reduce risks associated with flood-related disasters (e.g., floodplain restoration, green roofs).
- A sub-section of Nature-based Solutions are Natural Climate Solutions that are focused specifically on climate mitigation and adaptation – these require specific attention given the regional climate risks.
- *Type*: TA
- Regional cooperation: desirable

**10. Expanding capacity on climate and cryosphere impact modelling**

- *Summary*: there are still important knowledge gaps in terms of the magnitude and the spatio-temporal patterns of changes in the Central Asian high-mountain regions, and thus the impacts on the water resources – specifically for the next few decades, up to 2050. These gaps are related principally to the scarcity of reliable and appropriate data sets of these regions and a consequent lack of full understanding of the impacts on the hydrological response changes in snow and glacier dynamics in the headwater catchments. The Aral Sea Basin Program-4 proposes a similar project specific to the glaciers within the territory of Tajikistan.
- *Type*: TA
- Regional cooperation: desirable

## 5.3 Focus areas for climate mitigation

115. Climate mitigation is not part of this study but given the high carbon emissions related to water resources management in the downstream regions, a few opportunities are shortly highlighted here that can reduce carbon emissions of the sector, and in which CAREC could potentially be involved.

**11. Transition from energy-fueled pumps towards renewable energy**

- *Summary*: projects introducing or promoting wider adoption of solar irrigation pumps, possibly linking with public-private partnership initiatives and other contexts where off-grid solutions may be preferred
- *Type*: projects

- Regional cooperation: desirable

12. **Floating solar on reservoirs**

- *Summary*: projects introducing floating solar on reservoirs. For hydropower dams, assess how this technology can be used to manage and mitigate diurnal variability of reservoir releases. Floating solar on in downstream regions to meet energy demands for pumping in the distribution networks.
- *Type*: projects
- Regional cooperation: desirable

# 6 References


Abdullaev, I., Molden, D., 2004. Spatial and temporal variability of water productivity in the Syr Darya Basin, central Asia. Water Resour. Res. 40. https://doi.org/10.1029/2003WR002364

Aus der Beek, T., Voß, F., Flörke, M., 2011. Modelling the impact of global change on the hydrological system of the aral sea basin. Phys. Chem. Earth 36, 684–695. https://doi.org/10.1016/j.pce.2011.03.004

Bekturganov, Z., Tussupova, K., Berndtsson, R., Sharapatova, N., Aryngazin, K., Zhanasova, M., 2016. Water Related Health Problems in Central Asia—A Review. Water 8, 219. https://doi.org/10.3390/w8060219

Bhend, J., Whetton, P., 2013. Consistency of simulated and observed regional changes in temperature, sea level pressure and precipitation. Clim. Change 118, 799–810. https://doi.org/10.1007/s10584-012-0691-2

Bolch, T., Peters, J., Yegorov, A., Pradhan, B., Buchroithner, M., Blagoveshchensky, V., 2011. Identification of potentially dangerous glacial lakes in the northern Tien Shan. Nat. Hazards 59, 1691–1714. https://doi.org/10.1007/s11069-011-9860-2

Chen, H., Liu, H., Chen, X., Qiao, Y., 2020. Analysis on impacts of hydro-climatic changes and human activities on available water changes in Central Asia. Sci. Total Environ. 737, 139779. https://doi.org/10.1016/j.scitotenv.2020.139779

Daiyrov, M., Narama, C., Kääb, A., Tadono, T., 2020. Formation and Outburst of the Toguz-Bulak Glacial Lake in the Northern Teskey Range, Tien Shan, Kyrgyzstan. Geosciences 10, 468. https://doi.org/10.3390/geosciences10110468

Djumaboev, K., Yuldashev, T., Holmatov, B., Gafurov, Z., 2019. Assessing Water Use, Energy Use And Carbon Emissions In Lift- Irrigated Areas: A Case Study From Karshi Steppe In Uzbekistan. Irrig. Drain. https://doi.org/10.1002/ird.2321

FAO, 2011. The state of the world´s land and water resources for food and agriculture.

Gao, Y., Chen, F., Lettenmaier, D.P., Xu, J., Xiao, L., Li, X., 2018. Does elevation-dependent warming hold true above 5000 m elevation? Lessons from the Tibetan Plateau. npj Clim. Atmos. Sci. 1, 19. https://doi.org/10.1038/s41612-018-0030-z

Gerlitz, L., Vorogushyn, S., Gafurov, A., 2020. Climate informed seasonal forecast of water availability in Central Asia: State-of-the-art and decision making context. Water Secur. 10, 100061. https://doi.org/10.1016/j.wasec.2020.100061

Gerveni, M., Fernandes Tomon Avelino, A., Dall'erba, S., 2020. Drivers of Water Use in the Agricultural Sector of the European Union 27. Environ. Sci. Technol. 54, 9191–9199. https://doi.org/10.1021/acs.est.9b06662

Hunink, J.E., Droogers, P., 2011. Climate Change Impact Assessment on Crop Production in Uzbekistan. FutureWater Report 106.

Huss, M., Hock, R., 2018. Global-scale hydrological response to future glacier mass loss. Nat. Clim. Chang. 8, 135–140. https://doi.org/10.1038/s41558-017-0049-x

Immerzeel, W.W., Lutz, A.F., Droogers, P., 2012. Climate Change Impacts on the Upstream Water Resources of the Amu and Syr Darya River Basins. Wageningen, The Netherlands.

IWMI, 2020. Water Productivity Study for the Climate Adaptive Water Resources Management In The Aral Sea Basin Project 1–29.

Jia, Y., Li, Z., Jin, S., Xu, C., Deng, H., Zhang, M., 2020. Runoff Changes from Urumqi Glacier No. 1 over the Past 60 Years, Eastern Tianshan, Central Asia. Water 12, 1286. https://doi.org/10.3390/w12051286

Khanal, S., Lutz, A.F., Kraaijenbrink, P.D.A., van den Hurk, B., Yao, T., Immerzeel, W.W., 2021. Variable 21st Century Climate Change Response for Rivers in High Mountain Asia at Seasonal to Decadal Time Scales. Water Resour. Res. 57, 1–26. https://doi.org/10.1029/2020wr029266

Li, Z., Chen, Y., Li, Y., Wang, Y., 2020. Declining snowfall fraction in the alpine regions, Central Asia. Sci. Rep. 10, 1–12. https://doi.org/10.1038/s41598-020-60303-z

Liu, Y., Wang, P., Ruan, H., Wang, T., Yu, J., Cheng, Y., Kulmatov, R., 2020. Sustainable use of groundwater resources in the transboundary aquifers of the five central Asian countries: Challenges and perspectives. Water (Switzerland) 12. https://doi.org/10.3390/W12082101

Lutz, A., Droogers, P., Immerzeel, W.W., 2012. Climate Change Impact and Adaptation on the Water Resources in the Amu Darya and Syr Darya River Basins. Report FutureWater: 110.

Mannig, B., Pollinger, F., Gafurov, A., Vorogushyn, S., Unger-Shayesteh, K., 2018. Impacts of Climate Change in Central Asia, Encyclopedia of the Anthropocene. Elsevier Inc. https://doi.org/10.1016/b978-0-12-809665-9.09751-2

Marzeion, B., Jarosch, A.H., Hofer, M., 2012. Past and future sea-level change from the surface mass balance of glaciers. Cryosphere 6, 1295–1322. https://doi.org/10.5194/tc-6-1295-2012

OECD, 2020. Overview of the use and management of water resources in Central Asia. A discussion document.

Opstal, J. Van, Droogers, P., Kaune, A., Steduto, P., Perry, C., 2020. Guidance on Realizing Real Water Savings with Crop Water Productivity Interventions Guidance on Realizing Real Water Savings with Crop. FutureWater Report 198.

Perry, C., Pasquale, S., Fawzi, K., 2017. Does improved irrigation technology save water? A review of the evidence. https://doi.org/10.13140/RG.2.2.35540.81280

Reyer, C.P.O., Otto, I.M., Adams, S., Albrecht, T., Baarsch, F., Cartsburg, M., Coumou, D., Eden, A., Ludi, E., Marcus, R., Mengel, M., Mosello, B., Robinson, A., Schleussner, C.F., Serdeczny, O., Stagl, J., 2017. Climate change impacts in Central Asia and their implications for development. Reg. Environ. Chang. 17, 1639–1650. https://doi.org/10.1007/s10113-015-0893-z

Schlüter, M., Khasankhanova, G., Talskikh, V., Taryannikova, R., Agaltseva, N., Joldasova, I., Ibragimov, R., Abdullaev, U., 2013. Enhancing resilience to water flow uncertainty by integrating environmental flows into water management in the Amudarya River, Central Asia. Glob. Planet. Change 110, 114–129. https://doi.org/10.1016/j.gloplacha.2013.05.007

Straatsma, M., Droogers, P., Hunink, J., Berendrecht, W., Buitink, J., Buytaert, W., Karssenberg, D., Schmitz, O., Sutanudjaja, E.H., van Beek, L.P.H., Vitolo, C., Bierkens, M.F.P., 2020. Global to regional scale evaluation of adaptation measures to reduce the future water gap. Environ. Model. Softw. 124, 104578. https://doi.org/10.1016/j.envsoft.2019.104578

Sutton, W., Srivastava, J., Neumann, J., Strz, K.M., Boehlert, B.B., 2013. Reducing the Vulnerability of Uzbekistans's Agricultural Systems to Climate Change, World Bank Publications. https://doi.org/10.1596/978-1-4648-0043-6

Unger-Shayesteh, K., Vorogushyn, S., Farinotti, D., Gafurov, A., Duethmann, D., Mandychev, A., Merz, B., 2013. What do we know about past changes in the water cycle of Central Asian headwaters? A review. Glob. Planet. Change 110, 4–25. https://doi.org/10.1016/j.gloplacha.2013.02.004

Wada, Y., Flörke, M., Hanasaki, N., Eisner, S., Fischer, G., Tramberend, S., Satoh, Y., Van Vliet, M.T.H., Yillia, P., Ringler, C., Burek, P., Wiberg, D., 2016. Modeling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches. Geosci. Model Dev. 9, 175–222. https://doi.org/10.5194/gmd-9-175-2016

Wang, F., Wang, C., Chen, J., Li, Z., Li, L., 2020. Examining the determinants of energy-related carbon emissions in Central Asia: country-level LMDI and EKC analysis during different phases. Environ. Dev. Sustain. 22, 7743–7769. https://doi.org/10.1007/s10668-019-00545-8

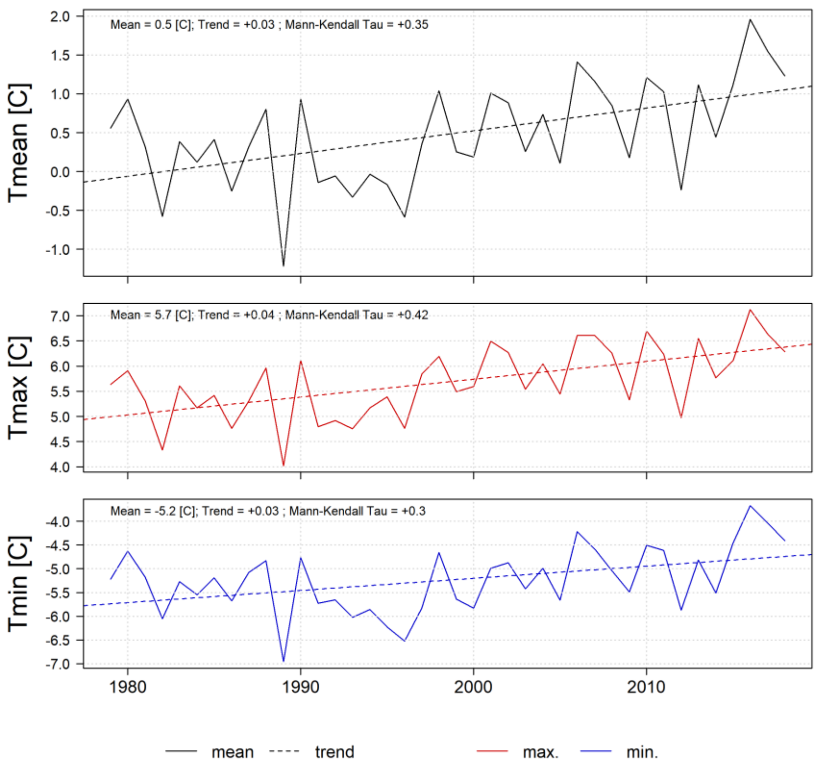
World Bank, 2017. The Costs of Irrigation Inefficiency in Tajikistan, Report No: ACS21200. https://doi.org/10.1596/26031

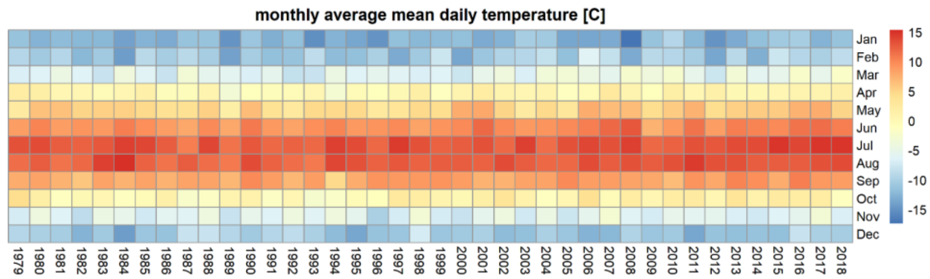
Zech, C., Schöne, T., Illigner, J., Stolarczuk, N., Queißer, T., Köppl, M., Thoss, H., Zubovich, A., Sharshebaev, A., Zakhidov, K., Toshpulatov, K., Tillayev, Y., Olimov, S., Paiman, Z., Unger-Shayesteh, K., Gafurov, A., Moldobekov, B., 2020. Hydrometeorological Data from a Remotely Operated Multi-Parameter Station network in Central Asia. Earth Syst. Sci. Data Discuss. 1–25. https://doi.org/10.5194/essd-2020-176

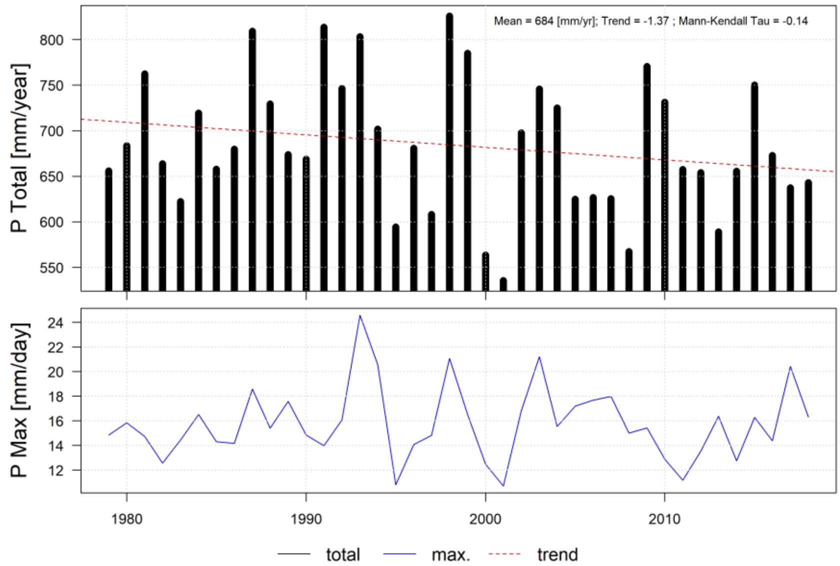
Zheng, G., Bao, A., Li, J., Zhang, G., Xie, H., Guo, H., Jiang, L., Chen, T., Chang, C., Chen, W., 2019. Sustained growth of high mountain lakes in the headwaters of the Syr Darya River, Central Asia. Glob. Planet. Change 176, 84–99. https://doi.org/10.1016/j.gloplacha.2019.03.004

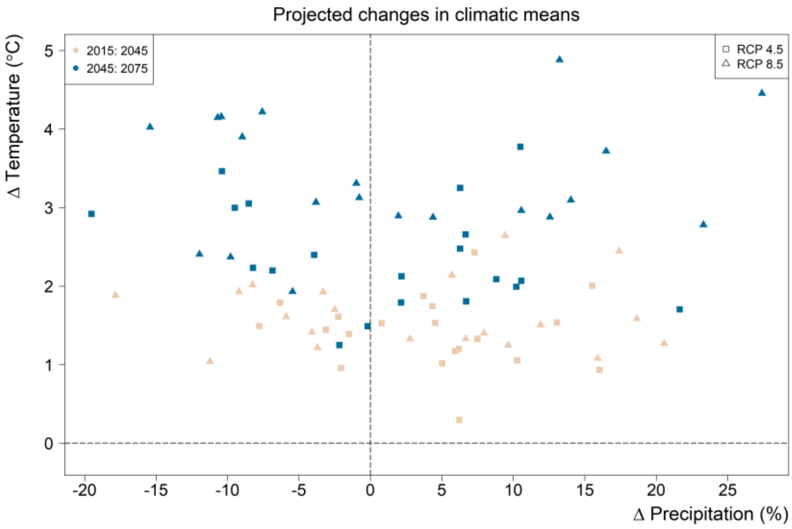
# Annex 1 – Climate trends and climate model projections

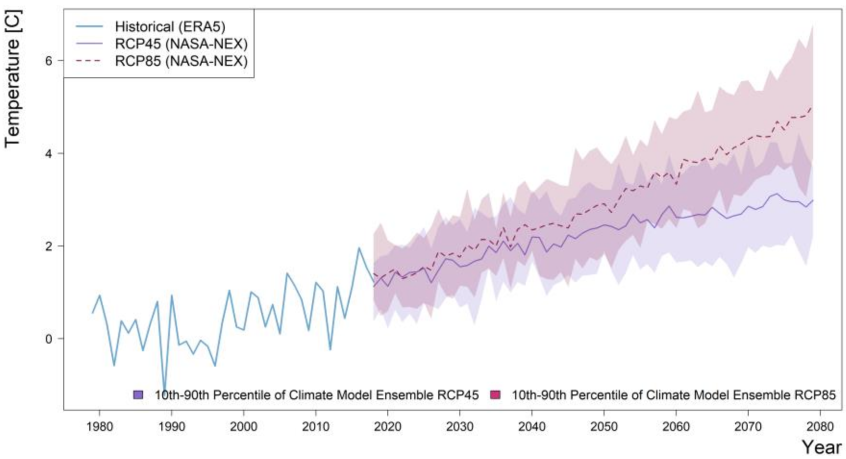
1. **Amu Darya upstream**

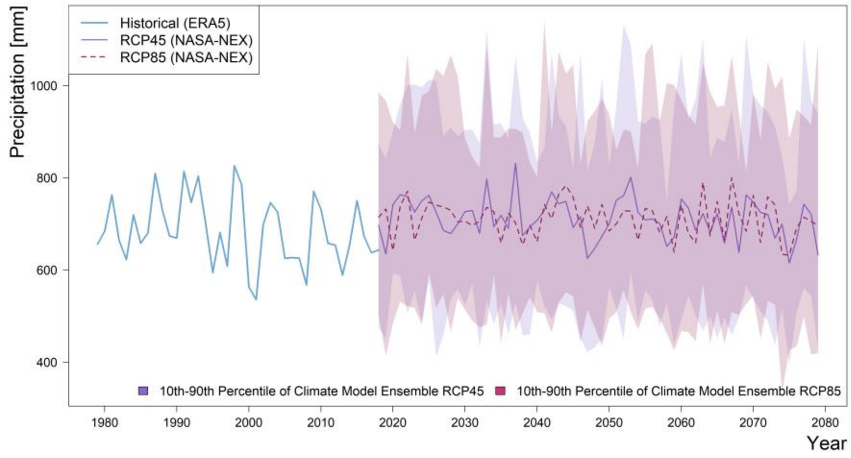


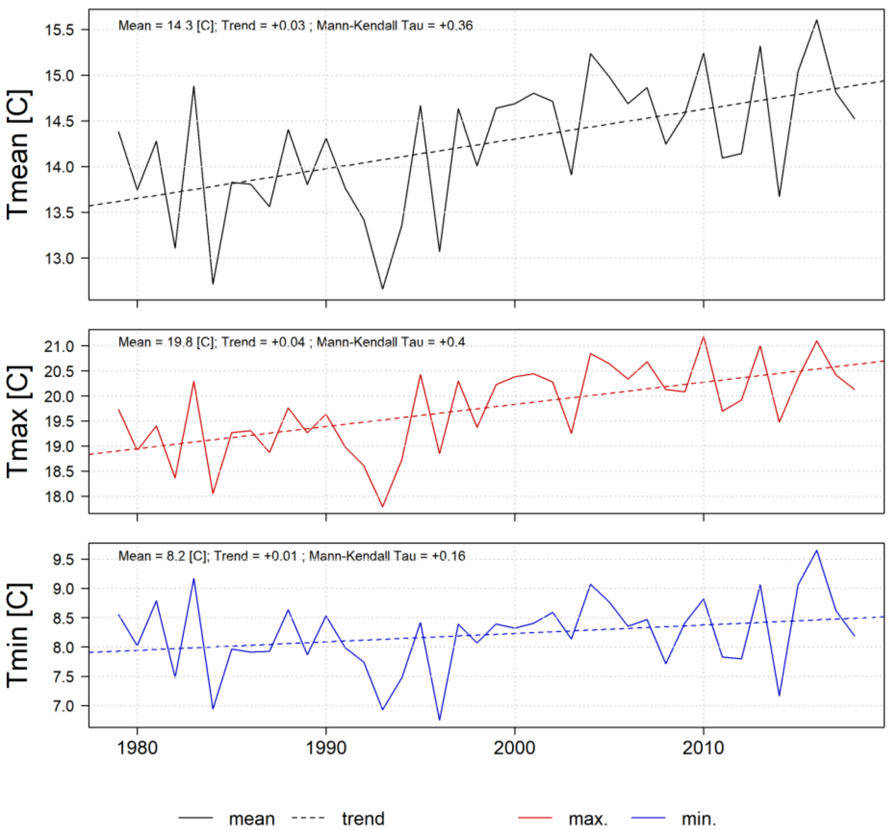

Mean = 684 [mm/yr]; Trend = -1.37 ; Mann-Kendall Tau = -0.14
P Total [mm/year]
P Max [mm/day]
total
max.
trend

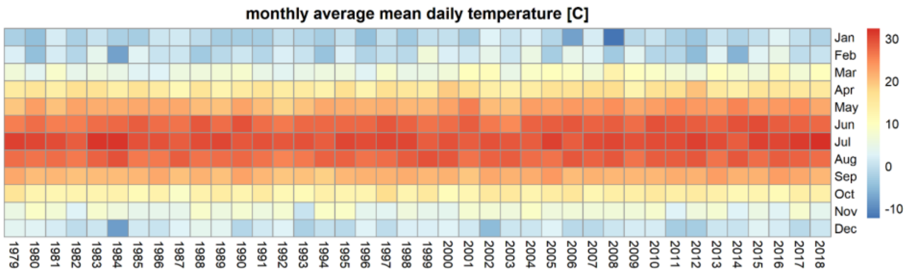

Projected changes in climatic means
2015: 2045
2045: 2075
RCP 4.5
RCP 8.5
Δ Temperature (°C)
Δ Precipitation (%)

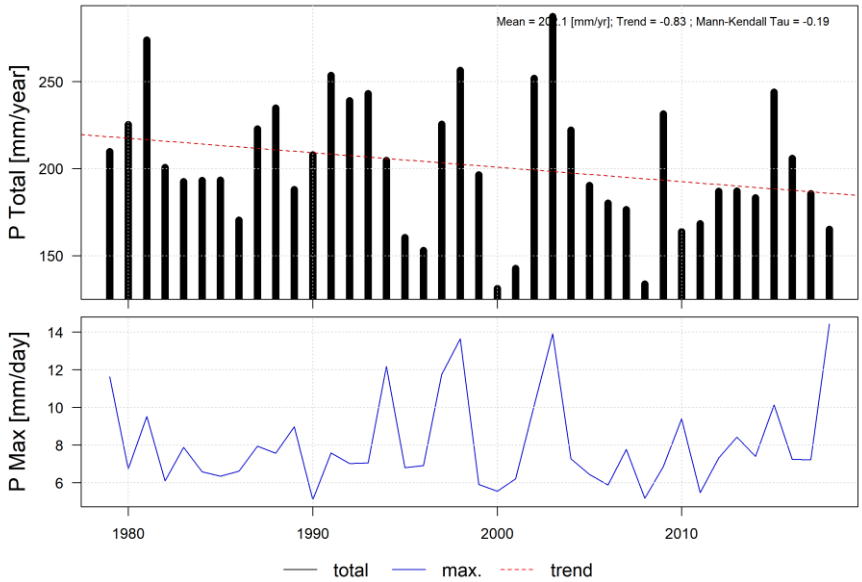

Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Temperature [C]
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
Year

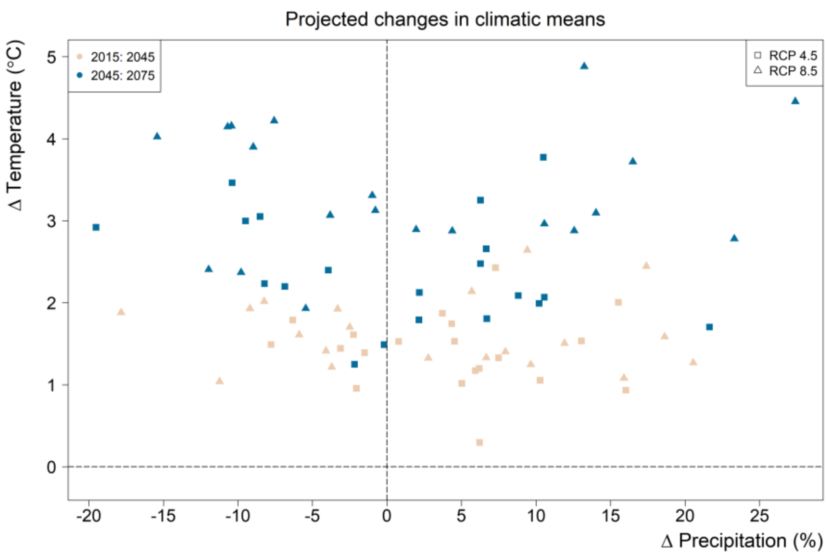


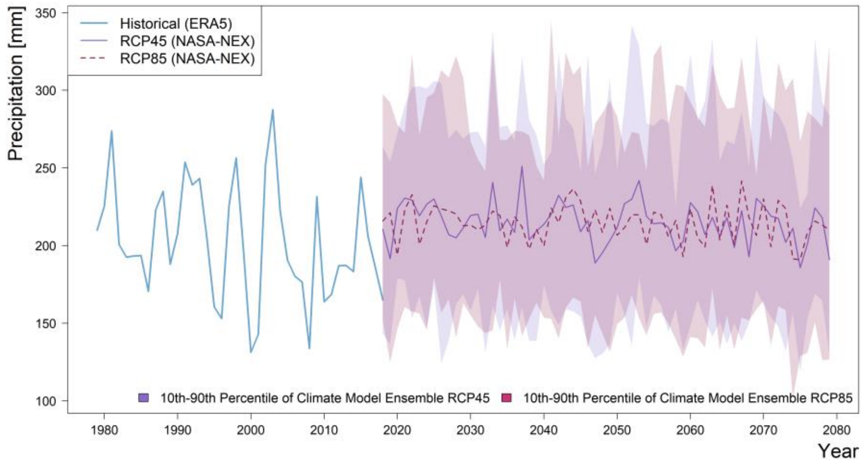

## 2. Amu Darya downstream

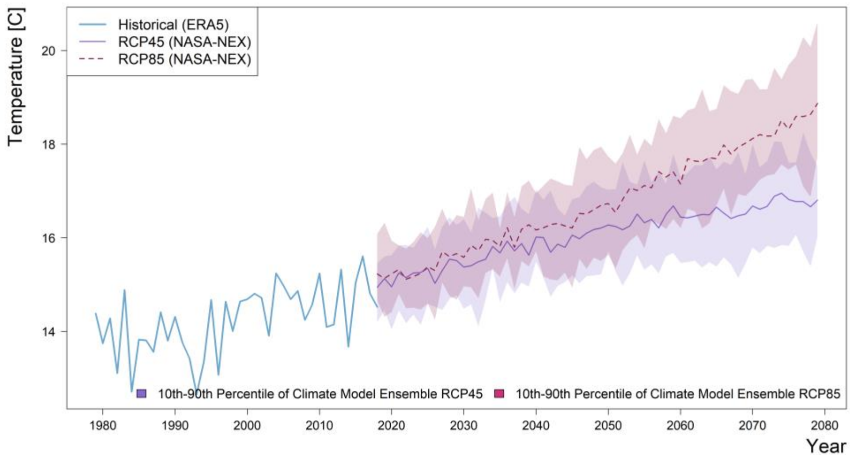



monthly average mean daily temperature [C]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
30
20
10
0
-10

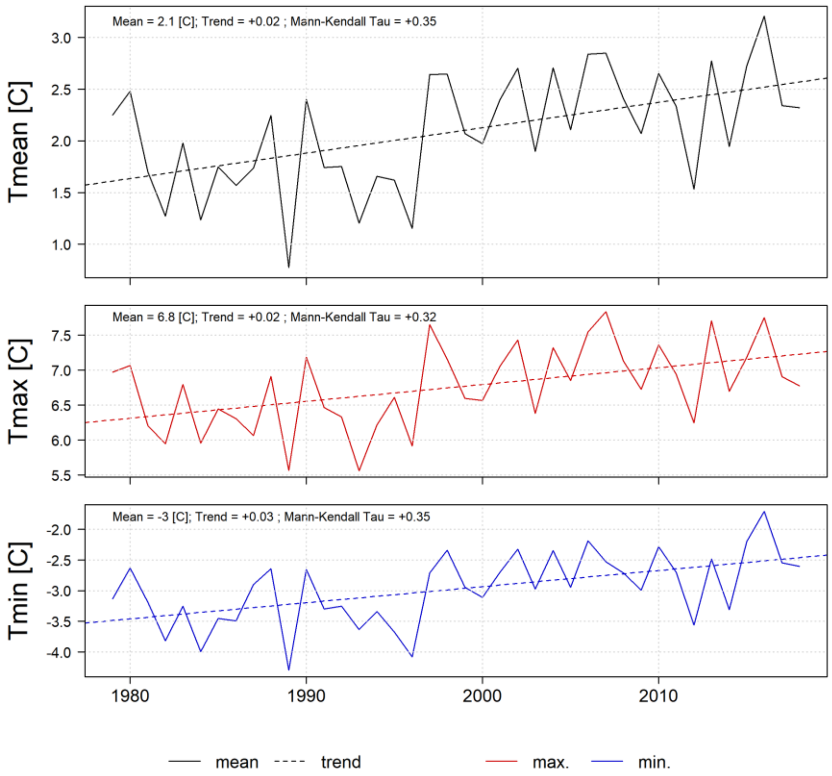

Mean = 20?.1 [mm/yr]; Trend = -0.83 ; Mann-Kendall Tau = -0.19
P Total [mm/year]
P Max [mm/day]
1980
1990
2000
2010
total
max.
trend

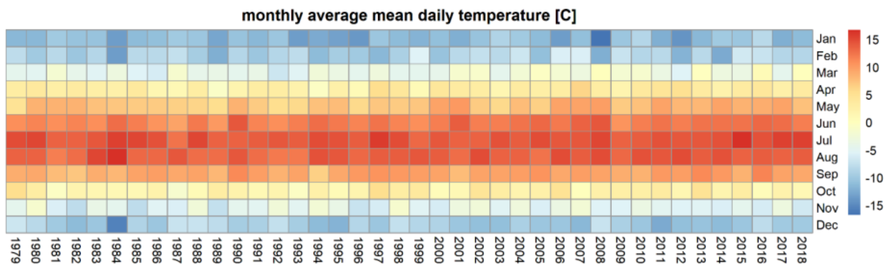

Projected changes in climatic means
2015: 2045
2045: 2075
RCP 4.5
RCP 8.5
Δ Temperature (°C)
Δ Precipitation (%)

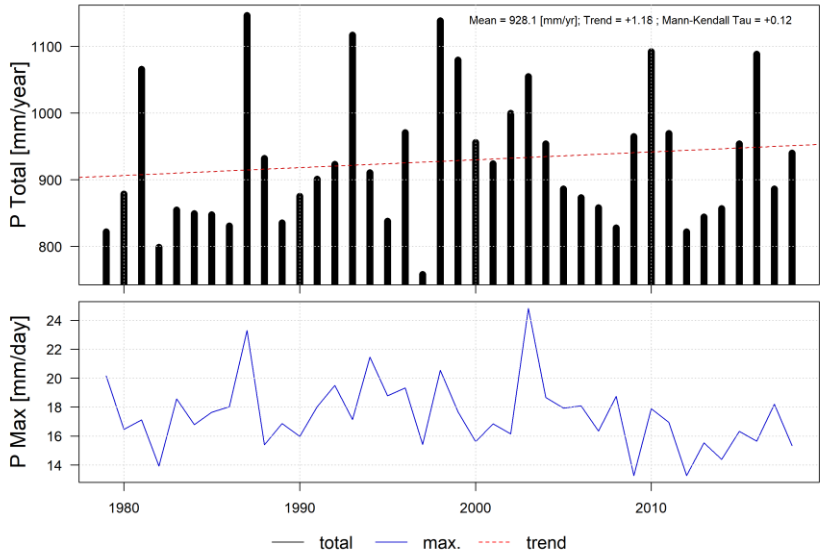

Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Precipitation [mm]
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
Year

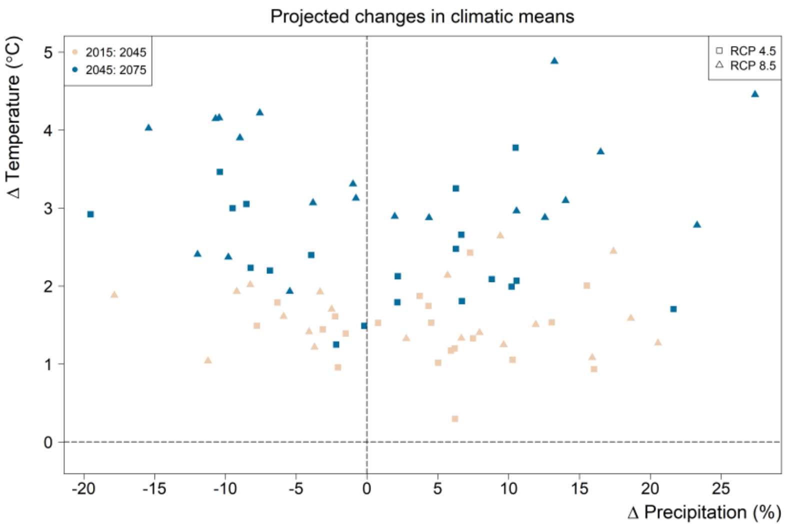

Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Temperature [C]
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
Year

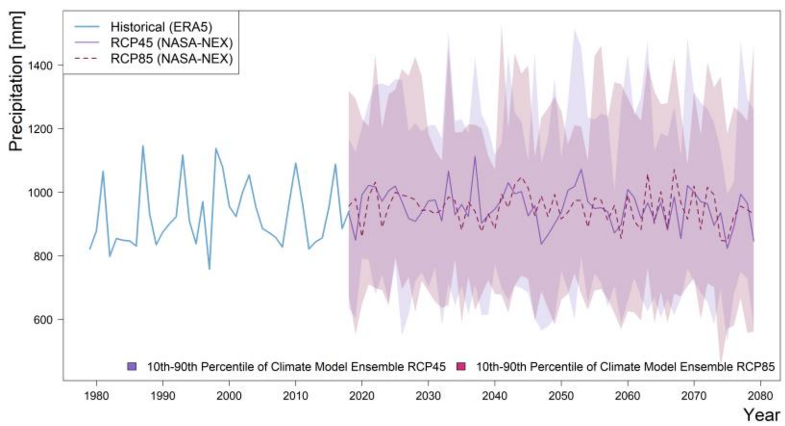
## 3. Syr Darya upstream

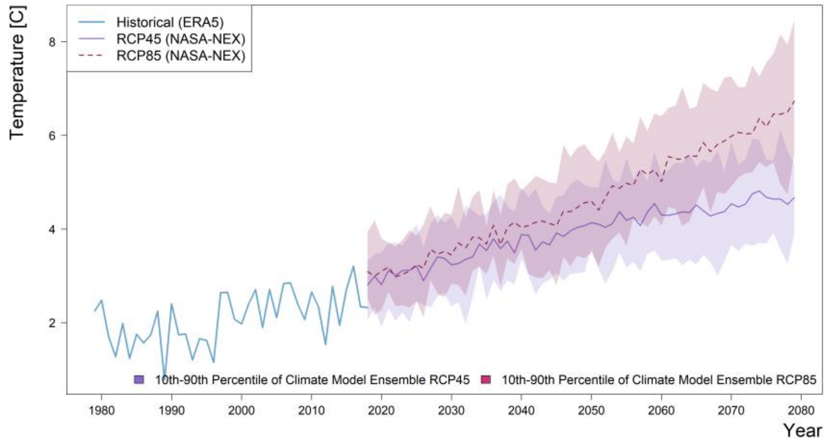


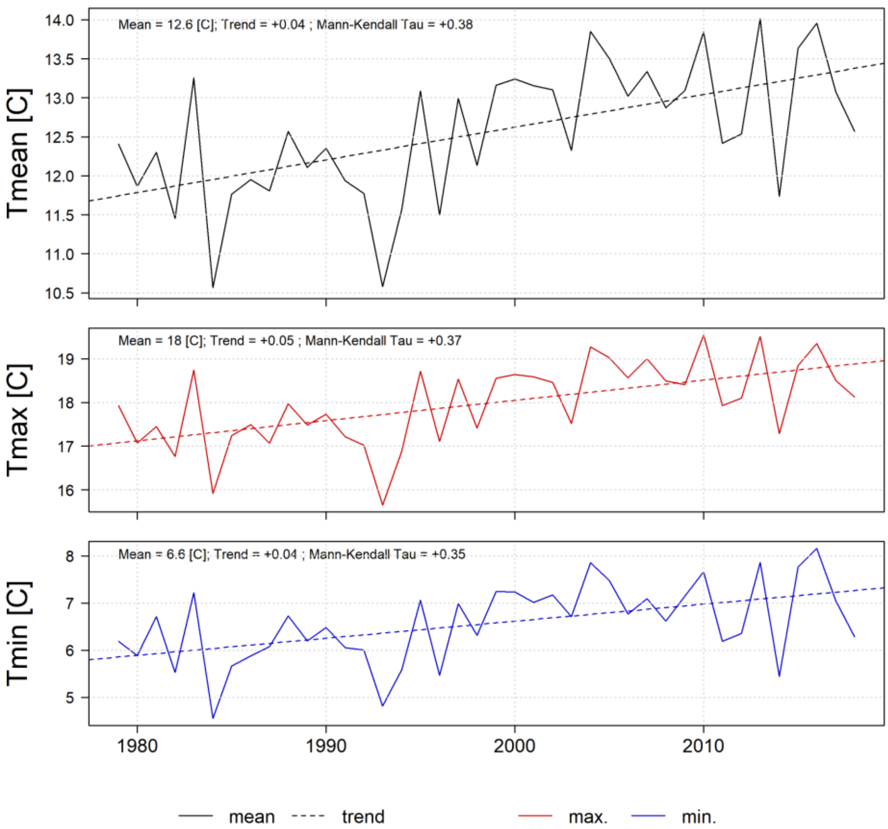

Mean = 928.1 [mm/yr]; Trend = +1.18 ; Mann-Kendall Tau = +0.12
P Total [mm/year]
P Max [mm/day]
total
max.
trend

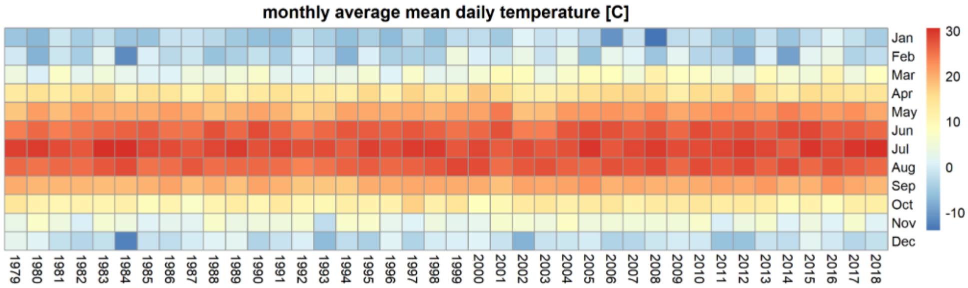

Projected changes in climatic means
2015: 2045
2045: 2075
RCP 4.5
RCP 8.5
Δ Temperature (°C)
Δ Precipitation (%)

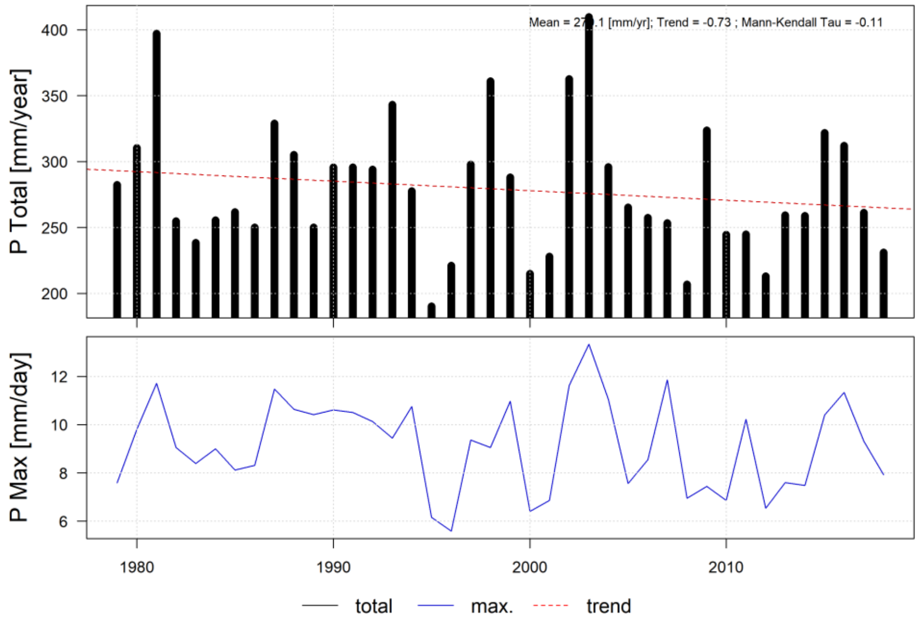

Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Precipitation [mm]
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
Year

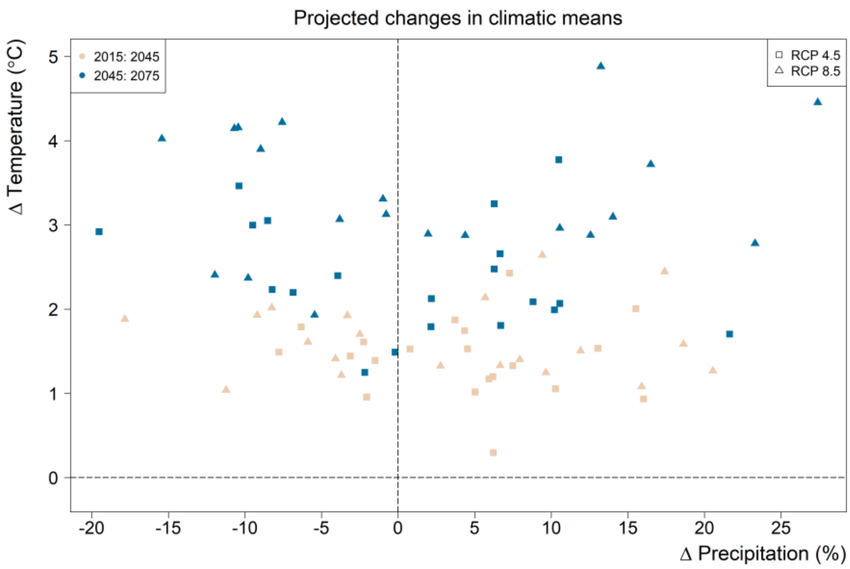


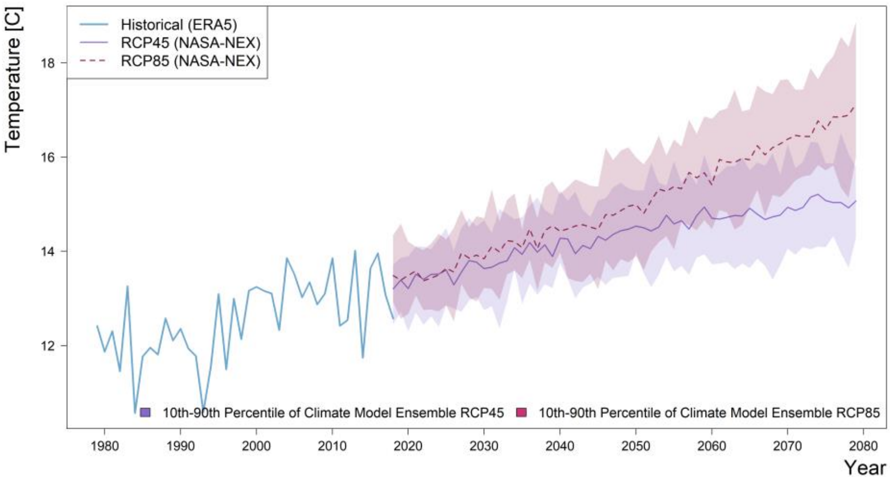

## 4. Syr Darya downstream

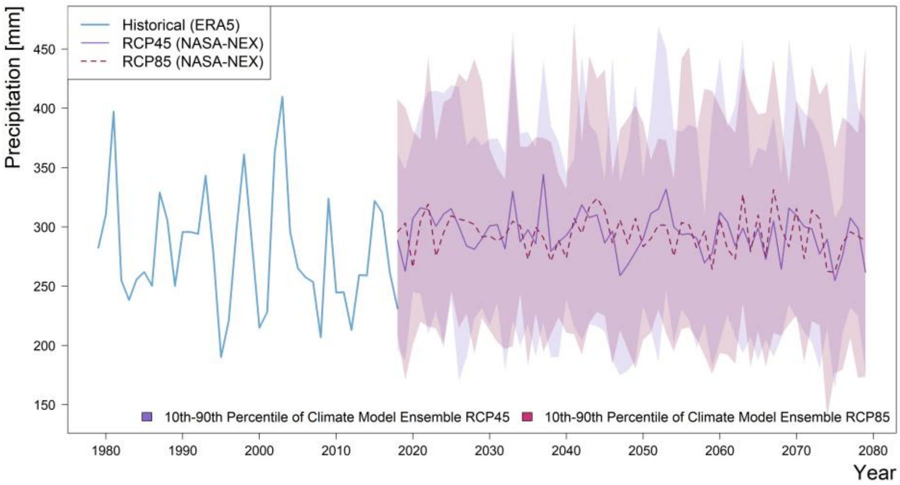



monthly average mean daily temperature [C]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
30
20
10
0
-10


P Total [mm/year]
P Max [mm/day]
Trend = -0.73 ; Mann-Kendall Tau = -0.11
total
max.
trend


Projected changes in climatic means
2015: 2045
2045: 2075
RCP 4.5
RCP 8.5
Δ Temperature (°C)
Δ Precipitation (%)


Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Temperature [C]
18
16
14
12
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
Year


Historical (ERA5)
RCP45 (NASA-NEX)
RCP85 (NASA-NEX)
Precipitation [mm]
450
400
350
300
250
200
150
10th-90th Percentile of Climate Model Ensemble RCP45
10th-90th Percentile of Climate Model Ensemble RCP85
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
Year

# Annex 2 – Existing regional water resources information systems

116. Based on the information received so far, a short description of operational water resources information systems in the region is given, which are considered most relevant. Additional portals are linked on the so-called Central Asia Water and Energy Data portal.[1]

1. **Overview of Hydrometeorological Services in Central Asia**

117. *Summary*: The Global Facility for Disaster Reduction and Recovery (GFDRR) supported a study on modernizing National Hydrometeorological Services in Kyrgyz Republic, Tajikistan, and Turkmenistan. The project delivered a portal with a comprehensive overview of these services and related infrastructure across the region

118. *Link*: https://geowb.maps.arcgis.com/apps/Cascade/index.html?appid=ac03200e7b834193938d95c38b58a15b

2. **Central Asia Climate Information Platform (CACIP)**

119. *Summary*: The Central Asia Climate Information Platform (CACIP) helps stakeholders to access, analyze, and visualize public-domain climate and climate-relevant data to support improved awareness, assessment, and decision support. The information platform provides comprehensive and up-to-date relevant data and information, linking with high-quality datasets from global, regional, and local sources, and analytical tools and interfaces for the visualization and interpretation of data and information.

120. CACIP is developed within the framework of the World Bank funded initiative Climate Adaptation and Mitigation Program for Aral Sea Basin (CAMP4ASB) led by the Central Asia Regional Environmental Center (CAREC) in collaboration with the International Center for Agricultural Research in the Dry Areas (ICARDA) and its partners.

121. *Link*: https://centralasiaclimateportal.org

3. **Water Use Efficiency Monitor in Central Asia**

122. *Summary*: the online information tool WUEMoCA intends to provide agriculturally relevant information (e.g., land use, productivity, and water use efficiency) to regional users to support planning in water management institutions and organizations. The tool was developed within the CAWa by the project partner University of Würzburg in collaboration with the Scientific Information Center of the Interstate Coordination Water Commission of Central Asia (SIC ICWC) and the Regional Environmental Center for Central Asia (CAREC).

123. The platform is currently not operational. It has data from 2000-2018 on land use, crop productivity, and water usage, water demand and water availability per crop type, the crop yield, and the

124. productivity per unit water consumed (water productivity) for the entire region, and for different administrative unit levels

125. Link: http://wuemoca.net/app/

[1] https://spatialagent.org/CentralAsia/

4. **<u>Regional Information System on Water and Land Resources in the Aral Sea Basin (CAWater-IS)</u>**

126. *Summary*: The Regional Information System on Water and Land Resources in the Aral Sea Basin (CAWater-IS) is currently the most used resource of information by the relevant authorities of the region. River basin authorities (BVOs) provide data on actual water withdrawals every ten days, which are posted online on the CAWater-Info portal (sections are password-protected) at http://cawater-info.net/amudarya/ and http://cawater-info.net/syrdarya/. The national authorized agencies have open access to data on this portal. SIC ICWC analyses ten-day data and publishes it online on the CAWater-Info portal at http://cawater-info.net/analysis/. Access is restricted but open for the ICWC members.

127. Syntheses of analytics on ten-day water withdrawals, flows, releases and reservoir storage are posted on the ICWC website (free public access) at http://www.icwc-aral.uz/reports_amudarya_ru.htm and http://www.icwc-aral.uz/reports_syrdarya_ru.htm . This information is also published in the weekly bulletin "Water management, irrigation and ecology of the countries of Eastern Europe, the Caucasus and Central Asia" (http://cawater-info.net/news/ ) and disseminated via email (mailing list includes 67 addressees)

128. After growing / non-growing season, SIC ICWC analyzes data on water use. The report is published in the ICWC bulletin and posted online <u>http://sic.icwc-aral.uz/reports.htm</u>.

129. *Link*: <u>http://cawater-info.net/carewib/index_e.htm</u>

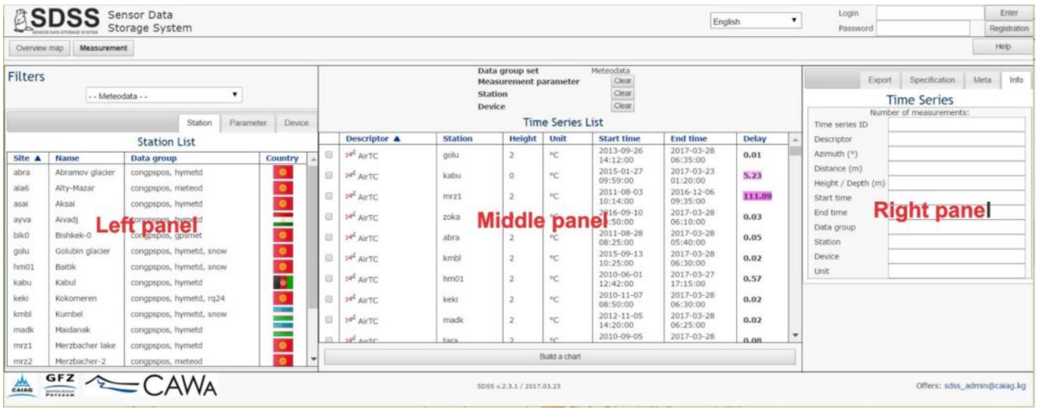
5. **<u>Sensor Data Storage System (SDSS)</u>**

130. *Summary:* Within the CAWa project, a network of automatic monitoring stations has been installed especially in remote areas and in higher altitudes providing continuously meteorological and hydrological parameters. In addition to the ground-based monitoring network, water levels of selected lakes and reservoirs are provided by the satellite-based radar altimetry. All data are stored in an open-access data base to support sustainable decisions in water management and to contribute to a scientific cooperation between the involved transnational agencies (Zech et al., 2020).

131. GFZ and CAIAG, in cooperation with national hydrometeorological agencies, research institutes, and universities, are offering unrestricted access to the hydrometeorological data of ROMPS and other stations. Remote sensing technologies, such as radar altimetry, allow assisting the water monitoring in urban as well as remote areas without the help of a local monitoring infrastructure.

132. Comparison between the remote sensing-based estimates for water stored in Toktogul reservoir, and ground-based data, show a very high correlation (R2 = 0.96), demonstrating the high potential that these information sources have to fill the gap in water-related data across the region

133. *Link: <u>http://sdss.caiag.kg/sdss/</u>*



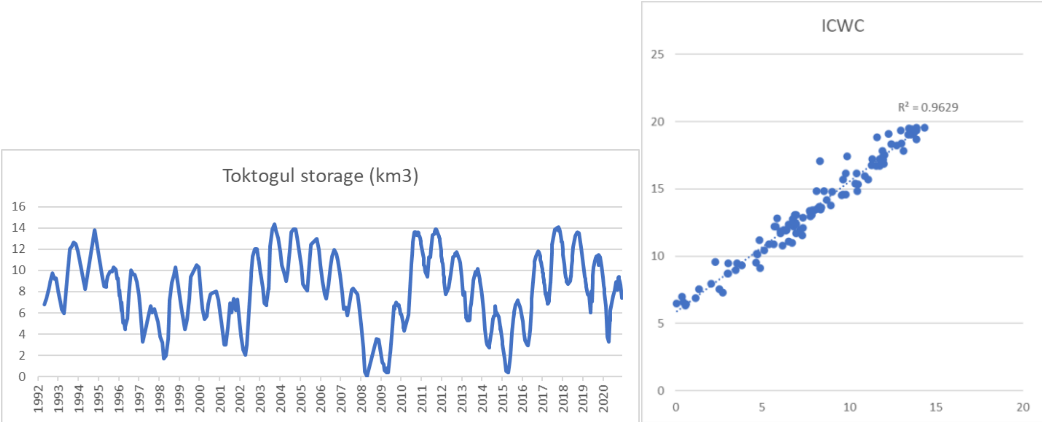



**Figure 26. Correlation between remote sensing-based and ground-based estimated reservoir storage for Totkogul reservoir (source: own analysis)**