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Assessment of risks and vulnerability to climate change at the local level, Tuyamuyun hydro complex, 2021

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

Climate risks and vulnerability assessment (CRVA) on local level – Tuyamuyun – Uzbekistan / Turkmenistan

D-1.7

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Abbreviations

CA	Central Asia
CAMP4ASB	Climate Adaptation and Mitigation Program for Aral Sea Basin
CAREC	Central Asia Regional Environmental Center
CB	Capacity Building
CC	Climate Change
CRVA	Climate Risks and Vulnerability Assessment
HPP	Hydropower plant
THC	Tuyamuyun Hydro Complex

1 SUMMARY

Following the method of Climate Risks and Vulnerability, based on the GIZ Guidebook on Climate Risk and Vulnerability Assessment and worked out in a by the countries agreed methodology a global assessment has been made of the Tuyamuyun Hydro Complex territory. [1]

The tasks to be carried out include the climate risk and vulnerability assessment for the Tuyamuyun Hydro Complex territory, the impact of climate change on the evaporation from the Tuyamuyun Hydro Complex reservoirs and a qualitative assessment of climate change on flood risk and sediment flow on the territory.

The climate risk and vulnerability include climate exposure (heat, precipitation, extreme precipitation and drought duration), natural or geographical sensitivity (water stress, drought risk, land productivity) and socio-economic sensitivity (income, life expectance, education, and health).

It was found that extreme weather parameters have the most impact on the sectors. Therefore, major indicators selected based on the Tuyamuyun land use are for climate exposure: heat, precipitation, extreme precipitation, and drought. The mapping is built on 7 climate models, which proofed to be the most reliable for Central Asia with a maximum resolution of 100 km and mapped according to the 16-percentile classification. Finally, the classified score is weighted and summarised to get the combined vulnerability maps.

A separate report can find a more detailed qualitative assessment of the processes and the impact of climate change and land productivity in the upper basin of the Amu Darya regarding flood risk and sediment flow by 2050.

The following conclusions can be drawn:

- Extreme heat increase (up to 3.1°C), warmth duration (+18%), and drought duration (up to 11 days) will have a significant impact on agriculture, water and energy management. Heat stress in agriculture (above 37°C) will be a significant factor in reduced agricultural productivity. However, the total precipitation is expected to increase (up to 17 mm/yr) this will be in the form of an increase of extreme precipitation (11 mm/day)
- Land conservation, education and health care need attention in relation to geographic sensitivity and adaptive capacity.

[1] CRVA methodology

- The evaporation of the reservoirs is under the RCP 4.5 climate scenario, expected to increase with 13-16% with a peak in winter of 25%.
- For the upper basin of the Amu Darya, an increase of precipitation is expected, but also in the form of extreme precipitation, increasing the risk of more extreme river discharge and flooding. This requires inclusive climate modelling of river discharge and reservoir management. More reservoir buffer capacity should be reserved to overcome the increased drought and extreme river discharge. The combination of land degradation and extreme precipitation leads to increased turbidity (sediment flow) for the Amu Darya. The role of glaciers in buffering the water flow will decrease further, resulting in a reduced but higher peak flow after 2040.

The impact of climate change differs from sector to sector, depending on its use of natural resources. The impact of climate is mostly indirect through the natural resources, the ecosystem services and only than on human use of the resources like water and soil. Through the value chain it impacts on the social economy.
Most impacted sectors for Tuyamuyun HC area are agriculture, energy and natural hazards.

Agriculture is most sensitive for extreme temperatures, warmth duration, total precipitation, extreme precipitation and drought duration. Extreme temperatures above 37 C give growth stress and above 40 C irreversible growth reduction may take place, depending on the breeds used. Extreme precipitation will cause runoff, erosion and reduce infiltration, resulting in less available water resources.

Energy is impacted by heat on reduction of fossil cooling capacity and transmission capacity and together with extreme precipitation, seasonal changes in precipitation and drought duration less effective available water resources for hydro energy.

Water sector will face under heat and drought increased evaporation and water request, and together with extreme precipitation reduced effective water availability.

For natural hazards heat and drought are impacting the most and in the highest economic cost, also on health sector. Every degree increase of temperature causes in average 2.5% more call into hospitals.

The vulnerability Is besides the climate exposure depending on the percentage of water resources used (water stress), the drought risk and the sensitivity for reduction of land productivity. The water stress and drought risk is very high for the Tuyamuyun Hydro Complex area. The northern and western part show a reduced productivity over the last 20 years. This makes the Tuyamuyun HC area very vulnerable for the changing climate as mentioned above.

The socio economic sensitivity and with this the adaptive capacity is depending on factors like income per capita, life expectance, education and health care. On income per capita Turkmen part of the THC area scores higher than the Uzbek part of the territory, also related to national levels. On education, health and life expectance both part of the THC area score low, also in relation to the national levels. Together with the growing population, Increased attention is needed for education and health care to decrease the vulnerability.

The climate vulnerability is not only depending on the THC area itself but also from the changes in the upper basin. Land degradation and more extreme precipitation is increasing the land erosion and therefore the sediment flow in the Amu Darya, but also increases the flood risk.

Without climate adaptation, losses for the economy of country of Turkmenistan of 350 million USD and the country of Uzbekistan, based on a 4% decrease, of 280 million USD (PPP), can be expected from the agriculture sector. Furthermore, the cost of land degradation is estimated even higher: 3% of the GDP or 7.5 billion USD (PPP) for Uzbekistan and 4% of the GDP or 3.5 billion USD (PPP) for Turkmenistan. For the Tuyamuyun the loss will be related to their share in the national agricultural production.

Climate Change Adaptation

Local climate adaptation measures will only be effective when supported by regional (services, cooperation, planning, knowledge transfer, awareness) and national (rights, priorities, policy, monitoring, early warning, research and education, budgeting, economic incentives, market development). By stacked supporting measures, financing from international organizations, government, businesses and locals can be activated and combined.

There are good options for climate change adaptation for the region. Therefore, good intersectoral cooperation and cooperation between the national authorities and the pilot region is required to make the local adaptation measures successful. In addition, the focus on water management needs a shift from the THC to the upstream basin of the Amu Darya.

Agriculture requires a transition to more climate-smart farming. Increased focus on soil quality, deeper rooting and less water-requiring crops (shift from annuals to perennials), more crop diversity and interaction between the crops, like with strip cropping, full soil cover and crop rotation, are essential. In addition, fodder supply from irrigated areas reduces the water request and supports livestock management in the arid areas. The enable this transition on a regional level has to be invested in services, cooperation and planning.

For energy, the cooling capacity for fossil energy needs attention, and for hydro, the modelling of the upstream water resources is necessary.

Together with water management, the focus on the upstream part of the Amu Darya basin is of significant importance and the adapted reservoir management. This includes sediment control and water efficiency for all sectors to enable the necessary flow to the Aral Sea. Water leakage reduction seems the be the first adaptation measure to be undertaken and the agricultural water efficiency (also to reduce the risk of salinization). Since the THC area has a very high water use per hectare, the most effects could be expected upstream. Nature-based Solutions for sediment catch and ripening can increase land productivity and land cover. Additionally, connecting or extending wetlands are significant measures.

With heat and drought as natural hazards, measures are needed to reduce their impact by intersectoral cooperation. Improving building quality and greening of the surrounding is a significant measure, as well the health infrastructure.

On Uzbekistan’s and Turkmenistan’s national levels, the intersectoral coordination has to be improved. The incentives (economic and others) for the businesses and private households to take their share in climate adaptation have to be brought in place. Besides that, risk-reducing policy tools like labour and construction regulation insurance, spatial planning, research and education on climate change adaptation and support to knowledge transfer needs to be stimulated. In addition, processing and market research and support for climate-smart agriculture needs more support.

Considering the relatively low Human Development Index for the THC pilot region (as well for Turkmenistan and Uzbekistan), more attention should be given to education, knowledge transfer and research, and the health sector to prevent loss of labour and social assistance.

Investment in climate adaptation is attractive with high benefits. For water management, a benefit of 4 USD avoided cost and increased productivity for every dollar invested can be expected. For agriculture and infrastructure, a benefit of 5 USD for every dollar invested can be expected, and for monitoring and early warning, 9 USD or more for every dollar invested. In addition, the loss of fee-based income will largely be compensated by tax from the increased economic use of the data.

The reduction of sediment flow and flood risk requires cooperation with the upper basin on land degradation neutrality and nature based solutions for widening the space for the river with fore shore protection, a major role for wetlands as flood buffer areas and sediment collectors. To reduce the sedimentation in the THC, nature based solutions as sediment traps and ripening of sediment are valuable solution, contributing to the sedimentation, the economic use of the reservoirs and biodiversity.

2 INTRODUCTION

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

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

This assessment is carried out in 8 phases following the GIZ Guidebook for Climate Risk and Vulnerability Assessment and worked out CRVA methodology for Central Asia[2].

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

This pilot Climate Risk and Vulnerability Assessment (CRVA) is selected based on national priorities, availability of relevant data, local stakeholder for implementation, climate coherence, having a recognizable size and matching natural resource-based and administrative structures.

The implementation of this pilot project involves two riparian countries – Uzbekistan and Turkmenistan, receiving water from the Tuyamuyun hydro complex on Amudarya River for irrigation, municipal and

[2] Methodology on climate risk and vulnerability assessment (CRVA) on national and sub national levels - Summary

production purposes. In addition, information on the Upper Amu Darya in relation to sedimentation in the Tuyamuyun Hydro Complex reservoirs is added to this report.

3 PILOT SITES DESCRIPTION

3.1 General description

The Tuyamuyun hydroelectric complex is located on the border of Uzbekistan and Turkmenistan in the lower reaches of the Amu Darya River and represents a system of four interconnected water reservoirs and canals. The Tuyamuyun hydropower station supplies drinking water and water to irrigated lands in Khorezm province and Republic of Karakalpakstan (Uzbekistan) and Dashoguz velayat (Turkmenistan) (Figure 1).

Figure 1: Location map of the Tuyamuyun hydroelectric complex

Tuyamuyun complex is the critical facility that controls the downstream flow of the Amu Darya River, allocating water and energy resources between Turkmenistan and Uzbekistan. The large hydro-complex, built by Uzbekistan in 1980, is located on the territory of Turkmenistan. Uzbekistan carries out the facility's maintenance and financing, and its occupied area of the object on the territory of Turkmenistan is used based on paid land use. The ownership and management of the hydro-complex are articulated by four interstate legal agreements signed by Turkmenistan and Uzbekistan, where the riparian countries should maintain the facility. But this does not detail the sedimentation issue.

Tuyamuyun hydroelectric complex consists of 30 critical hydro-technical facilities and 4 water reservoirs: Ruslovoe, Sultansandzharskoe, Kaparaskoe, Koshbulakskoe, with a total volume of 7.8 billion m^3 and a mirror area of 650.1 km^2 in total. It also includes a run-of-the-river HPP at Amu Darya River, channels, water intake, spillway dams, and substations. The 150 MW power plant has six hydroelectric units (turbines) on the main dam, each with a capacity of 25 MW, which uses a head of 14 m and can provide a total electricity production of 1 billion kWh per year (Figure 2).

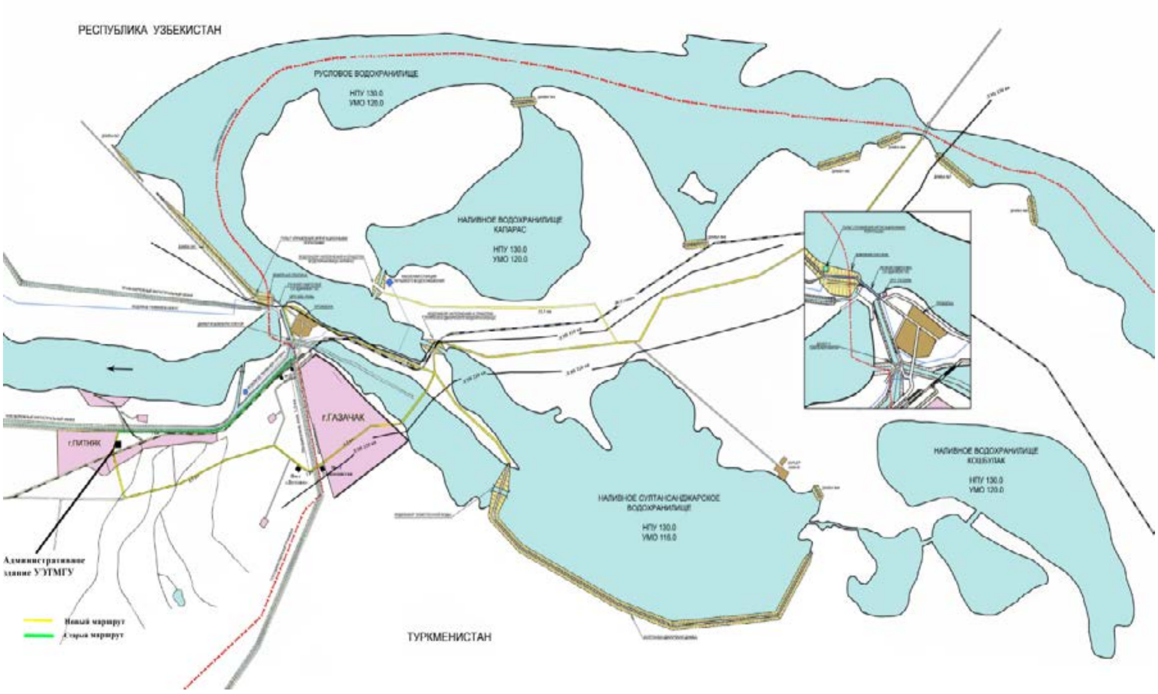


Figure 2: Water reservoirs of the Tuyamuyun hydroelectric complex

During the hydropower plant construction, the river valley was blocked by an earthen dam 34 m high and 900 m long, and a concrete section with culverts and machine hall was built directly in the river channel. The central part of the complex – the main dam of gravity type – is 141 m in length and 25 m in width and holds the Ruslovoye reservoir which is connected by channels to three other reservoirs – Kaparas, Sultansandjar and Koshbulak – located on the left bank. The total surface area of the reservoirs is 790 km^2, and their total volume is 7.8 billion m^3 (practical volume is 5.27 billion m^3). By the early 2000s, as a result of sedimentation, the total volume was reduced to 6.7 billion m^3. The canal system at the main dam supplies a network of irrigation canals in different areas of Uzbekistan and Turkmenistan (Figure 3).

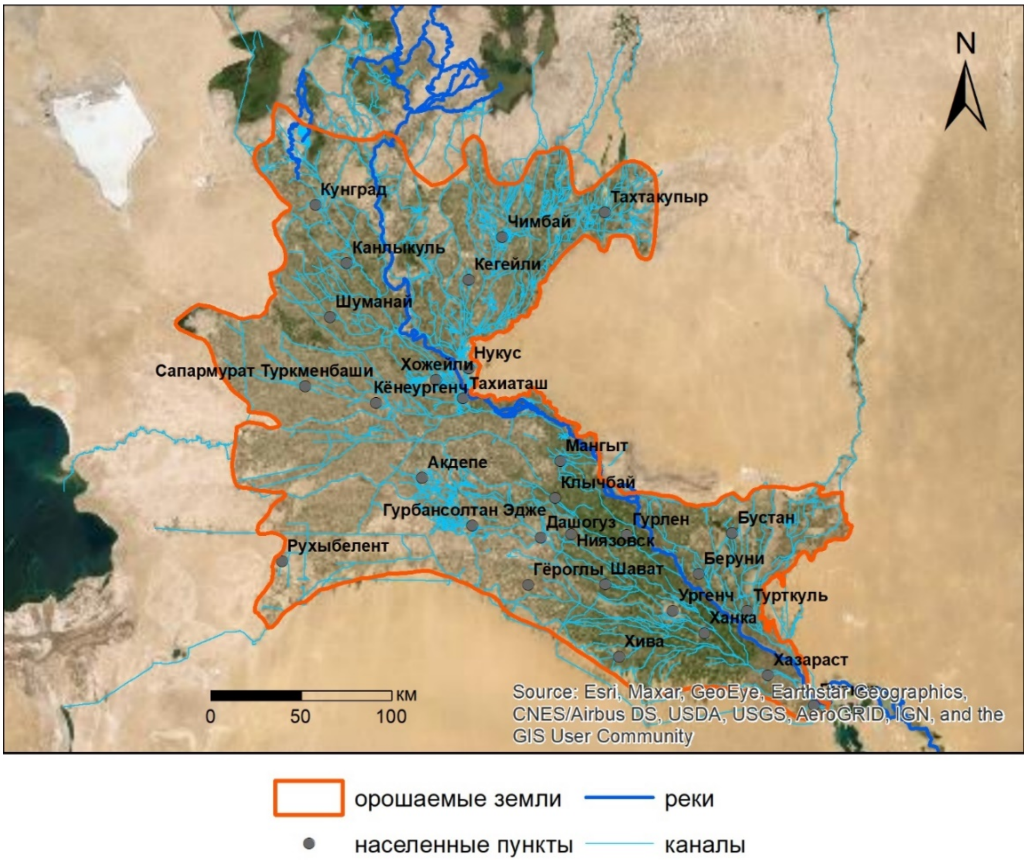


Figure 3: Irrigation canals supplying water from the Tuyamuyun hydroelectric complex(Uzbekistan-Turkmenistan)

Tuyamuyun hydroelectric complex plays an indispensable role in water management between the two countries. As such, it supplies i) water to 751 607 ha of irrigated lands in Uzbekistan (236 980 ha in Khorezm Region, 514 627 ha in the Republic of Karakalpakstan) and 425 000 ha in Turkmenistan; ii) electricity generation in Uzbekistan (450 mln kW/h per year), and iii) drinking water to Khoresm Region and Karakalpakstan; iv) highway and railway connections between two banks of Amu Darya River; v) a regulated seasonal hydro regime of Amu Darya River; vi) a regulated water discharge for Tachiatashsk hydrocomplex in Uzbekistan, and vii) protection against stream-bank erosion of Amu Darya River below the facility.

On the territory of Uzbekistan, lands irrigated with water from the Tuyamuyun complex are located within administrative boundaries of Khorezm province and Karakalpakstan. Districts where irrigated lands are located, and their areas are given in Table 1.

Table 1: Lands in Uzbekistan, irrigated with water from Tuyamuyun complex

District	Total area of the district, km^2	Irrigated lands area, km^2
Khorezm province		
Bagat	358.5	201.54
Gurlen	352.1	294.51
Koshkupyr	423.5	265.29
Urgench	491.8	273.91
Khazarasp	1834.1	184.81
Khanka	468.1	251.72
Khiva	292.0	177.76
Shavat	415.1	243.22
Yangiaryk	358.3	166.53
Yangibazar	261.9	211.32
Tuprakkalin		99.19
In total:		**2369.80**
Karakalpakstan		
Turtkul	6417.8	317.13
Beruni	3780.1	331.04
Ellikkala	5024.0	340.36
Amudarya	715.6	394.63
Khodjeyli	586.8	215.24
Takhiatash		79.73
Shumanay	487.6	291.18
Kanlykul	811.8	355.54
Kungrad	75215	414.64
Nukus	1076.7	308.01
Kegeyli	1803.6	323.84
Chimbay	2417.7	487.64
Karauzyak	5455.8	356.39
Takhtakupyr	20180	346.50
Muynak	42365	261.24

District	Total area of the district, km²	Irrigated lands area, km²
Bozataus		301.22
The city of Nukus		21.93
In total:		**5146.27**

The Amu Darya River is a source of water for irrigation in the Republic of Karakalpakstan.

On the territory of Turkmenistan, irrigated lands are located within Dashoguz velayat. The names of districts and areas of irrigated lands receiving water from the Tuyamuyun hydropower complex are given in Table 2.

Table 2: Lands in Turkmenistan, irrigated with water from Tuyamuyun complex

District (etrap)	Communities number	Irrigated lands area, ha
Akdepe	17	45 355
S.A. Niyazov	18	72 297
Gerogly	14	41 760
Gurbansoltan Edje	14	89 671
Rukhybelent	10	17 651
In total	**73**	**273 734**

Water for irrigation in Dashoguz province is supplied through the main inter-farm irrigation canals – Shavat, Khanyap, Turkmenderiya and Shasenem. The total water intake of the province from natural water sources in 2011 was 6,631.7 million m^3. A total of 3,257.1 million m^3 was used for water supply and agriculture – 3,231.1 million m^3, for domestic needs – 24.4 million m^3 and for production purposes – 1.6 million m^3.

3.2 Environment and climate change issues

Tuyamuyun hydroelectric complex experiences intense sedimentation of its key run-of-the-river Ruslovoe water reservoir located on the Amu Darya River. The mountainous relief and high concentration of muddiness in the Amu Darya River speed up the sedimentation process intensity. According to the latest sedimentation estimates carried out 11 years ago by KAZNIPI, the local Uzbek company, the sedimentation rate of the Ruslovoe water reservoir reached 1 270 mln cubic meters. Due to sedimentation, the Ruslovoe water reservoir lost 33% of its useful storage volume, while the sedimentation volume reached 70%. As a practice, the water reservoir's operation is put at severe risk if the sedimentation volume reaches 50%. However, Ruslovoe water reservoir has not underdone sedimentation cleaning since it was put into operation 40 years ago. The sedimentation results from the turbidity of the Amu Darya and depends on the heavy precipitation and land degradation upstream.

At present, Turkmenistan and Uzbekistan cannot fully utilize the water resources of Amu Darya River to cover its energy and irrigational needs due to the increased sedimentation rate of its key water reservoir.

Sedimentation cleaning at Ruslovoe water reservoir has not taken place since the facility was put into operation. Unfortunately, this is not only the case of this pilot site but a very common challenge for the rest of the water reservoirs in the region, which perform the central role of river flow regulation and flood control.

Another critical issue is that Ruslovoe water reservoir is an entry point for the water resources of Amu Darya River released further to the downstream water reservoirs of the Tuyamuyun hydroelectric complex, namely Kaparassky, Sultansanjar and Kushbulak. Those three water reservoirs supply water for irrigational and drinking purposes. As such, Ruslovoe plays an enormous role in water supply and its decreasing capacity volume due to the sedimentation means the allocation of less water to the customers and inefficient use of the massive and facility of the Tuyamuyun hydroelectric complex.

Besides the issue of water management, the impact of heat and drought on arable and vegetable farming is a growing issue.

Another main issue is the reduction of water delivery to the Aral Sea (Figure 4). In the nineties, 7000 Mm^3 was planned to be delivered in the Aral Sea, but, in 2020 this was reduced to 2100 Mm^3 for the growing season and from 3500 Mm^3 to 2100 Mm^3 for the non-growing season. The adequate average 10-years inflow has been steadily reduced from 8146 Mm^3 for 1992 – 2001 to 3118,5 Mm^3 from 2011 – 2020 for the growing season and from 3891 to 1748 Mm^3 for the non-growing season[3]. Seen the steady decline in the Aral Sea water level, it seems that the minimum ecological inflow is reached by long. This leaves little

[3] http://www.cawater-info.net/aral/data/index_e.htm

space for further use of the water from the Amu Dary, and the focus is limited to water efficiency (Figure 5).

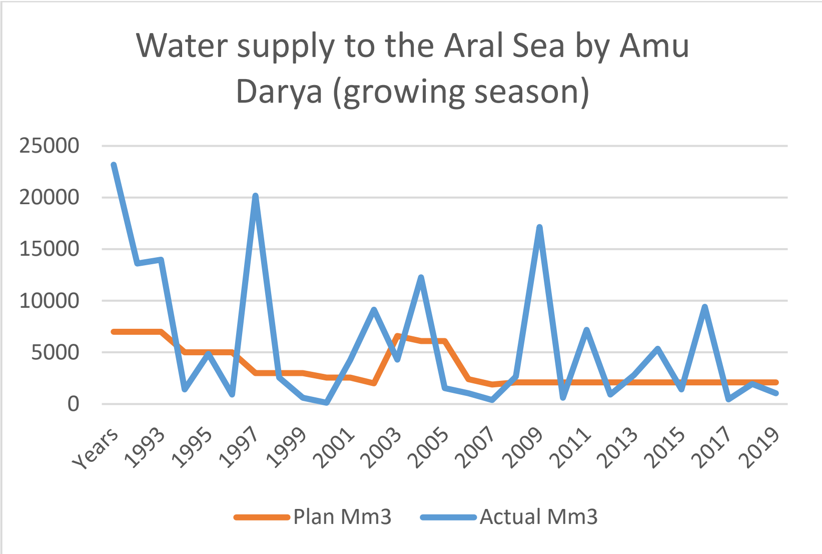


Figure 4: Water supply to the Aral Sea by Amu Darya (source: http://www.cawater-info.net/aral/data/index_e.htm)

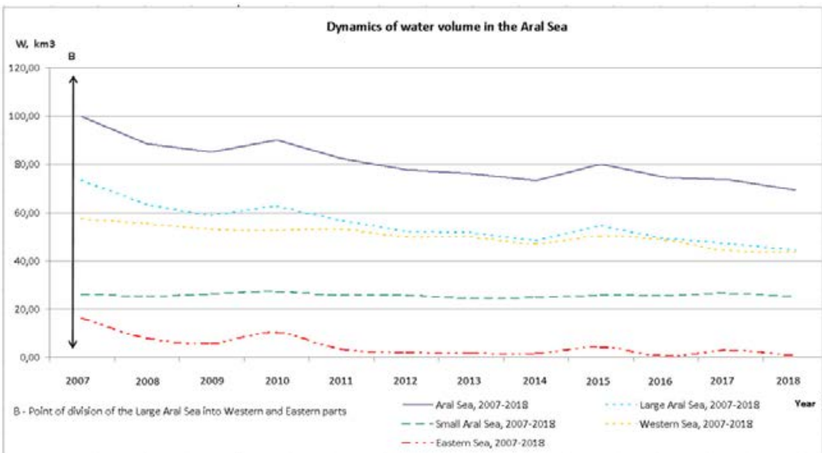


Figure 5: Dynamics of water volume in the Aral Sea (source: http://www.cawater-info.net/aral/data/index_e.htm)

According to previous assessments of climate change in the study area, an increase in temperature, an increase in the frequency of strong winds, and a decrease in precipitation are predicted, what will lead to a decrease in the yield of cotton and wheat, a deterioration in the quality of cotton fiber, an increase in water demand, degradation of pastures, a decrease in the productivity of livestock farms, an increase in evaporation and reducing the flow of water bodies.

As a result, critical indicators for the CRVA are the increase of heat and drought duration.

3.3 Socio-economic situation

The economy of the region is mainly agricultural, inclusive of agricultural processing and manufacturing.

3.3.1 Dashoguz velayat (Turkmenistan)

The Dashoguz velayat is located on the left bank of the Amu Darya River in the Karakum Desert in the northern part of Turkmenistan. In the north, north-west and north-east, the region borders Uzbekistan.

Most of the velayat is occupied by the part of Karakum Desert. The area of Dashoguz velayat is 73.43 thousand km^{2}, and the population is 1.37 million people (22% of the total population of Turkmenistan - 6.14 million people). Thus, the population density in the province is 18.66 people/km^{2}.

Dashoguz velayat consists of nine districts. There are nine cities, one settlement, and 612 villages in the territory of Dashoguz velayat (Table 3).

Table 3: Administrative-territorial division in Dashoguz velayat (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Areas	Area, thousands km^2	Etraps (rayons)	Quantity			
			Cities	Towns	Gengeshlyks (rural communitites)	Villages
Turkmenistan in total	491.21	43	51	62	504	1717
Dashoguz velayat	73.43	9	9	1	134	612
% from total	14.9	20.9	17.6	1.6	26.6	35.6

The etraps of Dashoguz velayat:

1. Gurbansoltan Eje;
2. Baldumsazi;
3. Kyoneurgench;
4. Akdepi;
5. Saparmurad Turkmenbashi;
6. Gyorogly;
7. named after S.A. Niyazov;
8. Gubodagsky;
9. Rukhybelent.

Out of the above 9 etraps of Dashoguz velayat at present time the lands of 5 etraps are irrigated with water of Tuyamuyun hydrocomplex, namely:

1. Gurbansoltan eje;
2. Akdepinsky;
3. Gyorogly;
4. named after S. A. Niyazov;
5. Rukhybelent.

The leading socio-economic indicators of Dashoguz velayat compared to the country's data are given in the table below (Table 4).

Table 4: Main socio-economic indicators of Dashoguz velayat (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Main socio-economic indicators	2014	2015	2016	2017	2018	In average
Labor productivity growth in Turkmenistan						
Growth rate of real GDP per person employed, in percent	9,6	6,0	6,2	8,6	6,7	7,4
The structure of the permanent population by urban and rural areas in Turkmenistan	2014	2015	2016	2017	2018	(± level of internal migration for 5 years)
Total population, mln people	5,90	5,96	6,02	6,08	6,14	
Urban	43,8 %	43,6 %	47,3 %	47,3 %	47,1 %	(+ 3,3 %)
Rural (± level of internal migration for 5 years)	56,2 %	56,4 %	52,7 %	52,7 %	52,9 %	(- 3,3 %)
Dashoguz velayat, mln people	-	-	-	-	1,37	
Urban (±level of internal migration for 5 years)	28,6 %	28,4 %	30,6 %	30,4 %	30,3 %	(+ 1,7 %)
Rural (±level of internal migration for 5 years)	71,4 %	71,6 %	69,4 %	69,6 %	69,7 %	(- 1,7 %)
Gender structure:						
Male					49,8 %	

Female					50,2 %	

According to UNDP, the Human Development Index (HDI), which combines life expectancy, well-being and access to education, Dashoguz velayat has an average score of 6.773 over 10 years (2010 – 2019)[4]. For Turkmenistan as a whole, this indicator for the same period is 6.914. Thus, during this period, there has been a steady increase in the human development index for all velayats and the country.

Economic entities in agriculture in Turkmenistan consist of Dayhan associations, subsidiary farms of enterprises, ministries and departments, private farms (including individual subsidiary farms and farms on land transferred for gardening), private commodity producers and Dayhan farms.

During the long-term observation period, the annual precipitation in Dashoguz velayat is 90-110 mm, which does not allow for rainfed farming. In this regard, there are no rainfed lands in etraps. The main crops grown in the irrigated lands of Dashoguz velayat are wheat, cotton, vegetables, potatoes, gourds, grapes and fruits. According to the statistical yearbooks of Turkmenistan, the main crops grown and sown areas of agricultural crops in the irrigated lands of Dashoguz velayat for the period from 2014 to 2018[5] are shown in Table 5.

Table 5: Main crops and sown area of agricultural crops in the irrigated lands of Dashoguz province (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Crops	Sown area, thousand hectares					
	2014	2015	2016	2017	2018	In average
Cereals and legumes	203.7	212.3	189.9	189.5	167.1	192.5
Cottonwood	140.6	140.5	140.6	140.7	140.3	140.5
Vegetables	7.1	6.8	8.6	7.4	7.2	7.4
Gourds	5.6	5.0	6.4	6.7	6.6	6.0
Potatoes	3.9	3.7	7.4	6.5	6.6	5.6
Fruits, berries and grapes	-	-	10.9	-	10.2	10.5

[4] Human Development Indices (Sub-National Level) 2010 - 2019. Global Data Lab: https://globaldatalab.org/shdi/shdi/TKM/?levels=1%2B4&interpolation=1&extrapolation=0&nearest_real=0

[5] Статистические ежегодники Туркменистана. Охрана окружающей среды и использование природных ресурсов в Туркменистане за 2018 г.

The main crops and crop areas under irrigation for 5 etraps of Dashoguz province that use water from the Tuyamuyun hydrocomplex are given in the table below (Table 6).

Table 6: Sown area (net) of main crops by etraps of Dashoguz velayat of Turkmenistan that use water from the Tuyamuyun hydrocomplex in 2018, thousand hectares (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Area	Raw cotton	Vegetables	Gourds, melons	Potatoes	Fruits and berries	Grape	Cereals, legumes, and other crops	Total sown area
Dashoguz velayat	141.3	7.2	6.6	6.63	6.478	1.298	169.49	339.0
Including:								
Dashoguz city		0.08	0.005	0.05		0.006	0.14	0.3
Etraps:							0	
Gurbansoltan eje	14.0	1.14	0.604	1.53	0.786	0.263	18.32	36.6
Akdepe	17.0	0.63	0.785	0.50	0.287	0.063	19.26	38.5
Gyorogly	17.4	0.87	0.579	0.41	0.713	0.343	20.31	40.6
Niyazov	21.4	1.74	0.697	1.87	1.867	0.217	27.79	55.6
Rukhybelent	2.9	0.24	0.343	0.13	0.123	0.023	3.76	7.5
In total:								178.9

On the territory of etraps of Dashoguz velayat, mainly surface irrigation is used, which is the primary traditional way of irrigation of all crops, fruit trees and vineyards. In addition, methods of irrigation by furrows, strips and checks are used. The advantage is the possibility of using the established water supply system without additional capital investments, simplicity, and extensive application experience. The disadvantage is the large water losses during irrigation for deep percolation, discharges at the end of the furrows and in the irrigation network, and soil moisture's unevenness.

Settlements of etraps in Dashoguz velayat of Turkmenistan do not use electricity from the Tuyamuyun hydropower station. Instead, electricity from the Tuyamuyun hydropower plant is used for settlements of Uzbekistan and the operation of hydraulic engineering structures at the Tuyamuyun hydrocomplex.

In Dashoguz velayat, only irrigated agriculture is practiced. According to the statistical yearbooks of Turkmenistan, the sown area (net) in Dashoguz velayat is given in Table 7. Sown area in 2014 was 370.4 thousand hectares, and, in 2018, 339 thousand hectares with an average of 362.4 thousand hectares for the 5-year period. There are no rainfed lands in Dashoguz velayat and etraps. The irrigated areas (gross) depending on the water content of the Amudarya River for the period 2014 - 2018 were 425.7 - 389.7 thousand hectares and an average of 416.5 thousand hectares for this period.

Table 7: Irrigated (gross) and sown (net) land areas in Dashoguz province in thousand hectares (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Main indicators	2014	2015	2016	2017	2018	In average
Irrigated area (gross)	425.7	435.7	418.16	413.4	389.7	416.5
Sown area (net)	370.4	379.1	363.8	359.7	339.0	362.4

Note: Planted area (net) is taken from statistical yearbooks of Turkmenistan. The irrigated area (gross) was calculated by multiplying the net area by the average coefficient of land use of 0.87. The net planted area (net) in Dashoguz province in 2012 was 355.1 thousand hectares, the irrigated area (gross) of B.K. Balakaev was 409.27 thousand hectares[6]. The average coefficient of land use was 0.87.

The names and locations of etraps and the irrigation network in Dashoguz velayat are shown in Figure 6.

[6] Balakaýew B.K. we başgalar. Türkmenistanyň suw gorlaryny rejeli peýdalanmak boýunça çäreleriň toplumy. – A.: Ylym, 2013, 204 sah.

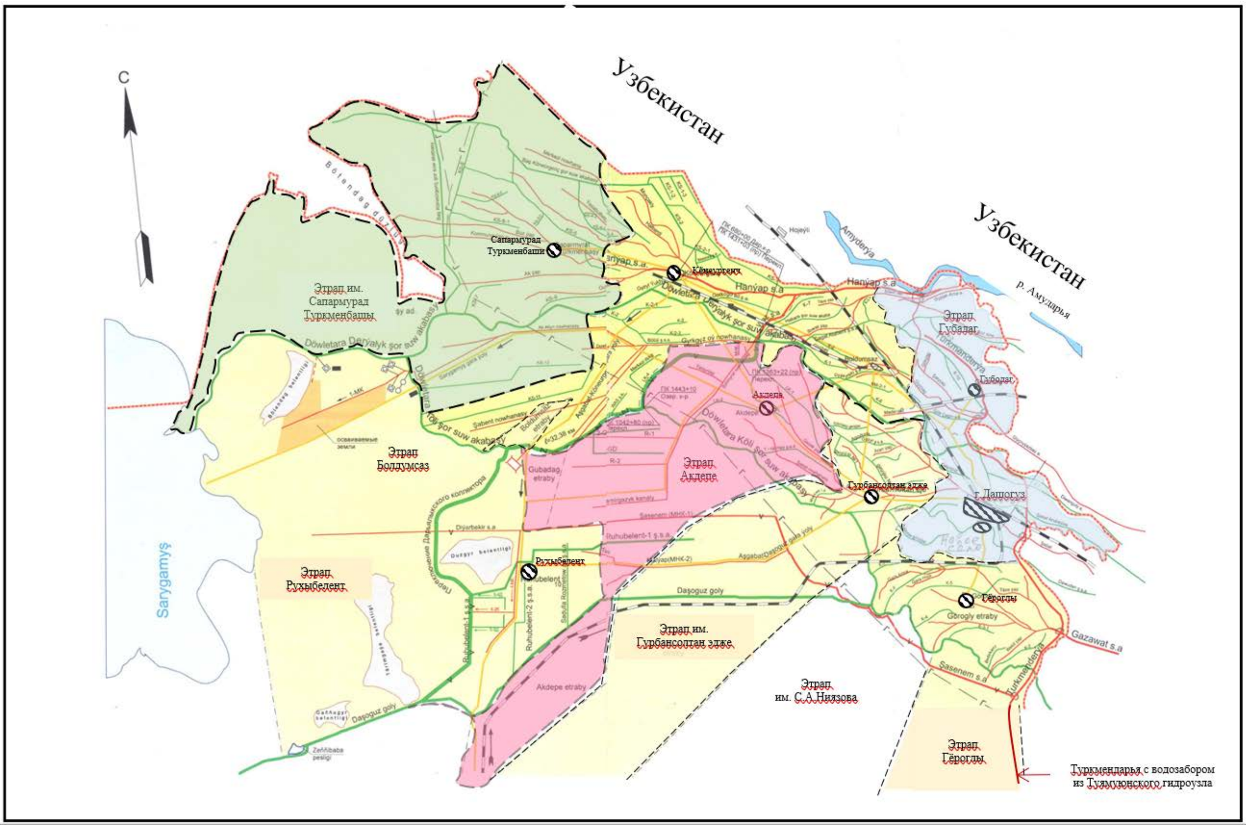


Figure 6: Map of etraps and irrigation network in Dashoguz velayat (Statistics yearbooks. Environmental protection and natural resources use in Turkmenistan, 2018)

The irrigated and rainfed land areas for each of the etraps of Dashoguz velayat are given in the table below.

Table 8: Sown (net) and irrigated (gross) areas by etraps of Dashoguz province

Etraps of Dashohuz velayat	Sown area (net), thousands ha	Irrigated area (gross), thousands ha	Rain-fed areas, thousands ha
Dashohuz velayat	339.0	389.7	0
Including by etraps:			
Gurbansoltan eje	36.6	42.1	0
Baldumsazi	22.8	26.2	0
Köneurgenç	42.8	49.2	0
Akdepi	38.5	44.3	0
Saparmurad Turkmenbashi	65.3	75.1	0
Gyorogly	40.6	46.7	0
named after S. A. Niyazov	55.6	63.8	0
Rukhybelent	7.5	8.6	0

Gubodag	29.3	33.7	0

The areas of irrigated and rainfed lands in 5 etraps of Dashoguz velayat that use waters of the Tuyamuyun hydrocomplex are given in the table below (Table 9).

Table 9: Sown (net), irrigated (gross) and rainfed areas using water from the Tuyamuyun hydrocomplex through the Turkmendarya irrigation system (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Irrigated areas along Turkmendarya from Tuyamuyun hydrocomplex			
Etraps	Irrigated area (net), thousand hectares	Irrigated area (gross), thousand hectares	Rain-fed areas, thousand hectares
Gurbansoltan Eje	36.6	42.1	0
Akdepinsky	38.5	44.3	0
Göroğlu	40.6	46.7	0
S.A.Niyazov	55.6	63.9	0
Rukhybelent	7.5	8.6	0
In total	178.9	205.6	0

Cattle breeding in Dashoguz velayat includes cattle, small ruminants (sheep and goats), camels, horses and poultry.

The number of animals in 5 etraps of Dashoguz velayat that use water from the Tuyamuyun hydrocomplex is given in the Table 10.

Table 10: Animal populations by etrap of Dashoguz velayat, which use water from the Tuyamuyun hydrocomplex (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Territory	Cattle		Sheep and goats		Camels		Horses		Poultry	
	2017	2019	2017	2019	2017	2019	2017	2019	2017	2019
Dashoguz velayat, in total, thousands	1044.6	1077.8	3551.7	3664.5	16.4	16.4	8.7	8.7	4429.1	4648.1
including										
Dashoguz city	5.0	5.1	4.7	4.7	-	-	-	-	167.9	172.0

Etraps, taking water from Tuyamuyun hydrocomplex										
Gurbansoltan Eje	83.2	86.0	163.1	169.6	0.6	0.6	0.7	0.7	359.9	376.6
Akdepinsky	120.7	124.6	457.3	478.5	0.9	1	0.9	0.9	636.7	688.9
Göroğlu	174.6	180.3	1028.5	1048.6	2.7	2.5	0.4	0.4	1189.0	1251.7
S.A.Niyazov	135.0	139.5	301.9	321.1	1.5	1.7	0.8	0.8	500.6	514
Rukhybelent	22.9	23.6	129.1	132.0	1.4	1.4	0.6	0.6	79.8	81.4
In total:	541.4	559.1	2084.6	2154.5	7.1	7.2	3.4	3.4	2933.9	3084.6
% from total	51.8	51.9	58.7	58.8	43.3	43.9	39.1	39.1	66.2	66.4

Indicators of water use as of 2018 by etraps of Dashoguz velayat for 2018 are shown in the Table 11.

Table 11: Main indicators of water resources use in Dashoguz velayat of Turkmenistan, million m^3 (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Type	2014	2015	2016	2017	2018
Water withdrawal from all natural sources in Turkmenistan	27697.1	28487.8	28117.7	28856.2	26880.0
Including Dashohuz velayat:					
Water withdrawal from natural sources (Amu Darya River)	6246.7	6309.8	6315.2	6321.5	5969.0

Almost all the irrigation network of Dashoguz velayat has an earthen channel (more than 99%). In Dashoguz velayat, there are the oldest irrigation systems laid in the earthen channel. According to B. Balakaev, the average coefficient of efficiency of the inter-farm irrigation network (COE) in Dashoguz velayat is 0.61[7].

The amount of water taken from the Amu Darya river source and supplied for irrigation to farms of all etraps in Dashoguz velayat, including the Tuyamuyun hydrocomplex (THC), is shown in the Table 12.

[7] Balakaýew B. we başalar. "Türkmenistanyň suw gorlaryny rejeli peýdalanmak boýunça çäreleriň toplumy", "Ylym" neşirýaty, 2013. -204 sah.

Table 12: The amount of water taken from the Amudarya River source and supplied for irrigation to farms of all etraps in Dashoguz velayat (2018) (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Indicators of water use	In total, mln m^3	
	Used in farms and households (according to statistics)	Water withdrawal from Amu Darya River (calculated by average value of efficiency coefficient)
Dashoguz velayat, in total	3641.0	5969
including		
Dashouz city	20.7	34
r. Köneurgenç	1.2	2
Etraps:		
Gurbansoltan eje (from THC)	379.5	622
Baldumsazi	250.0	410
Göneurgenç	424.7	696
Akdepinsky (from THC)	391.7	642
Saparmurad Turkmenbashi	895.0	1467
Gyorogly (from THC)	355.9	583
named after. S. A. Niyazov (THC)	445.2	730
Gubodag	329.5	540
Rukhybelent (from THC)	147.6	242

The amount of water taken from the Tuyamuyun hydrocomplex and supplied for irrigation to farms of 5 etraps in Dashoguz province is given in the table below (Table 13).

Table 13: The amount of water taken from the Tuyamuyun hydroscheme and supplied for irrigation to farms of 5 etraps in Dashoguz province (2018) (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Indicators of water use	In total, mln m^3	
	Used in farms and households (according to statistics)	Water withdrawal (calculated by the average value of efficiency coefficient)
Dashoguz province, total, 100%	3641.0	5969
including from TCH:		
Dashoguz city	20.7	34

etraps:		
1. Gurbansoltan eje.	379.5	622
2. Akdepinsky	391.7	642
3. Gyorogly	355.9	583
4. named after S. A. Niyazov	445.2	730
6. Rukhybelent	147.6	242
Total taken and used from TCH, % from total use in Dashoguz velayat	1741	2853
	47.8 %	47.8 %

Production of the most important products in physical terms by Dashoguz province for 2014 to 2018 are given in the Table 14.

Table 14: Production of the most important products in Dashoguz province for the period from 2014 to 2018 (Statistics yearbooks 2015, 2016, 2017, 2018, 2019)

Types of production	2014	2015	2016	2017	2018
Electric power, mln. kWh	1570.0	1518.0	1615.5	1592.4	1480.4
Prefabricated concrete elements for construction, thous. m^3	54.6	41.7	38.0	37.3	41.0
Building bricks, mln pcs of bricks	64.0	63.4	75.5	79.5	81.9
Cotton fiber, tons	80.2	86.0	57.6	67.7	53.5
Cotton yarns, thousands tones	11.0	12.8	12.9	13.0	11.2
Hosiery, thousand pairs	3705	4677	1858	1766	1807.3
Meat, including by-products, ths. tonnes	4.6	3.9	3.9	2.2	2.0
Cheese and cottage cheese, tons	108	123	104	144	143
Vegetable oils (unrefined), th. tonnes	23.4	21.3	17.3	16.2	14.9
Pasta products, tons	0.4	0.4	0.4	0.4	0.4
Confectionery, tons	1.4	1.4	1.4	1.5	1.4
Bread and bakery products, thous. ton	232.3	239.6	253.3	246.1	233.2
Flour, tons	104.3	112.6	121.8	138.1	135.8
Canned fruit and vegetable, mln pcs	47.0	47.3	41.9	63.4	63.1

3.3.2 Khorezm province and Republic of Karakalpakstan (Uzbekistan)

Khorezm region is one of the agrarian-industrial regions of Uzbekistan. Agriculture plays a key role in the region's economy. Farms, which exceeded 5,000 after the enlargement reform, play an increasingly important role in it. Farmers supply about 98% of the raw cotton and 65% of the grain grown in Khorezm. Local industry is mainly related to the processing of agricultural products. There are also companies producing carpets, construction materials and food products. The population of the Khorezm region is 1,866,493 people (505,982 families) as of 2020, with a relatively low population density of 243 persons/km^2.

According to preliminary data, the gross regional product of the Republic of Karakalpakstan in 2020 increased by 2.6%. The growth of GDP is due to favourable growth rates in the main sectors of the regional economy such as agriculture, forestry and fishing - 102.4% (the share in the GRP structure is 30.4%), industry - 104.1% (27.9%), construction - 101.5% (8.5%) and the services 101.6% (33.2%). As a result, GRP per capita increased by 1.1% and made up 11 093.5 thousand soums[8].

Figure 7: Sectoral structure of GDP of the Republic of Karakalpakstan (КОМПЛЕКСНЫЙ АНАЛИЗ ПО ДЕМОНСТРАЦИОННОМУ НЕКСУС ПРОЕКТУ НА ТУЯМУЮНСКОМ ГИДРОУЗЛЕ В УЗБЕКИСТАНЕ)

The main agriculture sectors in the Republic of Karakalpakstan are wheat and paddy rice production, cotton production, cattle breeding and silkworm breeding, industry and construction. The volume of agricultural production in January-December 2020 amounted to 249.8 trillion soums or 102.8% compared to the corresponding period of 2019, including crop production - 123.6 trillion soums (103.4%), livestock production.

[8] КОМПЛЕКСНЫЙ АНАЛИЗ ПО ДЕМОНСТРАЦИОННОМУ НЕКСУС ПРОЕКТУ НА ТУЯМУЮНСКОМ ГИДРОУЗЛЕ В УЗБЕКИСТАНЕ

As of 2019, the population of Karakalpakstan was 1875,400 (419,730 families). Karakalpakstan has the youngest population with an average of under 28 years.

The density is less relevant as the population is concentrated in the irrigated areas around the Amu Darya. The income of the people is strongly seasonal and related to the quantity of agriculture work in that month.

Between the provinces there are remarkable socio-economic differences. For example, the monetary poverty in Khorezm is low, and in the Republic of Karakalpakstan, it is medium to high. The Republic of Karakalpakstan scores, in general, lower than Khorezm on socio-economic factors. On migration, labor in Khorezm and Karakalpakstan score nationally above average. On economic factors, both provinces score just above the national average.

The economic dimension of Karakalpakstan is under the national average while it is in Khorezm above the national level.

The gross national income per capita (an indicator for poverty) Dashoguz scores above the national average with a GNI PPP of 16.000 USD, while Khorezm and Karakalpakstan score between medium and low with a GNI PPP of around 7000 USD.

On the human development index, Karakalpakstan and Khorezm score nationally in the middle class on this indicator with a score of 0.707-0,717.

But also inside the province, there are remarkable differences. On migration labor in Uzbekistan, Xonqu and Nukus district jump out with high levels of migration labor. Migration labor strongly influences adaptive capacity as young and middle-aged workers leave the region, and the attention to the natural resources reduces. This leads to lower costs and short-term solutions. On the other hand, it increases the cash flow to overcome difficult periods and hazards like heat and drought and increases recovery speed.

On the economic dimension, which includes business environment, both provinces score above the national average. In Uzbekistan, part of the area Shumanay and Qarao'zaq district jump out positively.

Also in medical services, Xonqu and Nukus are exceptions in their province with a deficient level of services. In Uzbekistan, Xonqa in Khorezm and Karakalpakstan, Amu Darya, and Kanlikol district perform worst and may be assumed to have the highest socio-economic sensitivity of the project area.

The Republic of Karakalpakstan, compared to other regions of Uzbekistan, have relatively low estimated consumption per capita, relatively less stable employment, higher levels of unemployment, and much higher reliance on remittances.

Single seniors are a larger share of the population in Karakalpakstan and several other regions of Uzbekistan. In contrast, mahallas in Khorezm are found to have relatively fewer single seniors. Karakalpakstan also struggles with the highest shares of the population who are registered as disabled[9].

Very few mahallas in Uzbekistan have immediate (within mahalla) access to hospitals, clinics, pharmacies and other health facilities. Those that do are mainly concentrated in urban areas. Thus, mahalla in the Republic of Karakalpakstan is more likely to have overlapping risk factors (Table 15).

Table 15: Average by Region of Indicators Related to Local Service and Infrastructure (Seitz W. et al. Uzbekistan. Dynamically Identifying Community-level COVID-19 Impact Risks. WorldBankGroup. 2021. 51 pp.)

Territory	No local hospital	No local clinic	No local pharmacy	No public bathrooms	Density (apt/family)	Mid-sized urban mahalla
Karakalpakstan	86.0%	60.7%	66.6%	80.8%	65.4%	18.3%
Khorezm	91.1%	76.6%	53.7%	89.0%	17.7%	18.1%

International out-migration is common in rural areas of Uzbekistan and is highly associated with low levels of labor income. Mahallas in Khorezm all send high numbers of migrants abroad. However, many districts and mahallas struggle to record migration patterns accurately, and survey estimates are relatively rough.

Across all measures in this dimension, mahallas in Karakalpakstan and Khorezm are most commonly identified as most reliant on migration and remittances, with many overlapping concentrations on both indicators.

[9] Worldbank, Dynamically Identifying Community-level COVID-19 Impact Risks, 2020

3.4 Key sector possibly impacted by climate change

Water and energy management, livestock and irrigated agriculture and as cross-cutting issue natural hazards.

3.5 Stakeholders in Climate Risk and Vulnerability assessment process

Major sectors depending on the Tuyamuyun hydrocomplex include hydro-energy production, irrigation, arable farming, agriculture and drinking water supply.

Therefore, major stakeholders involved in the process of CRVA are from the Turkmenistan side – State Committee for Water Resources of Turkmenistan, Ministry of Agriculture and Environment (Turkmenhydromet), Ministry of Energy of Turkmenistan, local administrations of etraps, daikhan (farmer) communities.

From the Uzbekistan side, stakeholders include - Ministry of Water Resources, Ministry of Energy, Ministry of Agriculture, Center of Hydrometeorological Service (Uzhydromet), State Committee on Ecology and Environmental Protection, Central Asia Scientific Research Institute for Irrigation, local administration and communities in mahallas.

These institutes play a significant role in the policy and management of the territory.

4 MAJOR CLIMATIC PROCESSES IN CENTRAL ASIA

4.1 Regional Processes

Different climate systems (Figure 8) influence the climate of Central Asia:

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

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

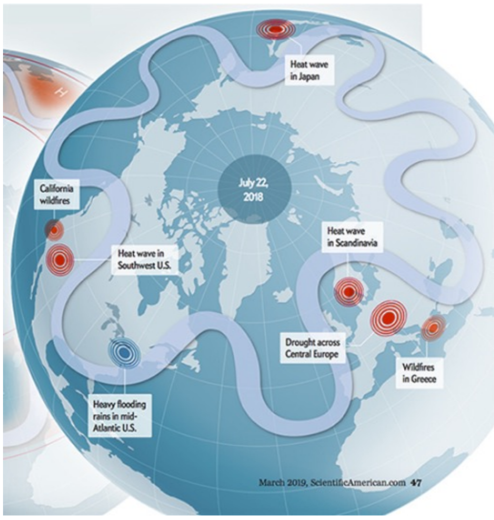


Figure 8: Climatic processes in Central Asia

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

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

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

The **Persian High** is in summer under the pressure of the Sahara High and is increasingly pushed towards the Caspian Sea. As a result, the Westerlies are bendeda result. The Westerlies are bent Southwards and deliveringa result. The Westerlies are bent Southwards and deliver the soft summer rains to southern regions like Pakistan. The halting of the Rossby waves further increases this process.

The **Monsoon** is moving northwest wards and becoming more extreme as a result of the warming Indian Ocean. The chance the Monsoon jumps over the Hindu-Kush is therefore increasing. This effect, especially the Pamir and in less extend the Tien Shan, causes extreme precipitation (Figure 9).

Figure 9: Major climate systems processes influencing the climate of Central Asia.

The mountains of Central Asia are the main geographic feature, decisive for the climate and water resource of the region. The Westerlies lose their humidity when they are pushed up against the mountains. As a result of the processes described above, more precipitation is in the form of rain, precipitation is on a lower elevation, and the temperature on high altitude increases. This results in glacier melt (Figure 10).

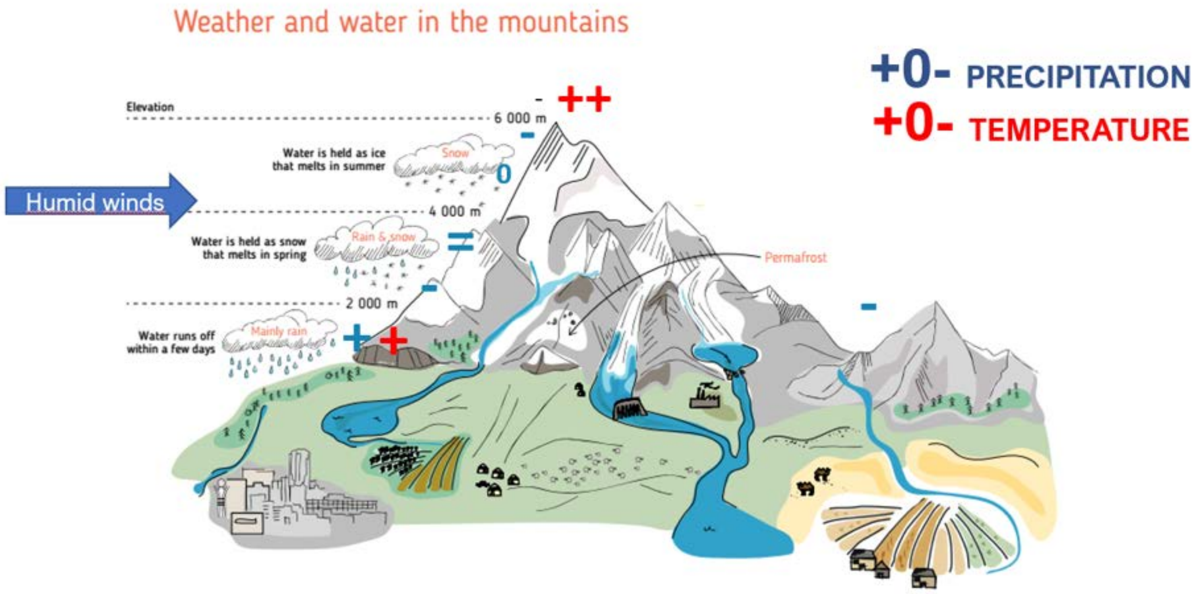


Figure 10: Changes in temperature and precipitation by elevation

4.2 Consequences for Central Asia

The impacts of climate systems were mentioned above (Figure 9). They are projected on Central Asia's climate change impact mapsCentral Asia's climate change impact maps for extreme maximum temperature, drought duration, precipitation, and extreme precipitation for Central Asia (RCP 4.5) based on the 7 most appropriate models[10]. They show a clear link between climate systems change and climate scenarios for relevant climate indicators in Central Asia (Figure 11).

[10] Методология оценки рисков и уязвимости к изменению климата (ОРУИК) на национальном и субнациональном уровнях - Обзор

Heat **Drought**

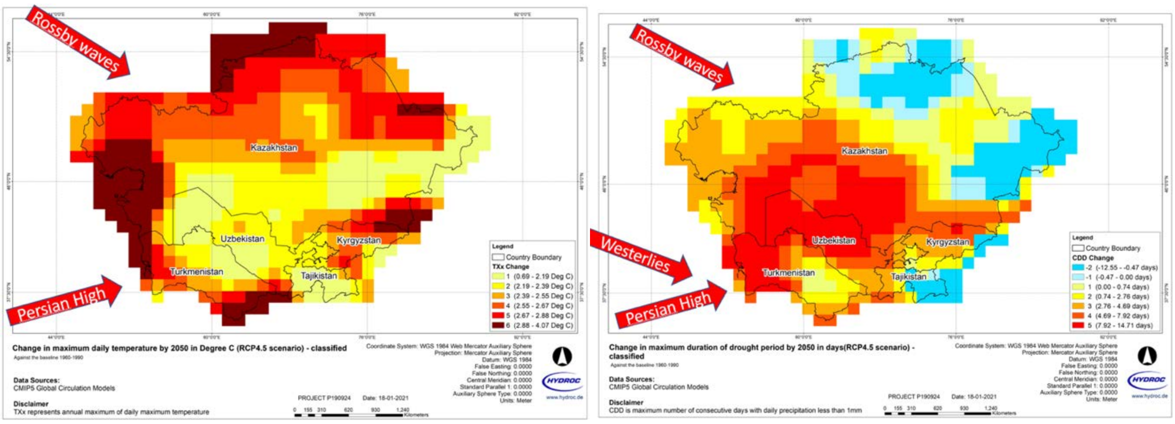


Figure 11: Climate exposure map for Central Asia

The same climatic processesThe mainly rules heat and drought same climatic processes mainly rule heat and drought.

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

Move of the Persian High northwards causes dry and hot weather and bends the humid westerlies to the south. As result the heat and duration are increasing in Central Asia. With the exception of the Pamir. In Northeast Kazakhstan, it results in decreased drought periods (Figure 12).

Total precipitation **Extreme precipitation**

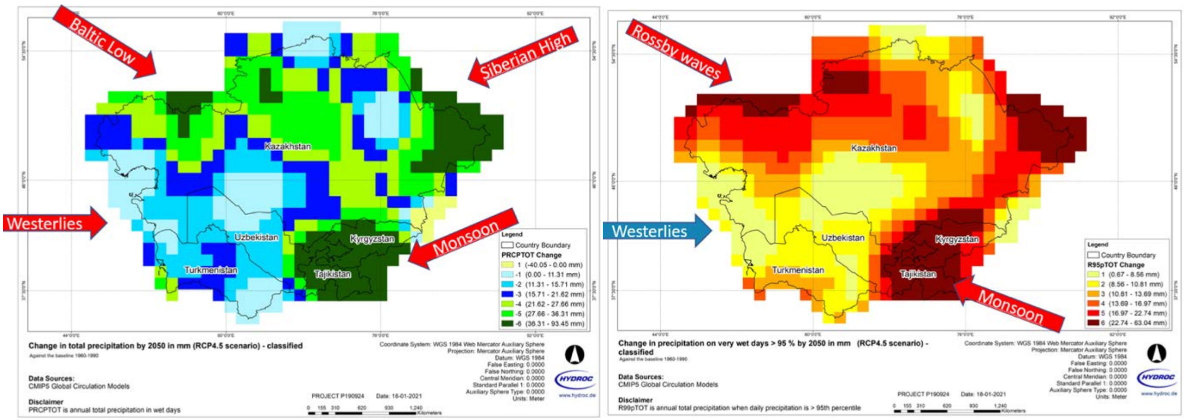


Figure 12: Central Asia precipitation map

Monsoon moving northwest and causes heavy precipitation in southwest CA.

- Westerlies bringing soft rain, Baltic Low bring rain.
- Weakening Siberian High causes more influence in winter of westerlies and Baltic low and precipitation at lower altitude. As a result, the total precipitation in Central Asia is increasing, especially in the mountain areas.

- Monsoon moving northwest and becomes more extreme.
- Halting Rossby waves results in cyclone and anticyclones halt in place for longer period. As result the weather can stay the same for a longer period. In summer this results in drought but also in increase of extreme precipitation. This effect is the strongest in the mountain areas.

5 SECTORAL IMPACT OF CLIMATE CHANGE (FOR SELECTED PILOT SECTORS)

The information and analyses in this section include both original data from our work and data drawn from the World Bank's Climate Change Knowledge Portal[11].

The conceptual scheme of climate change impacts on different spheres and sectors is given in Figure 13.

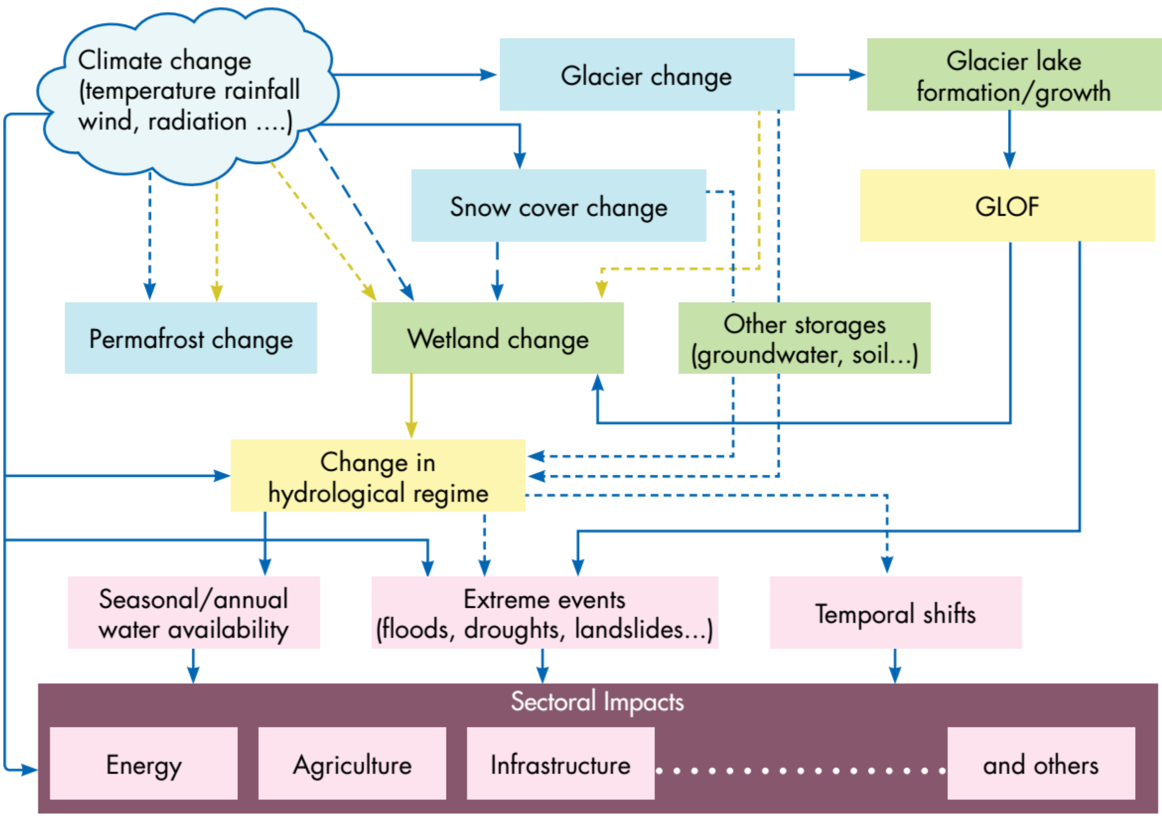


Figure 13: Source: Impacts of Climate Change on the Cryosphere, Hydrological Regimes and Glacial Lakes of the Hindu Kush Himalayas, Lutz et all., ICIMOD, 2016

The following chapter gives a short overview of the potential impact of climate change on the relevant sectors in the pilot region and the relations to the climate indicators. This information is used a basis input for the risk and vulnerability assessment.

As major sectors for Tuyamuyun Hydro Complex territory, agriculture, water, energy, and cross-cutting issues were identified.

[11] https://climateknowledgeportal.worldbank.org/

5.1 Agriculture

Due to projected impacts of global climate change and extreme weather on crop nutrient content and yields, livestock, fisheries and aquaculture, and land use, food security will be threatened. Climate changes have already affected crop suitability in many areas, resulting in changes in the production levels of main crops. Crop production is negatively affected by the increase in both direct and indirect climate extremes. Direct extremes include changes in rainfall extremes, increases in hot nights, extremely high daytime temperature, drought, heat stress, flood and chilling damage. And indirect effects include the spread of pest and diseases, which can also have detrimental effects on cropping systems[12].

Some of the most direct inputs that climate change might have on the agriculture sector are listed in the following table (Table 16).

Table 16: Summary of the impacts that different climate indicators have on the agriculture sector in Uzbekistan and Turkmenistan

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

[12] https://www.ipcc.ch/sr15/

5.2 Water

Over the past century, substantial growth in population, industrial and agricultural activities, and living standards have exacerbated water stress in many parts of the world, especially in semi-arid and arid regions. Climate change, however, will regionally exacerbate or offset the effects of population pressure for the next decades. It is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions. In contrast, water resources are projected to increase at high latitudes. Proportional changes are typically one to three times greater for runoff than for precipitation. Furthermore, Climate change is projected to reduce raw water quality, posing risks to drinking water quality even with conventional treatment[13].

Some of the most direct impacts of climate change on the water sector are listed in the following table (Table 17).

Table 17: Summary of the impacts that different climate indicators have on the water sector in Uzbekistan and Turkmenistan

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

[13] https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

5.3 Energy

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

Some of the most direct impacts of climate change on the energy sector are listed in the following table (Table 18).

Table 18: Summary of the impacts that different climate indicators have on the energy sector in Uzbekistan and Turkmenistan

Heat	Precipitation	Extreme Precipitation	Drought
Fossil energy requires water for cooling. An increase in the temperature of the water bodies will inevitably cause a decrease in cooling capacity. Furthermore, water discharged into the environment from the cooling systems will have a higher temperature thus increasing the environmental risks. It is expected that the energy required by 2050 for cooling will increase as much as 25% Reduced generation effectivity Reduced transmission capacity	More precipitation means more water in the river and an increase in hydropower potentials. However, the occurrence of more extreme precipitation means that reservoirs will need to increase their ability to buffer dangerous floods thus reducing the overall efficiency of hydropower schemes	Due to the increased risk of flooding, normal operation levels will have to be lowered, thus reducing the overall production efficiency of the hydro schemes. Furthermore, flood risks may hinder energy transmission and transportation. In addition to that, larger floods will cause more sediments transport, an increase in water turbidity, and an increase in the mechanical equipment's wear.	Droughts limit the availability of water required for cooling fossil power plants, thus reducing energy production. To account for more frequent droughts, reservoir will need to retain more water thus reducing the hydro power production.

5.4 Hazards

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

Some of the most direct impacts that climate change might have on increasing the likelihood of hazardous events are listed in the following table (Table 19).

Table 19: Summary of the impacts that different climate indicators have on natural hazards in Uzbekistan and Turkmenistan

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

6 CLIMATE IMPACT CHAIN

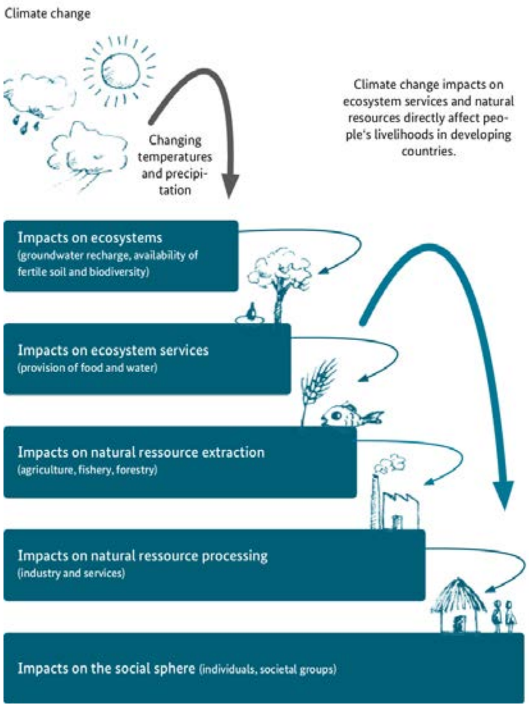


Figure 14: Climate change impacts

Climate change is not putting direct stress on sectors. The pressure of climate change goes through the impact on the ecosystem and ecosystem services and first than our use of natural resource, processing, marketing and human impact (Figure 14). [14]

Besides the ecosystem, human behavior is also influencing the impact chain, through publics adaptive capacity, but also through its influence on natural resources like land degradation, which is multifolding the climate risk on natural hazards. Also, infrastructure like dikes influences the impacts (Figure 15).

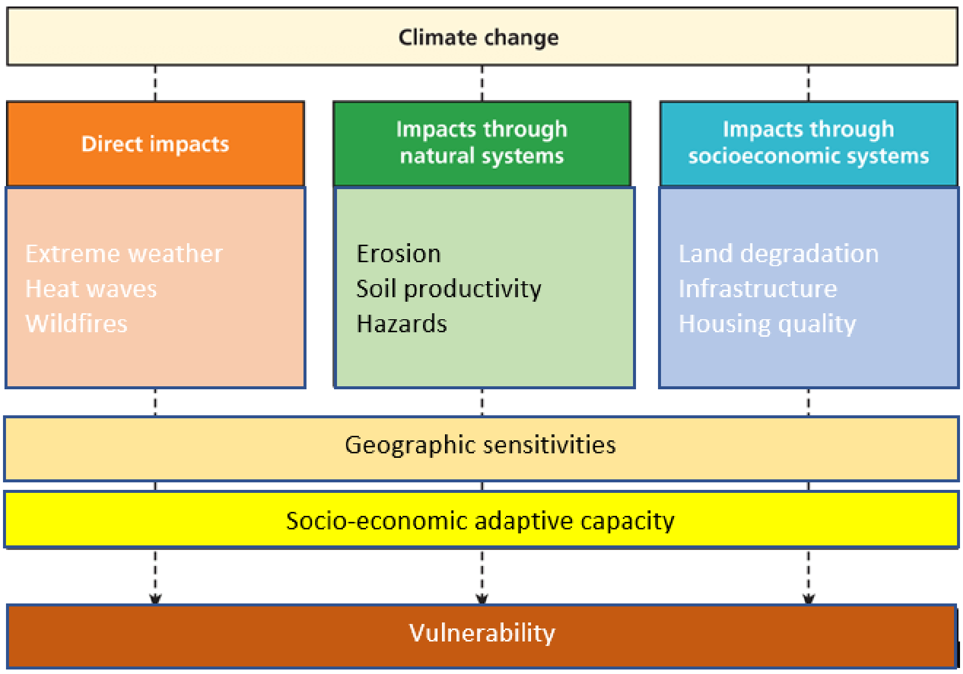


Figure 15: The climate impact chain

[14] Fritzsche et.all (2014). The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments.

The direct impact is on the extreme weather like heat waves, part of the impact is through the natural systems and causing erosion and hazards. Human activity has a strong influence on the impact of climate exposure, likea strong influence on the impact of climate exposure, like unsustainable land use and resulting land degradation, and positively through adapted housing quality and infrastructure.

Local geographical circumstances can increase climate exposure, like drought risk, water stress, vulnerability for land productivity.

The socio-economic situation strongly influences the adaptive capacity, the capacity to cope with climate exposure. Here factors as poverty, health and education are coming into the scope.

7 CLIMATE RISK AND VULNERABILITY ASSESSMENT

7.1 General Aspects

Climate Risk and Vulnerability Assessments aim to bridge the gap between climate exposure and climate change adaptation. This is done by, besides climate change exposure, including sensitivity to climate change and adaptive capacity in the process of decision making. This results in a vulnerability assessment. Based on the vulnerability assessment, the adaptation measure can be more easily selected and prioritized[15].

The Climate Risk and Vulnerability Assessment comprise 8 main tasks, from issue identification through data collection to aggregation of maps. As CRVA is issue-driven, the issues and the sectors involved must be clearly described in the preparation phase. Based on the sectors the climate indices must be selected[16].

Table 20: Climate indicators used for CRVA for different sectors

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

Sensitivity can be divided between:

- Geographic sensitivities

[15] Methodology on climate risk and vulnerability assessment (CRVA) on national and sub national levels - Summary
[16] UNFCCC reports and ADB climate proofing of investments

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

7.2 Methodology Adaptation to National Level CRVA

To understand the priority adaptation measures (Figure 16), it is needed to understand[17]:

- Climate exposure

Sensitivity

Adaptive capacity

And as result the vulnerability

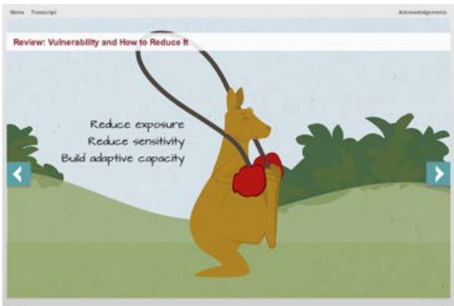


Figure 16: Climate change adaptation measures

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

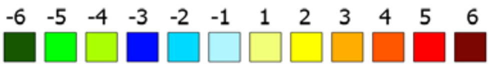
[17] WWF, Understanding of vulnerability

7.3 Set up of the Climate Exposure

The climate exposure assessment is based on comparing the average between 1960-1990 and the modelled data for the scenarios for RCP[18] 4.5 and 8.5 (scenarios for a world climate temperature increase of 4,5 °C respectively 8,5 °C . Extreme parameters within CIMP6 are expected to be defined by the ETCCDI working group by the end of this year, and the first extreme parameter models are expected to be available by the end of 2022.

The mapping is comprised of seven tested and best-fitting models: CMCC-CM, CSIRO-Mk3.6.0, GFDL-ESM2G, MIROC5, MPI-ESM-LR, MPI-ESM-MR and MRI-CGCM3. The scale is limited by the scale of available models under CIMP5 – extreme climate indicators and is 100x100 km.

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



improved – vulnerability - worsened

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

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

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

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

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

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

In the figure below (Figure 17) you find a schematic of how the information is composed.

[18] RCP means 'Representative Concentration Pathway', used in science, which represent the concentration of CO_2. RCP8.5 represents a world average temperature increase of 3,7°C; RCP4.5 represents a world average temperature increase of 1,8°C

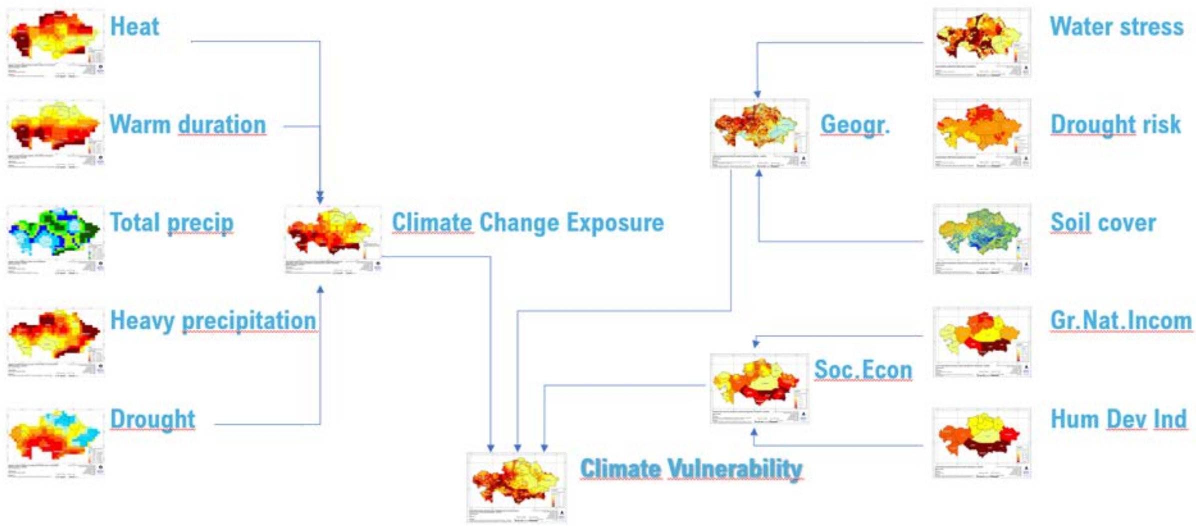


Figure 17: Schematic representation of the Climate Risk and Vulnerability Analysis

8 CLIMATE RISK VULNERABILITY ANALYSIS FOR TUYAMUYUN HDRO COMPLEX AREA

The national CRVA[19] is built from the following components:

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

The scenarios used are RCP4.5 and RCP8.5, representing a world average temperature increase of 1.8°C resp. 3,7 °C. The maps cover the area irrigated by the Tuyamuyun Hydro Complex in Uzbekistan and Turkmenistan.

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

- **Climate Change Exposure**: The Tuyamuyun Hydro Complex area has a high climate exposure. Increase of heat (up to 3.1°C) and drought (up to 11 days) are pressing the most on this area. Extreme maximum temperatures are increasing the most on the northeast of the complex (Figure 18). The duration of the warm period increases the most in the northern part of the pilot area by 18% (Figure 19). The increase of precipitation up to 17 mm/yr (Figure 20) is nihilated by the increased heat and thus evaporation and the extended duration of drought periods (Figure 24). The increase of precipitation will mainly come down in the form of heavy precipitation (up to 11 mm) (Figure 21–23). This counts especially the southern half of the area. As result the highest climate exposure is expected in the south western districts of the Tuyamuyun area (Figure 25).
- **Climate Change related Geographical sensitivity**: The whole of the Tuyamuyun Hydro Complex area is under very high water stress (high percentage (over 80%) of water resource is used by the sectors) (Figure 26). Also, the drought risk is medium to high (Figure 27). In average over the last 20 years the soil productivity has been slightly increasing in the central part of the Tuyamuyun Hydro complex area, most probably due to improvements in irrigated agriculture. At the edges and outside of the irrigated areas there is a clear reduction in soil productivity, partly due to climate change, partly due to water and human induced land degradation. The most increase is visible in the northern and eastern part of the area (Figure 28). As result the geographic sensitivity

19 Based on the adapted methodology of GIZ guidebook for Climate Risk. Assessment for Ecosystem-based Adaptation

is concentrated in the northern and western outskirts of the Tuyamuyun Hydro Complex Area (Figure 29).

- **Climate Change related Socio-economic sensitivity:** Adaptive capacity is related to the income per capita, Education, health, life expectation and distant to market. The GNI PPP per capita is substantial higher in Turkmenistan (16.000 GNI PPP per capita) than in both Uzbekistan provinces (average 7.000 GNI PPP per capita). On human development index (combining Life expectance, education and health) all three provinces score low. Dashoguz scores lower than Khorezm and Karakalpakstan. With a growing population the education and health care are spheres of attention for all three provinces in both Uzbekistan and Turkmenistan. In combination the single-sectoral economy and seasonable income of households, at least in Uzbekistan, this leads to a high socioeconomic sensitivity for all three provinces in the area. Remarkable differences are found between the districts in the three provinces. In Uzbekistan part of the Tuyamuyun Hydro Complex area Xonqa in Khorezm, Amudarya and Kanlikol in Karakalpakstan may be considered as the having the highest socio-economic sensitivity. For the Turkmenistan part of the area not such a differentiation per district could be made.

  Analysis of socio-economic data shows that the share of water intake decreases less than discharge into the Aral Sea. As a result, the available supply to cover the increased water demand as a result of climate adaptation is not available. Therefore, adaptation should be aimed at increasing the efficiency of water use.

  The high loss of water between abstraction from the Amu Darya and use on farms in Dashoguz velayat is around 40%. Water consumption per hectare of crops is also relatively high. Both of these factors increase vulnerability, but also offer good opportunities for saving water and improving water use efficiency.

  In the territories of Turkmenistan and Uzbekistan, which are part of the Tuyamuyun hydrocomplex area, the population is increasing, which further increases vulnerability.

  In the territory of Dashoguz velayat of Turkmenistan, the number of livestock increases. As a result of reduced grazing opportunities on dry pastures, the dependence on irrigation water will increase, as well as the risk of land degradation.

  In the Turkmen part of the territory, incomes are relatively higher, but dependence on agriculture is also higher. As a result, higher income does not lead to reduced vulnerability.

In conclusion, the climate-risk vulnerability map (Figure 30) derived from the three components described above, provides indication that the vulnerability for climate change is based on drought risk, increased heat, under-level education and health care. The land degradation on the Aral Sea side of the territory increase the vulnerability.

The details of the Climate Risk Vulnerability Analysis conducted over Tuyamuyun Hydro Complex area are provided in the following sections.

8.1 Sectoral Vulnerability (only for the selected pilot sectors)

Based on the CRVA and the impact of climate change on the sectors described in chapter 5, the following sectoral conclusions can be drawn.

The different sectors are influenced differently by the climate change.

- **Agriculture** is expected to be hit by climate exposure in Tuyamuyun Hydro Complex area. An increase of extreme temperature (Figure 18) and warmth duration (Figure 19) will have the most significant impact. The temperature above which crops are experiencing heat stress is 37°C. As temperatures above 37-40oC will be reached earlier in the growing period, the effective growing season may become shorter. Wheat, and fruit, with a relatively low-stress temperature, are expected to be hardest hit by climate exposure. Cotton accepts higher extreme temperatures, but also for this crop, the climate exposure exceeds the stress temperatures. The increase of extreme precipitation (Figure 22) will level out the advantages of increasing total precipitation (Figure 20). Land degradation north and west of the pilot area. The water stress and drought risk as mentioned under water puts additional pressure on the climate change impact. Increased education and knowledge transfer is expected to increase the adaptive capacity and needs to be a point of attention, as is the medical health service.
- **The water sector may expect increased stress due to the increased drought periods, water stress,** and drought risk in the area (Figure 26, Figure 27). These factors may also influence drinking water availability. This goes hand in hand with the increased request for water for most sectors. The increased heavy precipitation will increase the need for increased buffer capacity. Together with the increase of evaporation, will this reduce the effective capacity of water reserves. In the upper Amu Darya (Pyanj) basin, precipitation is increasing, but mainly in extreme precipitation. Also, in the upper basin there is a tendency of land degradation (Figure 28). This combination is expected to increase maximum discharge of around 20%[20]. This means for Amu Darya that the flood risk is increasing. In addition, the shift in elevation of precipitation to lower

[20] Climate Resilience in design and operation of irrigation and flood control projects in the Pyanj valley, ADB, 2017

altitude and the seasonal shift to spring[21]. After 2050 the impact of glacier melt will decrease[22,23] but the increase precipitation will proceed. It is expected that the combination of glacier melt, land degradation, increased precipitation, but also increased drought duration will result in more extreme discharges and sediment flow in the Amu Darya, on which the water reservoir management and the flood risk management has to be adapted. This does not take into account the developments in hydro power and irrigation upstream[24] [25] [26]

- **The energy sector may expect more significant extremes in water supply, which requires more buffering for drought and extreme discharge, reducing** efficiency. The extreme discharge is expected to increase by 20% for the Pyanj[27], in combination with the increased 5 days precipitation in Pamir and Afghanistan mountains and the land degradation in Afghanistan and southern Tajikistan, increased turbidity in the Amudarya is ongoing[28] and can be further expected, resulting in increased sedimentation in the Tuyamuyun hydro Complex. This will also impact the water reserves for irrigation.
- The main **hazards** which are expected to increase are heat and drought. These are expected to become the highest climate change-induced economic costs.

Education and health care in the region need additional attention in relation to vulnerability.

8.2 Climate Change Exposure

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

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

[21] Snow cover variability in central asia, Andreas Dietz, a.o., 2013
[22] impacts of climate change on the cryosphere, hydrological regimes of the Hindu Kush and Himalayas, Lutz et all., ICOMOD, 2016
23 Glacier Resources of Tajikistan, Kyamov.A
[24] WFP/UNEP, climate chnage in afghanistan 2016
[25] The Afghan part of the Amu Darya Basin, IMpact of irrigation in Northern Afghanstan on Water use in the Amu Darya Basin, W.Klemp et.all. FAO, 2010
[26] Review of current and possible future relations in Amu Darya Basin, Hassani, Kabul, 2017
[27] Climate Resilience in design and operation of irrigation and flood control projects in the Pyanj valley, ADB, 2017
[28] ESA Climate Dashboard, water reservoirs and lakes - https://climate.esa.int/en/odp/#/project/lakes

world average temperature increase of 1,8 °C and RCP8.5 for 3,7 °C. For both Turkmenistan and Uzbekistan, the relative change for the country is used for this assessment.

8.2.1 Change in maximum daily temperature (TXx)

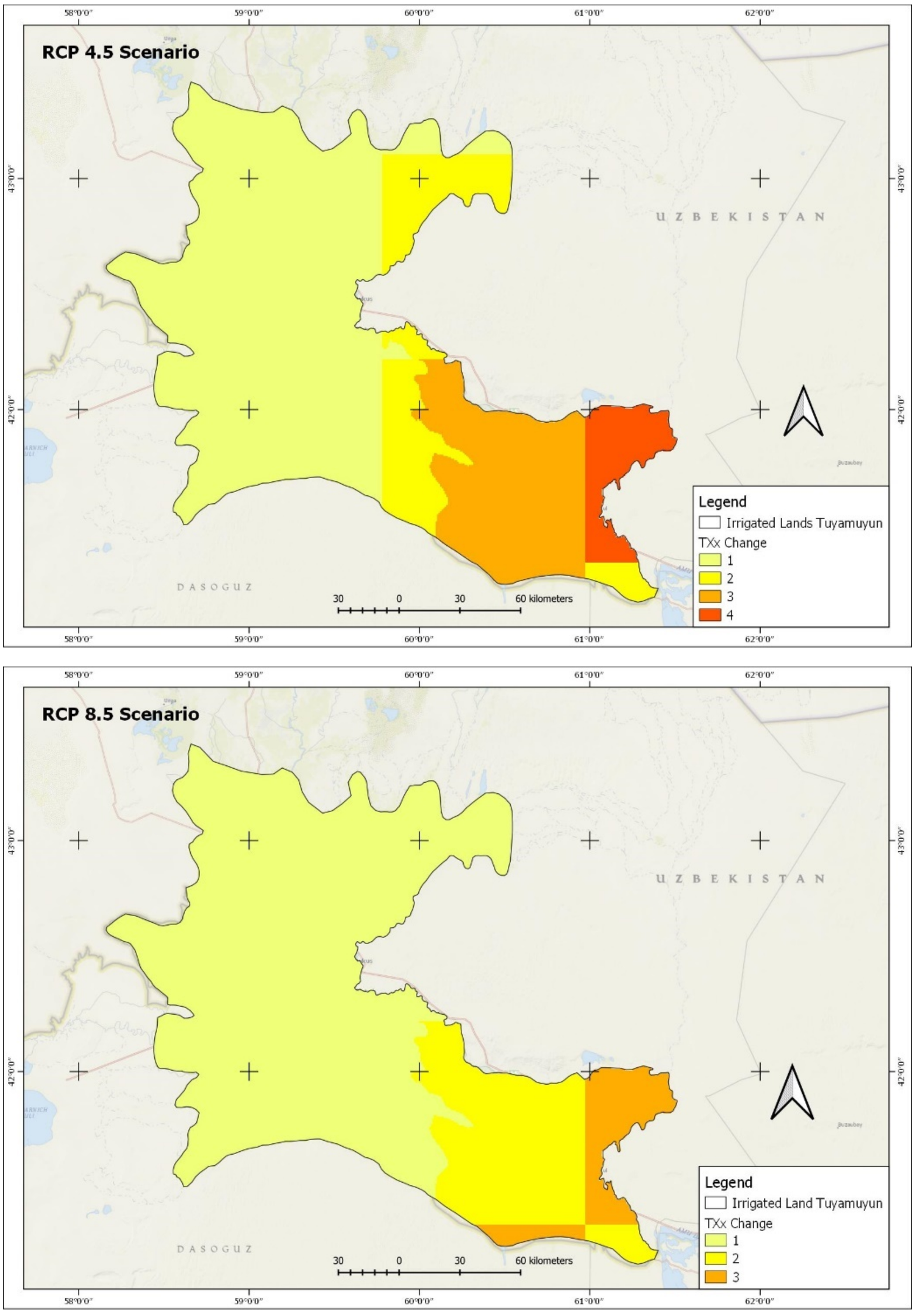


Figure 18: Projected Change in Maximum Daily Temperature (TXx) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. TXx represents annual maximum values of daily maximum temperatures

The most significant changes in the maximum daily temperature are expected in the east of the study area. The primary influence on this is exerted by the Persian anticyclones, which generally show a tendency for a gradual shift northward, reducing the total amount of precipitation and providing hot weather.

8.2.2 Change in warmth duration (Tx90p)

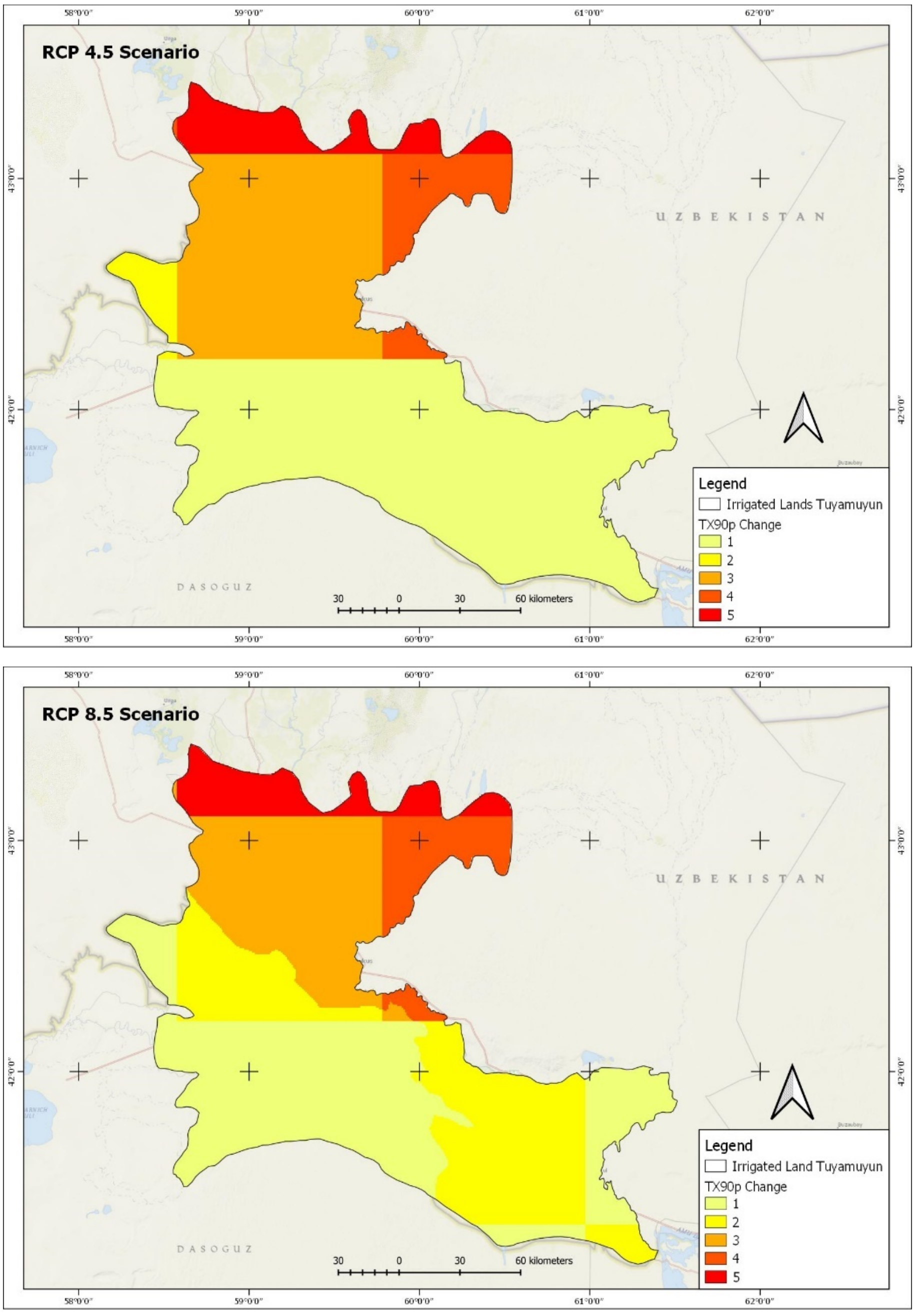


Figure 19: Projected change in percentage of warm daytime > 90% (TX90p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. TX90p represents % of days when the daily maximum temperature > 90th percentile

The percentage of days with maximum temperatures in the year also increases, especially in the northern part of the territory, mainly in its Uzbek part towards the Aral Sea. However, it should be noted that this spatial pattern does not coincide with the distribution of absolute values of maximum temperature in the territory.

8.2.3 Change in total precipitation (PrcpTOT)

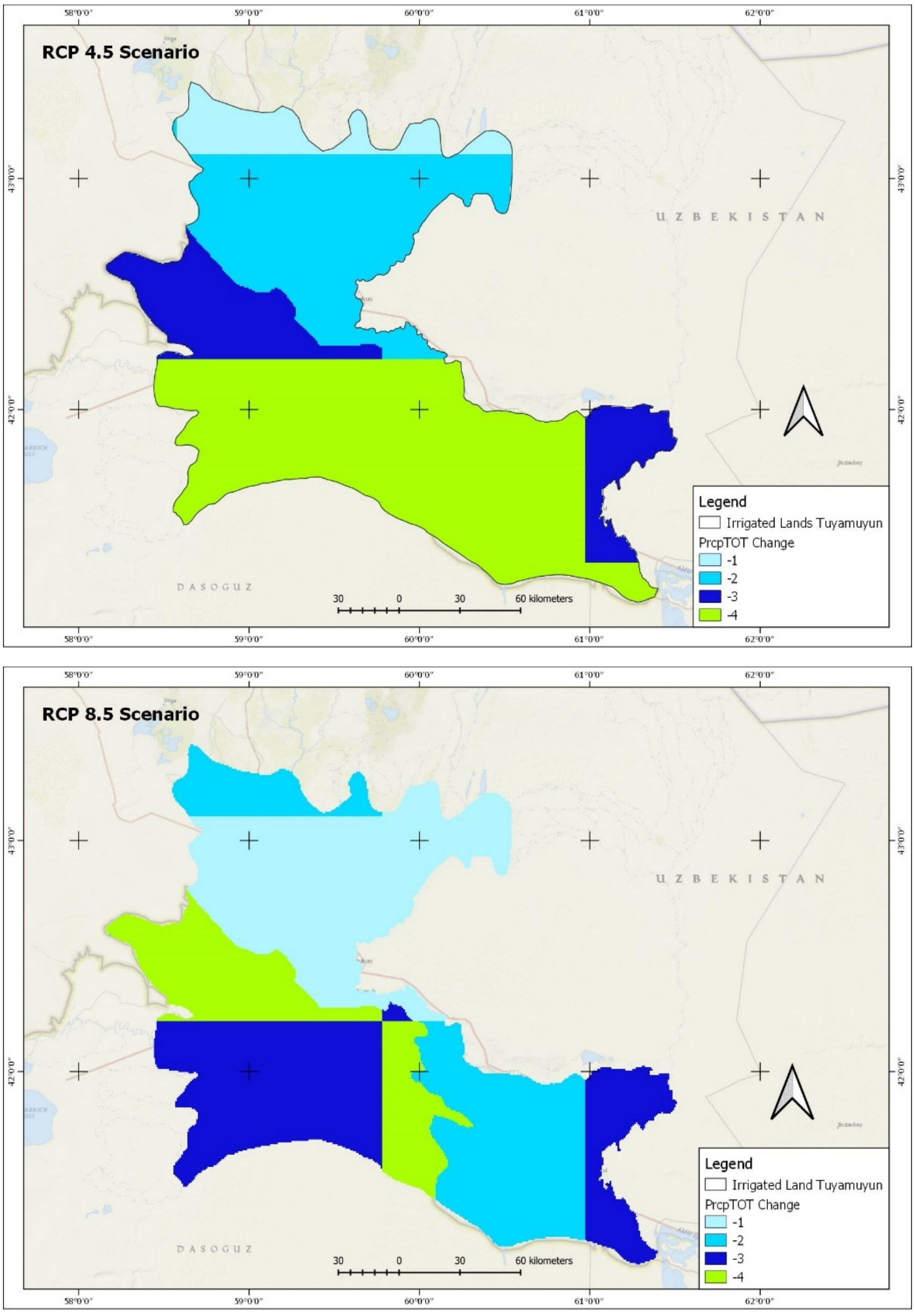


Figure 20:Projected change in total precipitation by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Total precipitation represents annual precipitation in wet days

The total amount of precipitation in the study area increases in the northern part to a lesser extent than in the southern part (according to the more probable scenario RCP 4.5). Due to the gradual weakening of the action of Siberian cyclones, there is a seasonal shift in precipitation from early winter to late winter and from early summer to early spring.

8.2.4 Heavy precipitation (Rx95p)

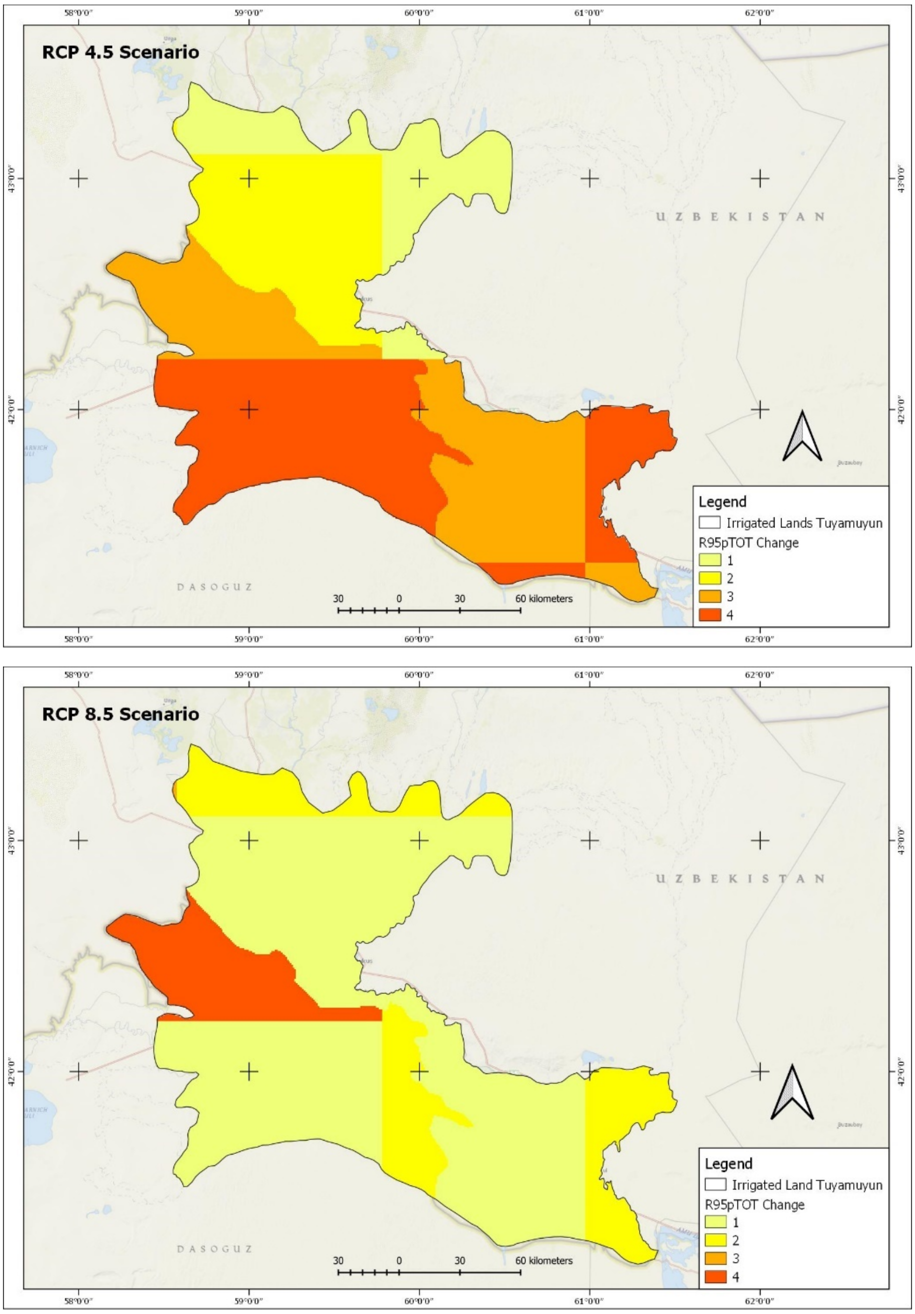


Figure 21: Projected change in precipitation on very wet days >95% (R95p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. R95p represents annual total precipitation when daily precipitation is > 95th percentile

The amount of heavy precipitation, as well as the total amount of precipitation, will increase. According to the RCP 4.5 scenario, a more intensive trend of increasing heavy precipitation is observed in the southern (predominantly Turkmen) part of the Tuyamuyun hydrocomplex area.

8.2.5 Extreme precipitation (Rx99p)

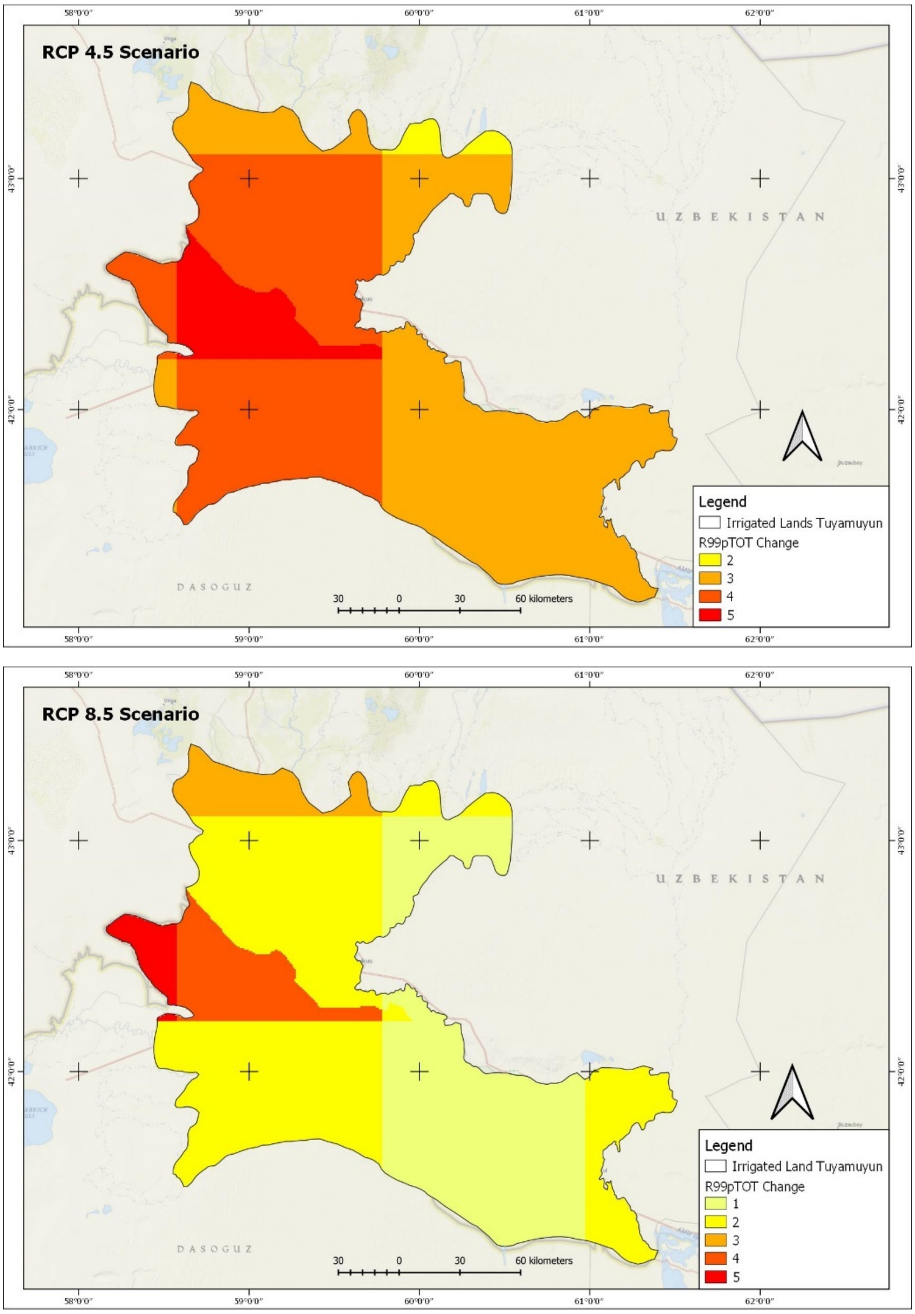


Figure 22: Projected change in precipitation on extremely wet days >99% (R99p) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. R99p represents annual total precipitation when daily precipitation is > 99th percentile

The extreme precipitation value also tends to increase, especially in the western part of the Tuyamuyun hydrocomplex. This leads to flooding risks, intensification of suspended solids removal with river flow and sedimentation in reservoirs.

8.2.6 Day maximum precipitation (Rx1-day)

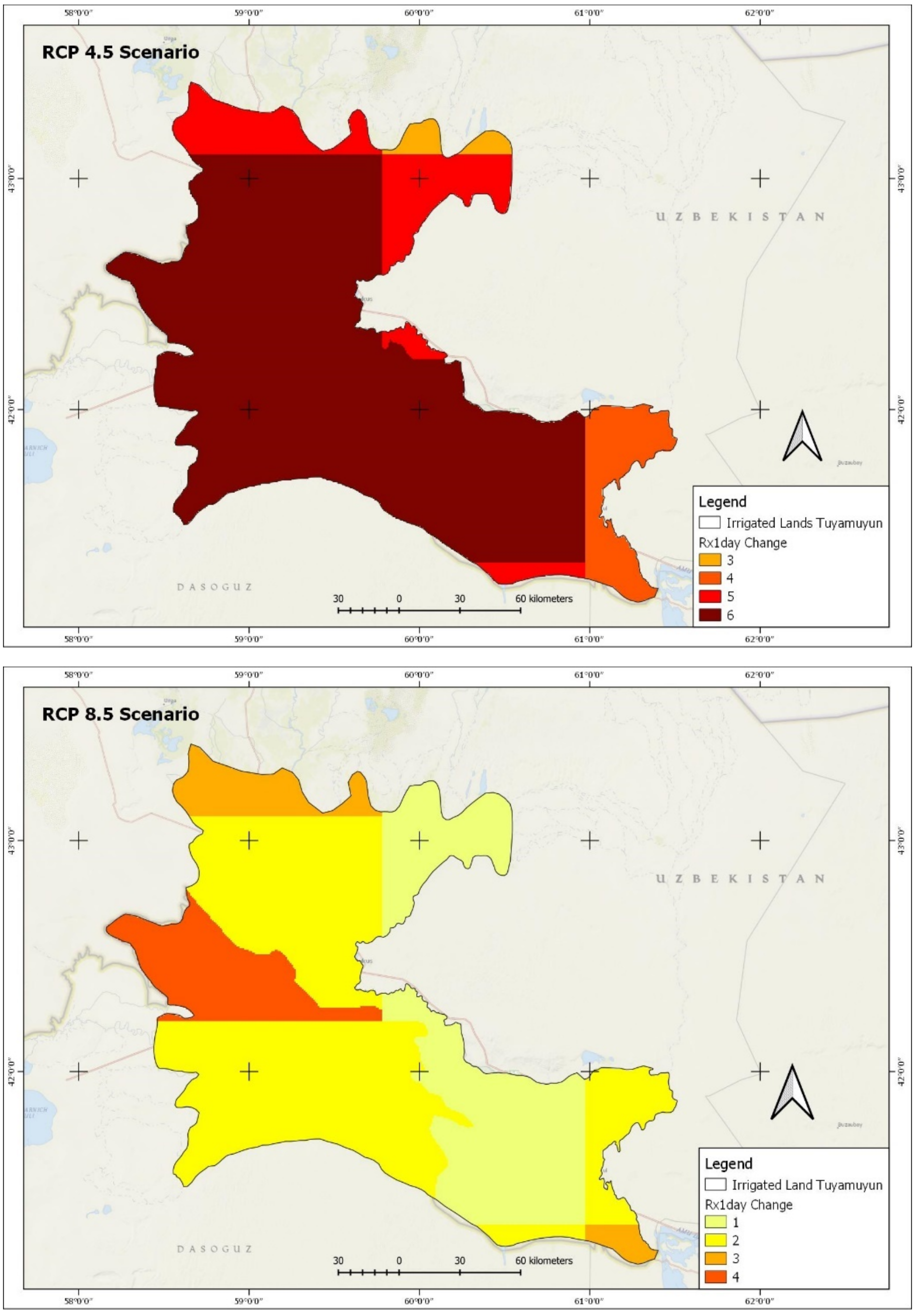


Figure 23: Projected change in highest 1-day precipitation per year (R1-day) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Rx1day represents annual maximum 1-day precipitation.

Maximum daily precipitation shows a noticeable tendency to increase practically over all Tuyamuyun hydrocomplex, especially for the RCP 4.5 scenario. This indicator also indicates increased risks of floods on Amu Darya river and its tributaries.

8.2.7 Drought period duration (CDD)

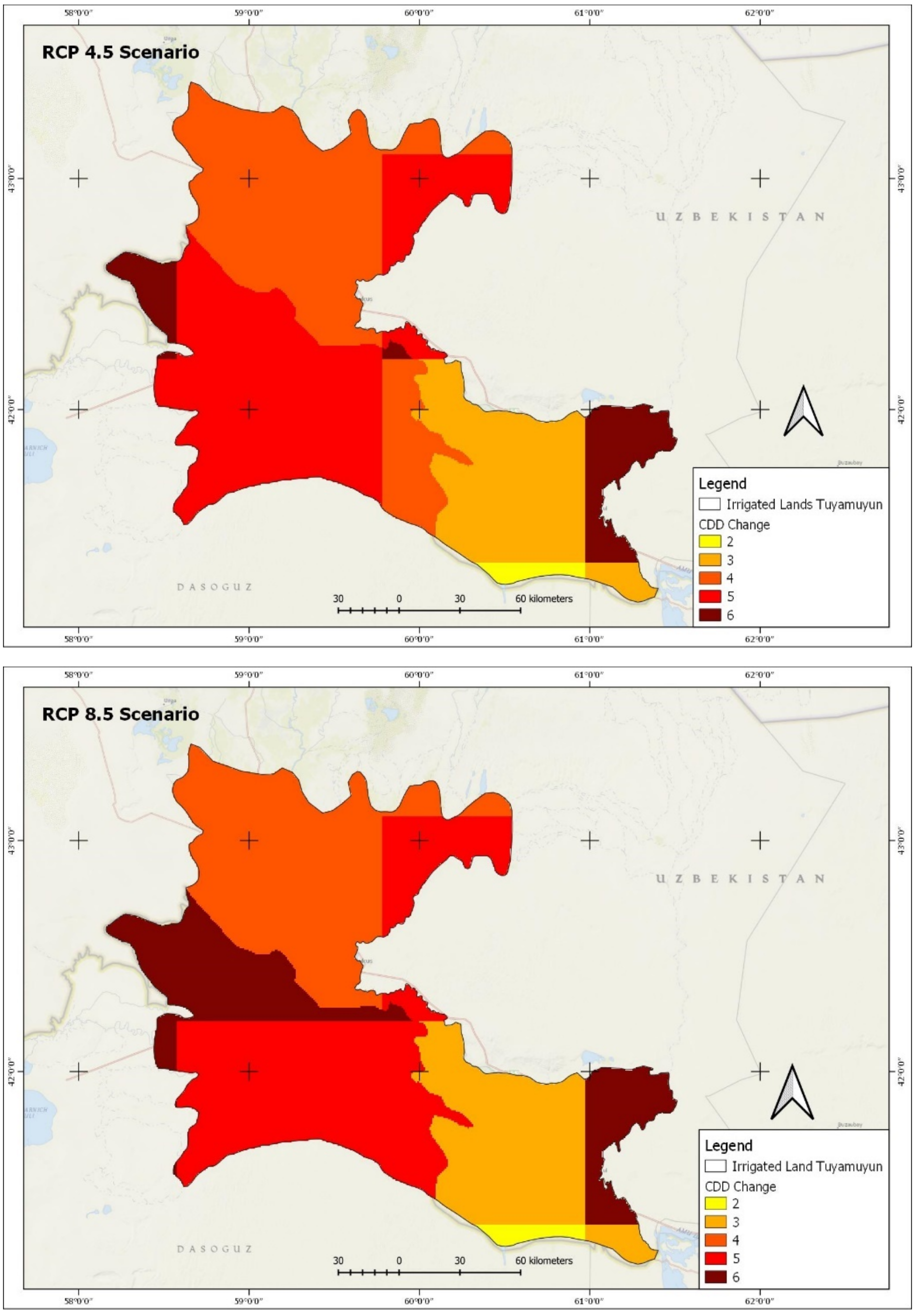
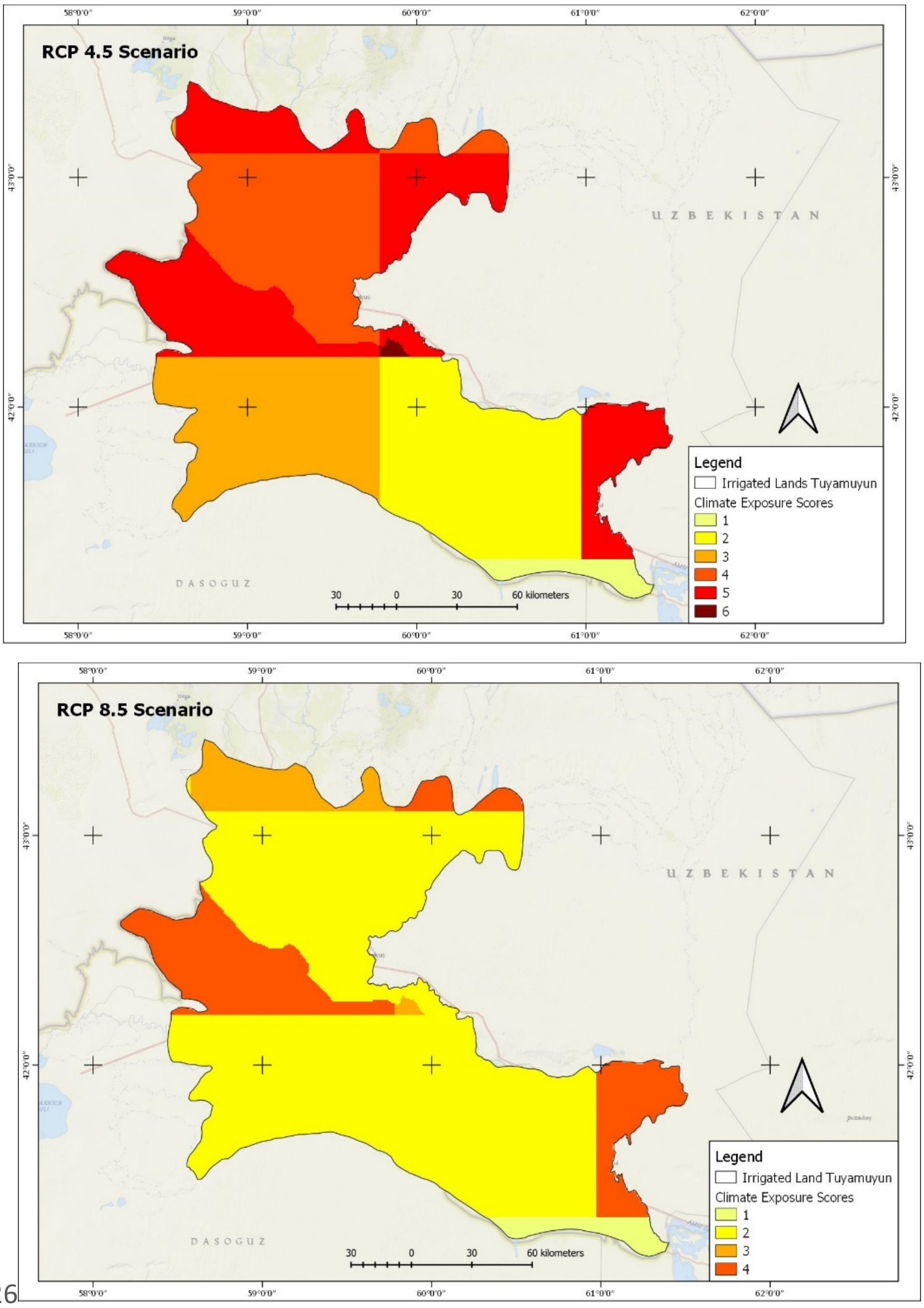


Figure 24: Projected change in maximum duration of drought period (CDD) by 2050 against the baseline 1960-1990. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. CDD is maximum number of consecutive days with daily precipitation less than 1mm.

The duration of the dry period during the year will increase throughout the Tuyamuyun hydrocomplex, although the degree of increase varies depending on the spatial distribution of temperatures and precipitation.

8.2.8 Combined climate exposure



[26]

Figure 25: Total climate exposure as a summary of scores of the classified climate maps for heat / total precipitation/share of heavy precipitation/drought duration by 2050. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios.

The general impact of climatic factors is more pronounced in the northern half of the Tuyamuyun hydrocomplex. The most significant contribution to this is the corresponding changes in the maximum temperature and duration of the dry period during the year.

8.3 Climate change related geographical sensitivity

8.3.1 Water stress (percentage of water resources used)

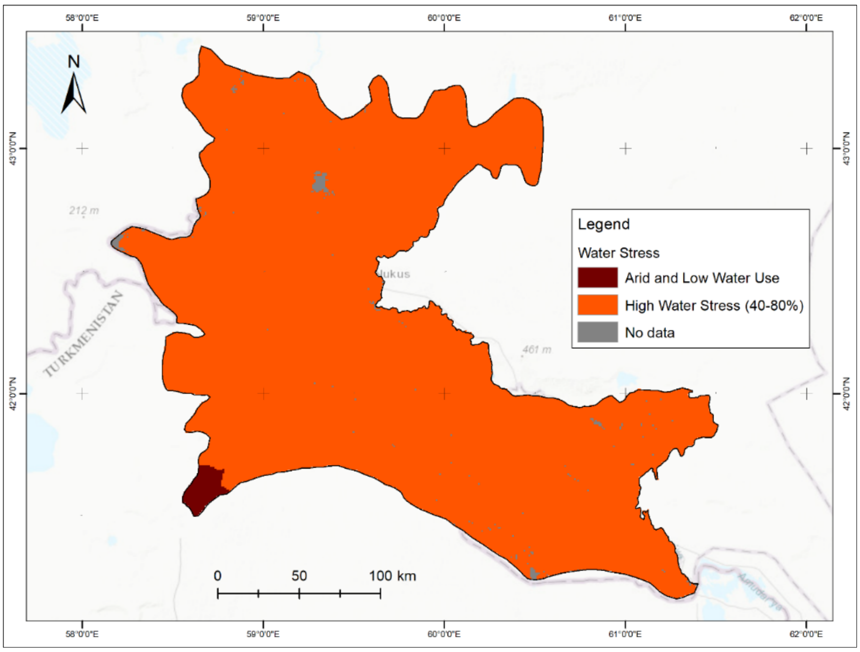


Figure 26: Annual Baseline (1960-2014) water stress. From Aqueduct 3.0, World Resources Institute. Baseline water stress measures the ratio of sectoral water request to water availability, which is then, expressed in percentage.

Water resources deficit, which is expressed by the ratio of water demand to available water volume, belongs to the high category for the whole territory of the Tuyamuyun hydrocomplex. It means that from 40 to 80 % of available water resources are used for different needs, first of all for irrigation.

8.3.2 Drought risk (population, frequency, % water use)

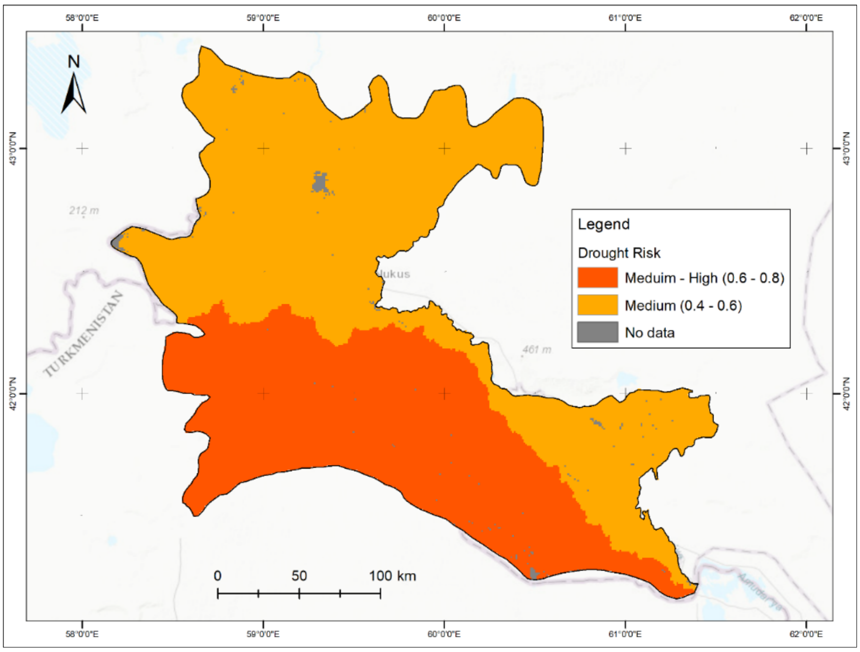


Figure 27: Annual Baseline (2000-2014) Droughts risk. From Aqueduct 3.0, World Resources Institute. Droughts risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects.

Drought risk is a calculated indicator that indicates the locations of likely droughts, the concentration of population and assets exposed to drought, as well as the vulnerability of population and assets to the adverse effects of droughts. The drought risk is estimated from medium to high for the southern part of the territory (mainly Turkmenistan). For the northern part, this indicator is slightly lower and belongs to the medium category. This is due to higher population density and a higher frequency of droughts in the southern part of the territory.

8.3.3 Land productivity (change in soil cover 2000-2020)

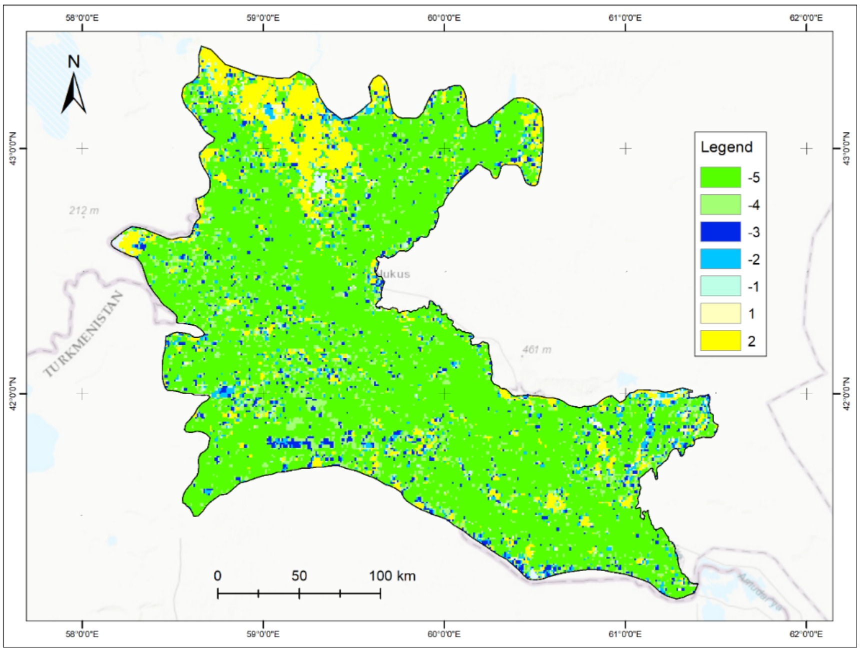


Figure 28: Change in NVDI as indicator for soil productivity from 2000-2020 for the project area. Data from NASA LP DAAC at the USGSEROS Center. The MODIS NDVI is computed from atmospherically correlated bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols, and cloudy shadows

NDVI index shows that practically on the whole territory of Tuyamuyun hydrocomplex, relatively favorable change of soil cover condition is observed towards its improvement as result of improved agricultural practices since 2000. However, in the northern part of the territory and some places on its edges, the deterioration of this index is traced which means the processes of soil degradation are related, probably, to more intensive farming and cattle grazing (Figure 28 above).

8.3.4 Combined geographic sensitivity to climate change

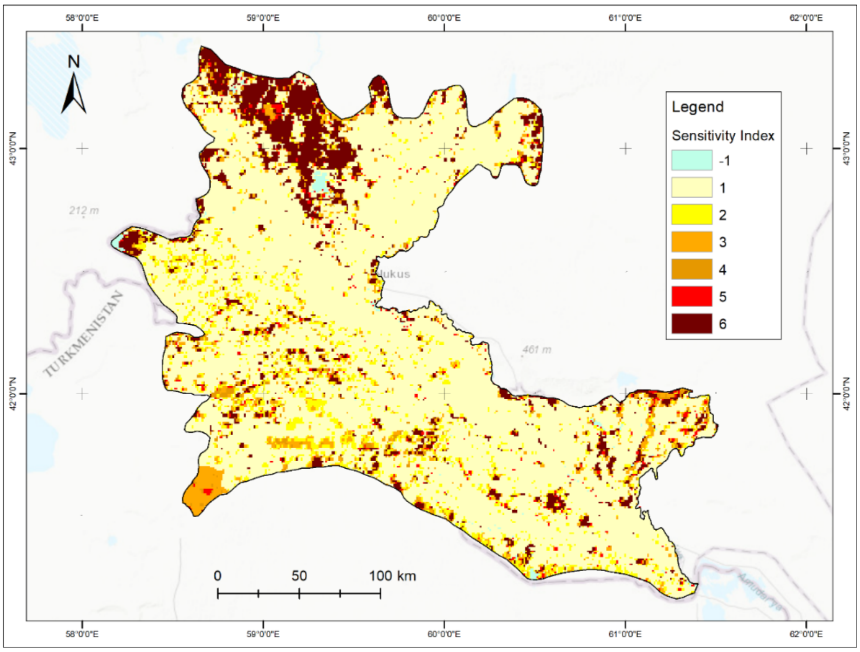


Figure 29: Combined geographic sensitivity to climate change. From NASA LP DAAC at the USGSEROS Center; EU Copernicus Space Agency (ESA); Aqueduct 3.0, World Resources Institute. The combined geographic sensitivity map is obtained using the equation: 2 * NDV Trend + 2 * baseline water stress + baseline droughts risk

Combined geographical sensitivity, which is an integral indicator compiled based on values of water resources deficit and soil productivity, shows weak growth in most of the area. However, the northern part of the studied area (on the territory of Uzbekistan, towards the Aral Sea) is characterized by the highest sensitivity.

8.4 Climate change vulnerability map

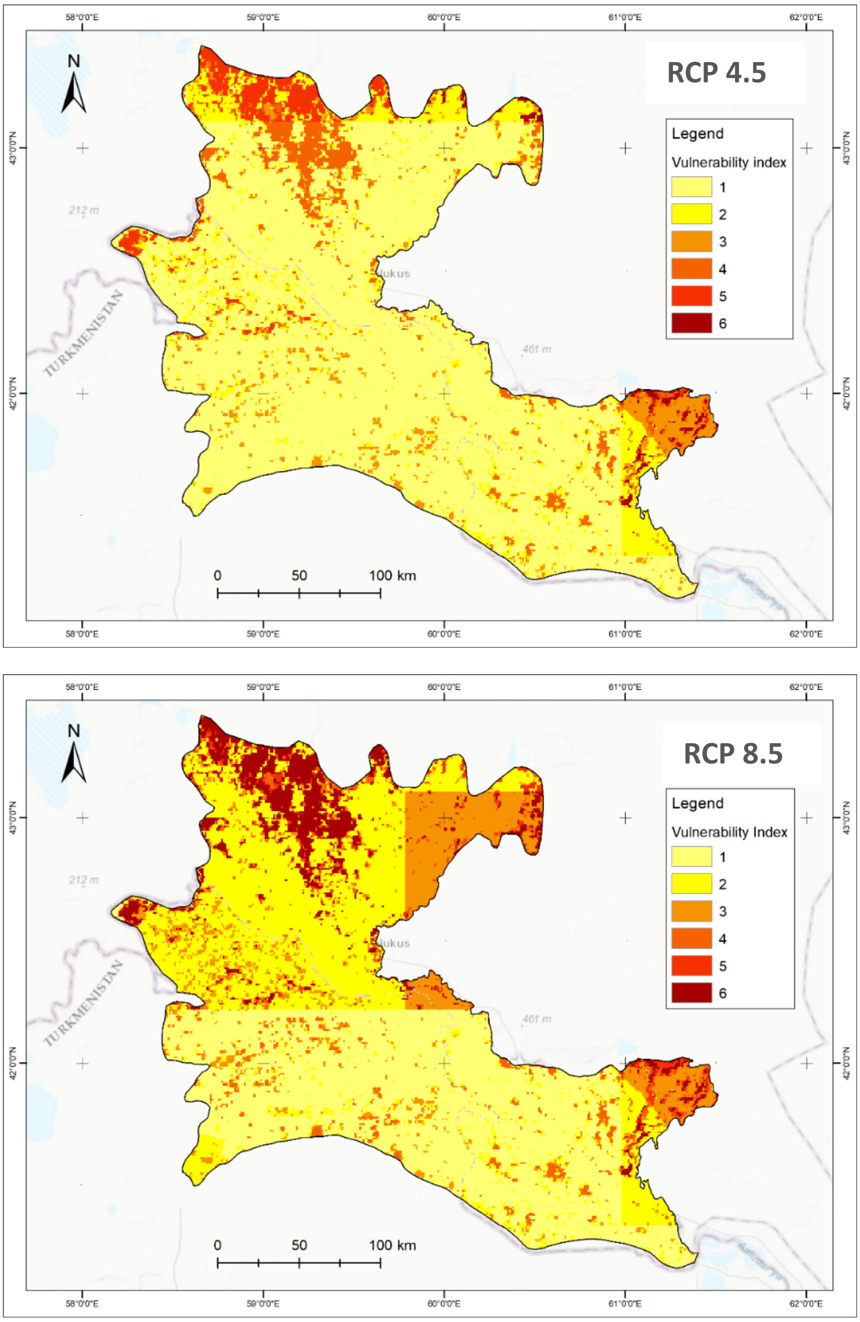


Figure 30: Climate change vulnerability map based on climate exposure, geographic and socio-economic sensitivity. The climate change vulnerability map is obtained using the equation: climate exposure + geographic sensitivity + socio-economical sensitivity.

The final map of vulnerability to climate change, which takes into account the combined impact of climate, geographic and socio-economic sensitivity, shows that the greatest vulnerability is typical for the northern part of the territory.

8.5 Thematic Maps

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

8.5.1 Agriculture

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

- **Land use map,** which was developed to help identify specific climate and geographic sensitivities for certain land uses.
- **Elevation map** which was developed to identify slope risk

8.5.1.1 Land use map

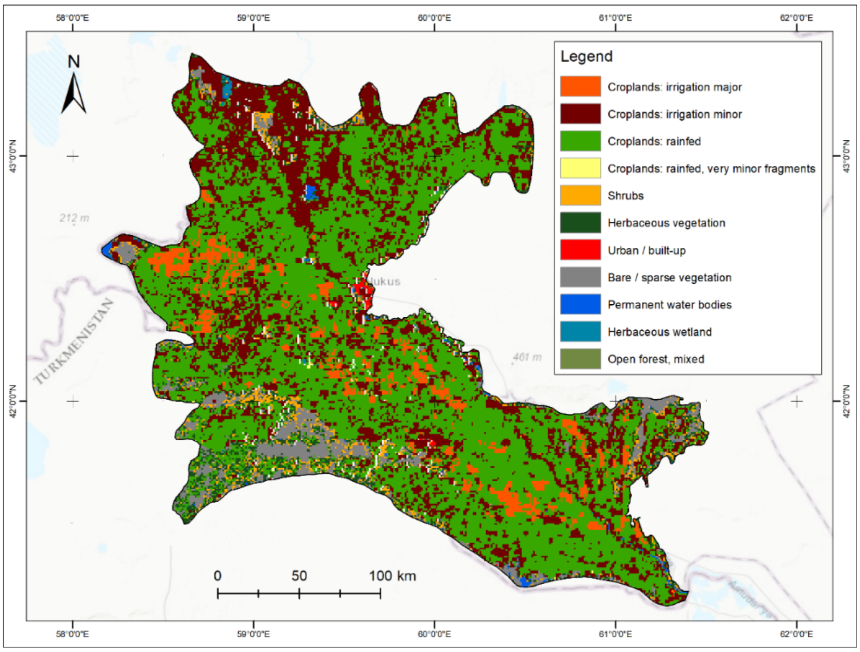


Figure 31: Global land cover map. Data from EU Copernicus. The land cover map represents spatial information on different classes of physical coverage on the Earth's surface, e.g. forests, grasslands, croplands, lakes, wetlands.

The predominant land use classes on the territory of the Tuyamuyun hydrocomplex are irrigated agricultural lands.

8.5.1.2 Elevation map

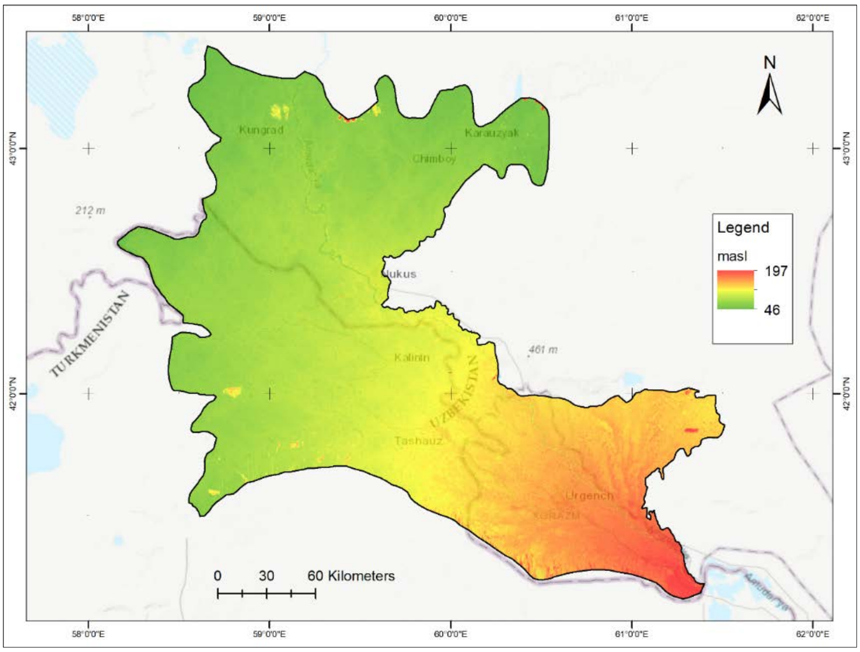


Figure 32: Shuttle Radar Topography Mission (SRTM) Digital Elevation Map. The SRTM digital elevation data provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. The data is obtained from the USGS EROS Center.

Absolute elevations on the territory of the Tuyamuyun hydrocomplex vary from 46 to 197 m above sea level. Consequently, heights gradually decrease from the elevated southeastern part of the territory to the lowered northwestern part in the Amu Darya river flow towards the Aral Sea.

8.6 Water resource of the Amu Darya basin under climate change

This chapter is abstract is included in the report of climate change in the Amu Darya basin.

8.6.1 Sensitivity of the THC for changes in the upper Amu Darya basin

The sensitivity of the THC for changes in the upper Amu Darya basin lies in seasonal and yearly discharge, flood risk and sediment flow.

The seasonal and yearly discharge of the Amu Darya and, therefore, the Tuyamuyun Hydro Complex depend on indicators like seasonal precipitation in the upper basin, type and altitude of precipitation, glacier melt, and also the availability on the water use and resource management in the upper basin.

The flood risk is related to an indicator like the 5-day extreme precipitation and the type and altitude of precipitation and soil cover. Besides that, the space of the rivers, functioning of foreshores and wetlands as water buffers and management of water reservoirs are of influence.

The sediment flows in the Amu Darya is depending on the soil cover (and thus land degradation) and the extreme precipitation. Besides this, the functioning of the foreshores and wetlands as a sediment trap is essential.

8.6.2 Climate change in southern Tajikistan

8.6.2.1 Heat

Southern Tajikistan is the area with the highest increase of temperature in the country, concerning the increase of extreme maximum temperature and increase of the warmth duration.

8.6.2.2 Precipitation

Analysis has indicated that the number of days with rain is decreasing but conversely, the number of days with heavy rain is increasing. This is especially the case for the Khatlon Oblast were heavy rains increases of 37% - 90% are recorded for elevations up to 2500 m. Thunderstorms tend to decrease[29]. In lowlands,

[29] WMO database and analysis

the precipitation tends to decrease, in Shartuz with -5-10%. Kulob, however the precipitation tends to increase, most as result of heavy rain[30].

As a result of the change in precipitation and snowmelt, the number of spring floods in the Yakhsu river increases. In the Kujob region in the mountains, increased precipitation of up to 20% is recorded. Partly this is received as increased snowfall at lower altitudes (<1800 m), or in the form of heavy rain in summer, especially at the middle slopes of the surrounding mountains, causing increased mudflow and flooding risk. The decrease of thunderstorms and the number of rainy days result in increased heavy rainfall.[31] In line with the whole Pyanj basin the snow cover is received earlier in the year, so snow arrives earlier but is less significant. The late snow cover also melts a little earlier and is increased on a lower level. Resulting in a peak river flow up to one month earlier in summer and a reduced flow in summer.

8.6.2.3 Water balance

The water balance available in the cropping season is strongly reduced as the crop water demand increases and the river flows occur earlier in the year. This impact is increased by land degradation, and as a result there is an increase in run-off, causing peak flows but not regular supply for irrigation. Major rivers in Eastern Khatlon are the Kizilsu and the Yakhsu. Both are snow-rain fed. As a result of land degradation and precipitation pattern, the river peak flow is changing. The rain intensity in summer is also contributing to the increased peak flow. Also, more sediment (rocks and sand) is transported from the upper basin. The change in snow cover (earlier cover and earlier snowmelt) results in a reduced summer flow. This impact is strengthened by the reduced rainfall and increased rain intensity. As result, the summer flow will be further reduced. The maximum monthly flow for both rivers is shifting a couple of weeks earlier on the year. This is related to the increased snow cover at lower altitudes and reduced snowfall above 2500 m.

The Vakhsh River is glacier-snow-rain fed. As a result of the Nurek and Roghun water reservoir, their discharge is more regulated and less influencing the sediment flow.

8.6.3 Climate change in the Pamir (GBAO) (Tajikistan)

The Pamir, due to high altitude, has a separate climate change impact. At first glance, in line with the expectations due to the altitude, the climate is changing less intensively than in the low Tajik land. As a

[30] WMO database
[31] Snow-cover variability in central Asia between 2000 and 2011 derived from improved MODIS daily snow-cover products, Andreas Juergen Dietz, Claudia Kuenzer & Christopher Conrad, 2013

result, average temperatures and precipitation appear to be more stable. However, there are significant differences in climate between the western part of the Pamir region (with more significant topographic variability and precipitation up to 2000 mm/year) and the eastern Pamir, which is plateau-like and generally arid (annual precipitation typically less than 200 mm).

8.6.3.1 Temperature

The number of days each year with a temperature above 32ºC is stable, but the maximum temperatures slowly increase.

8.6.3.2 Precipitation

Precipitation in West Pamir is going up a little. Anomalies for WMO precipitation show stable precipitation but a higher share of maximum daily precipitation in the monthly average, in other words, heavier rain. The share of heavy precipitation in the total precipitation for Khorog is increasing from 35% to 45%. In the West Pamir, the weather cycle counts like elsewhere in Tajikistan around 24 years. This is contrary to East Pamir, which is included in another climatic system with a 6-7 and 12 years cycle. In Central and East Pamir, the climate is less influenced by climate change due to the high altitude. The mean temperatures are fractional rising, just like the extreme maximum temperatures. The precipitation is slightly decreasing. Records for Murgab indicate these features.

At the Fedchenko glacier at 4000 m altitude, the precipitation is increasing (see Figure 33). However, there are indications (from our earlier work in Kyrgyzstan) that above 3500 – 4000 meter, the snow precipitation is strongly decreasing. Unfortunately, high-altitude information from Tajikistan is lacking.

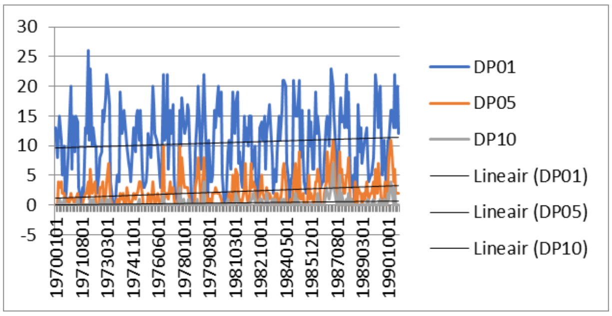


Figure 33: Number of days with rainfall of more than 2.5 mm, 5 mm and 10 mm per day at Fedchenko weather station at 4000 meter

8.6.4 Climate change in Pyanj basin of Afghanistan

Since 1950, Afghanistan's mean annual temperature has increased significantly and pronouncedly by 1.8°C. The spatial distribution of the warming between the 30-year periods from 1951-1980 and 1981-

2010 shows a strong warming trend across large parts of the country. In the Central Highlands and North, warming was noticeably distinct, with 1.6°C and 1.7°C increases. In the Hindukush region, warming was around 1°C. Also, here the temperature change increases with the altitude. The higher the altitude the more substantial the temperature increase. As result the spring melt is shifting from June to April[32] .

Where there is historical in Northern Afghanistan a reduction in precipitation and increase of heavy precipitation visible, present models estimate an increase of total precipitation. This is the result of the increased influence of the monsoon, resulting in increased heavy precipitation (10-15% by 2050). But also, the dry spell duration is expected to increase by 10-20 days by 2050. Altogether this results in a negative water balance by 2050 by an average of -/- 15% (see Figure 34).

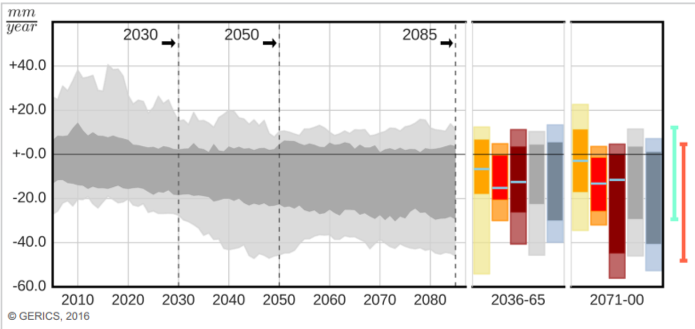


Figure 34: Change in climatic water balance (GERICS)

In conclusion, the water resources will be affected by increasing temperature and related evaporation and sublimation, total precipitation, extreme precipitation, increasing dry spell, and negative development in the total water balance.

The monsoon is increasingly influencing the precipitation in Northern Afghanistan as the Hindu Kush primarily blocks this. The northwestern shift of the monsoon and its more extreme character increase the risk of jumping over the Hindu Kush, resulting in increased (heavy) precipitation in summer, especially high altitude. This area usually is more under the influence of the westerly winds. Just as in Tajikistan, the snow cover is shifting to later in the season. Lower altitude receives more snow but higher altitude loss, comparable with the Pamir.[33] [34]

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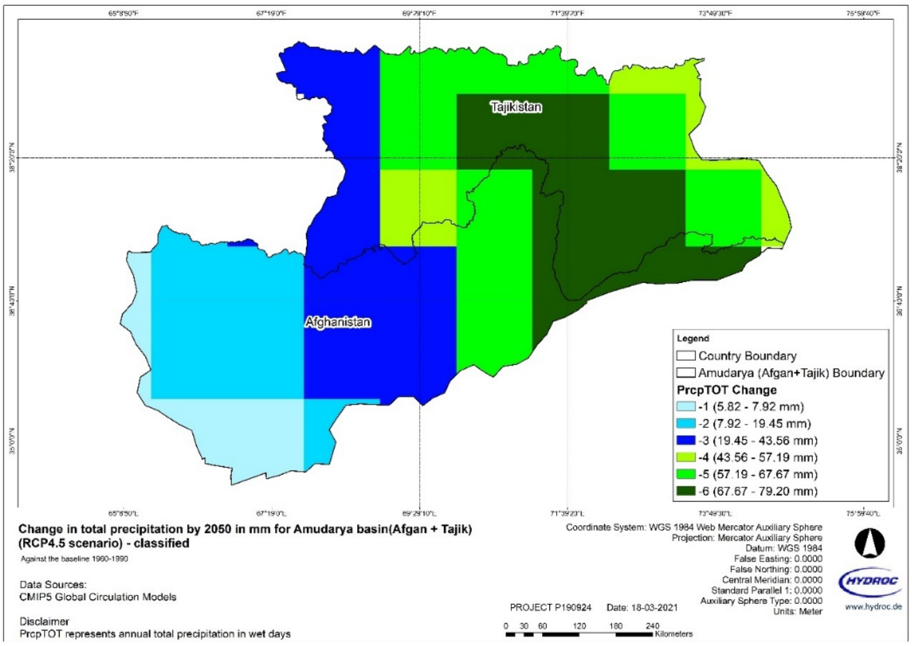
[32] Impacts of Climate Change on the Cryosphere, Hydrological Regimes and Glacial Lakes of the Hindu Kush Himalayas, Lutz et all., ICIMOD, 2016

[33] Global Land Ice Measurements from Space, Part of the series Springer Praxis Books pp 509-548, Date: 08 July 2014

[34] Remote Sensing of Glaciers in Afghanistan and Pakistan, Michael P. Bishop , et all.

8.6.5 Concluding for the upper Amu Darya (Pyanj) basin

Concluding for the upper Pyanj basin is that the total precipitation will increase but to a large extent in the form of heavy and extreme precipitation, especially the 5-day extreme precipitation. They were combined with the land degradation, the flood risk and sediment flow is expected to increase. In addition, as a result of the long drought period and higher summer temperatures, the evaporation and request for water in the upper basin will increase.



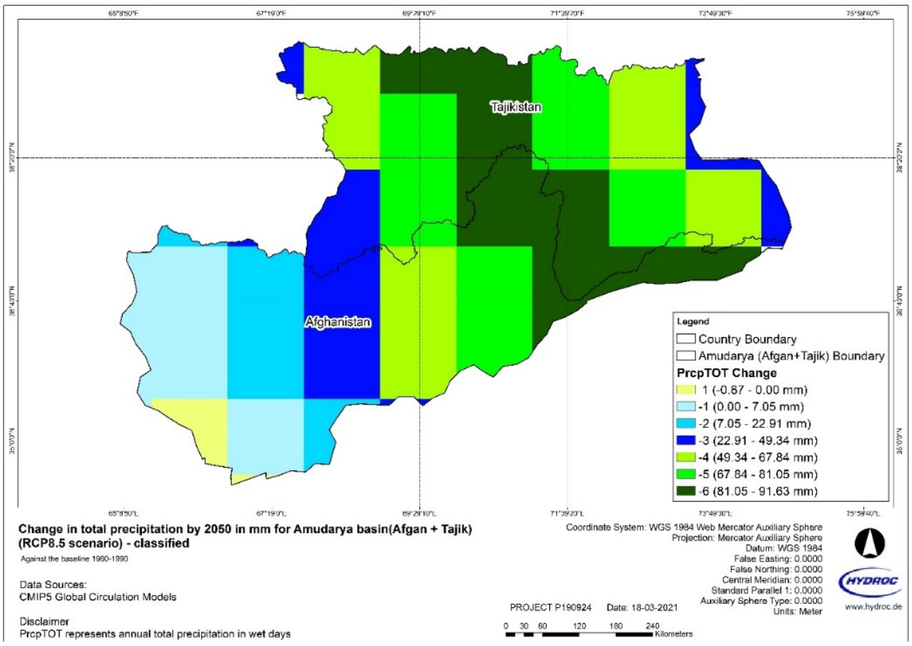


Figure 35: Projected Change in Total Precipitation by 2050 against the baseline 1960-1990 for the upper Amu Darya basin. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Total Precipitation represents annual precipitation in wet days

This is visible in the 5-day maximum precipitation change (Rx5-day) as major indicator for flood risk.

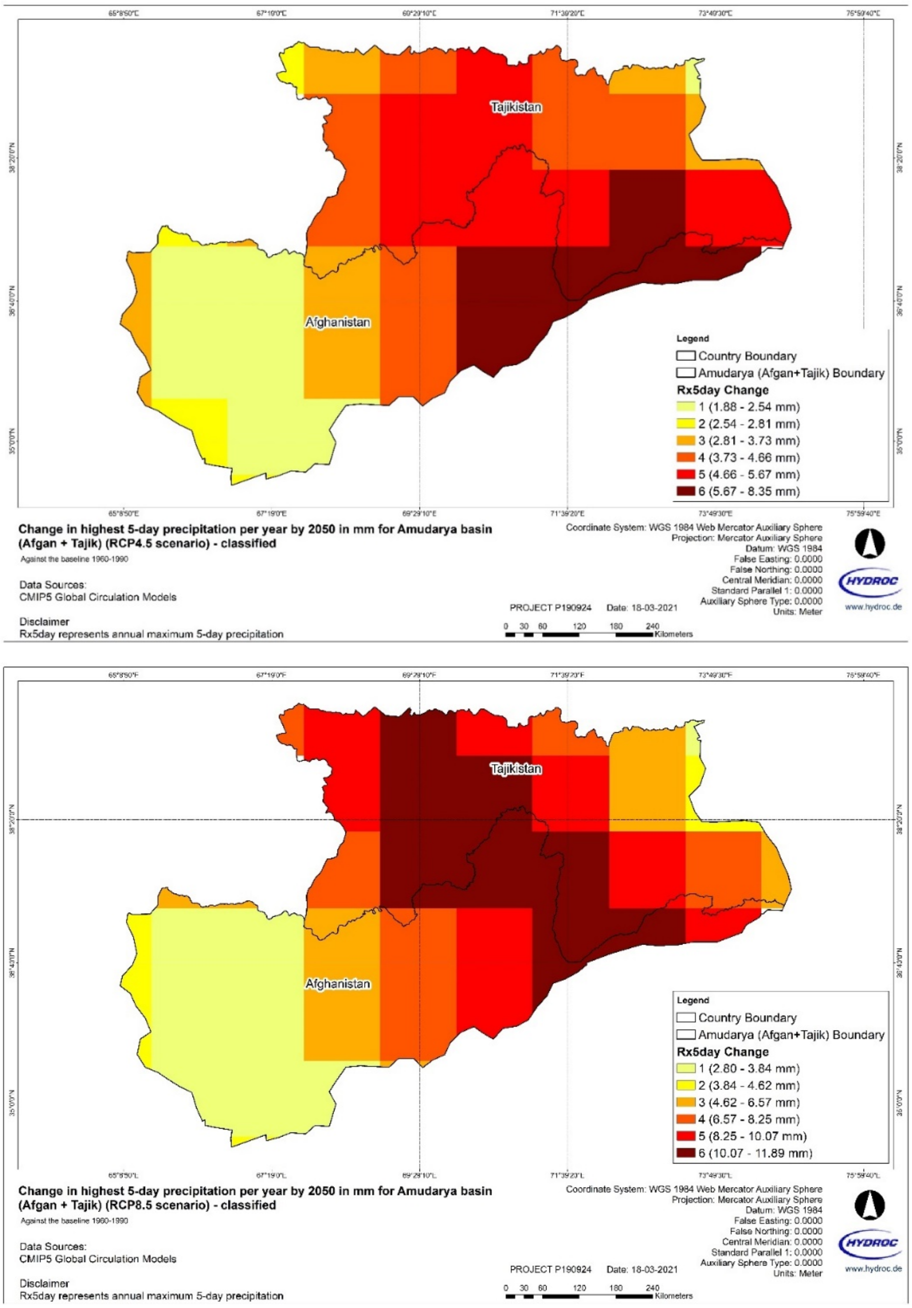


Figure 36: Change in 5-days precipitation by 2050 for the upper Amu Darya basin. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. The higher scores indicate more risk while lower scores indicate less risk.

In the upper part of the Amu Darya River Basin, an increase in maximum 5-day precipitation is forecasted due to the increasing influence of monsoons crossing the Hindu Kush Mountain ranges. Accordingly, in the summer months, the risk of floods increased turbidity of river flow and sedimentation of particles in the reservoirs downstream increases.

Concluding, the climate is changing the natural conditions under which the water infrastructure of the Amu Darya basin is operating. This is asking for an adaptation of the water management, also for the Tuyamuyun Hydro Complex. A major vulnerability in maintenance and management of water infrastructure in the lower Amu Darya lies in the flood risk reduction, increased need for a buffer for summer drought, sediment flow reduction and hydropower infrastructure. This becomes more urgent seen the plans in Afghanistan for extension of its irrigation system.

Seen the relation with land degradation, the attention of the maintenance of the water infrastructure should focus more on the source and upper flow of the river, taking measures at the source against land degradation in cooperation with the stakeholders. The central part of the issue lies in other countries, namely Afghanistan and Tajikistan, which requires increased transboundary cooperation. However, the upstream water use and management in Uzbekistan and Turkmenistan should also be regarded.

8.6.5.1 Flood risk

For estimating the possible impact of climate change on peak flood flow rates in the rivers of the Pyanj the ADB 2011 study provided basin analysis of the simulations carried out, developing estimates of the 1 in 100-year peak flow rates in the modelled sub-catchments for a range of scenarios. On average, an increase by 160% for 2040-2069 for the 1 in 100-year flood peak was estimated, reducing to 143% for 2070-2099. These figures show surprisingly significant increases in severe flood runoff. By the peak flow modelling a couple of recent aspects are not being taken sufficiently into account. This includes the change in snow cover, precipitation at lower altitudes, the historic glacier melt and the reduced glacier volume in the Afghan basin. These factors result in a flattening of the peak flows. Snowmelt and rain were not peaking with the glacier melt but following each other, resulting in a more extended period of increased flow but with a decreased maximum peak flow. The second aspect to be taken into account is that the Pyanj water level is measured but not the flow due the conditions as border river.

The flow calculations are based on outdated profiles of the eighties. Recent detailed studies of the Pyanj are pointing at a decreased maximum monthly flow of 20% instead-but spread over a more extended period and a shift of the peak flow with one month earlier in summer[35] . It is prognose that by 2030 the Afghan share in the discharge of the Amu Darya will reduce to up to 21%.[36] Resulting from the risk of flooding by 2040 is estimated to increase for the Amu Darya. The map below shows the estimation

[35]Glacier and runoff changes in the Rukhk catchment, upper Amu-Darya basin until 2050, Wilfried Hagg, , Martin Hoelzle, Stephan Wagner, Elisabeth Mayr, Zbynek Klose, 2013
[36] MEW. (2017). National Water Sector Strategy 2019-2025. Kabul: Ministry of Energy and Water

between maximum river water level and the elevation of the surrounding land, not taking into account the diking.

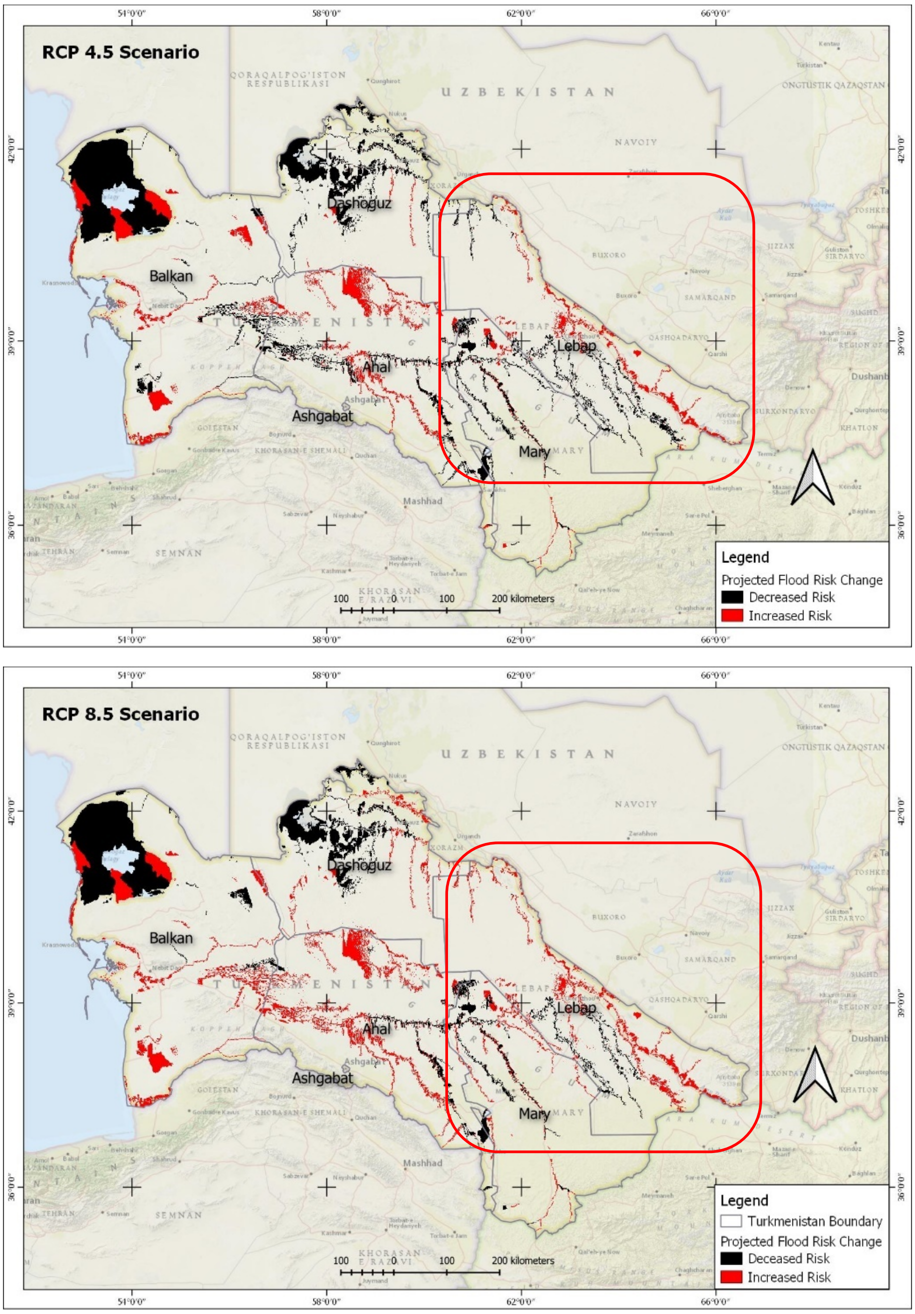


Figure 37: Projected Change in Flood risk by 2050 with return period of 50 years. Projections are based on CMIP5 Global Circulation Model for RCP 4.5 and 8.5 scenarios. Flood map is obtained by taking difference between RCP flood map and historic flood map

The risk of floods and floods on the rivers will increase, especially for the upper part of the basin, upstream of the Tuyamuyun reservoirs. Downstream of the reservoirs, due to intensive water diversion for various needs, the risk of floods is significantly reduced. On small rivers in desert terrains in the region the increase of flood risk is also observed, especially according to the RCP 8.5 scenario.

8.6.5.2 Sediment flow

8.6.5.2.1 Tajikistan

The impact of climate change is increased by other anthropological factors, including land-use changes and land degradation. Land degradation in Tajikistan is linked to livestock density, pasture management and irrigation. The number of livestock reaches far above the Soviet time and is increasing yearly. This is resulting in land degradation, especially on the mountain slopes. This process is specifically visible in Khatlon. Unsustainable pasturing reduces vegetation cover on the slopes and compacts the soil. Reduction of vegetation cover can lead to significant increases in the precipitation run-off and increased peak flow. In addition, loss of vegetation cover increases soil loss and erosion with storm runoff and so increases the risk of mudflows and landslides. This land degradation process intensifies the impact of the increased peak precipitation rates expected with climate change.

The impact of land degradation cannot be overestimated. Climate change produces changes of up to 20%, but land degradation has increased to 50-75%. For example, where land with full soil cover has a relative run-off of 15-25% during heavy rain, degraded land with a 25% land over (a typical situation in the slopes in Khatlon) results in a relative run-off of around 50-75%, thus tripling the run-off[37,38].

This results in topsoil loss and further degradation of land. But when the run-off sweeps down into the valley, it causes erosion, mudflows, landslides, etc. It also results in increased peak flows in summer and sediment stock in the rivers

8.6.5.2.2 Afghanistan[39]

Large parts of Afghanistan are affected by land degradation and desertification. Most of the country has been classified as having “degraded soil,” and it is estimated that 80% of the land area is at risk of soil erosion. Land degradation is mainly caused by overgrazing and deforestation, which is one of the largest contributors to desertification in Afghanistan. Degradation and desertification present a significant risk to livestock grazing. Livestock products from rangelands form the livelihoods for more than 80% of Afghan

[37] Relationships between runoff and land degradation on non-cultivated land in the Middle Hills of Nepal R. A. M. Gardner and A. J. Gerrard, International Journal of Sustainable Development & World Ecology Vol. 9 , Iss. 1,2002.
[38] FAO database
[39] http://www.fao.org/3/cb2364en/cb2364en.pdf

households and contribute more than 50% to the agricultural GDP. Current rates of land degradation and desertification will be exacerbated by climate change, which is predicted to cause decreases in mean annual rainfall and increased temperatures. Afghanistan's forests are severely damaged due to deforestation, mismanagement, and drought, and today account for only 2% of the country's total area. Lack of capacity in rangeland management, insufficient information to inform decision making and planning and limited national planning mechanisms are barriers in land conservation.

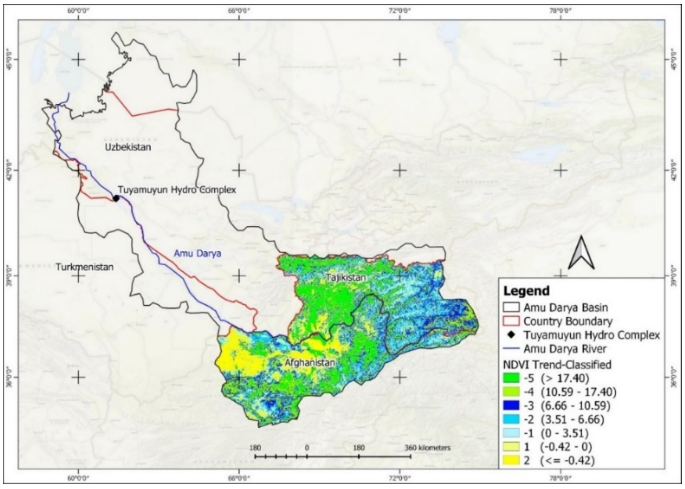


Figure 38: Change in Soil productivity based on NDVI from 1999-2019

The decrease of soil productivity based on NCVI analysis is a sharp indicator for land degradation. This is especially visible in the Afghan part of the Amu Darya Basin. This is the main factor of increase of flood risk, increase of turbidity of river flow and sedimentation in reservoirs of Tuyamuyun Hydro Complex.

8.6.5.2.3 Sediment flow Lower Amu Darya

The Amu Darya River has a high natural sediment flow and is one of the rivers transporting the highest amount of suspended solids. Gwosdetsky and Michilow (1978) estimated a suspended solid concentration of 3300 mg/l, and Letolle (1996) reported concentrations between 1000 and 3500 mg/l for the Amu Darya River. Generally, the main part of the annual sediment load is carried in the summer months. During the passing of the summer flood (May to September), the maximum amount of debris is observed; the minimum is seen in November and December (Suslov, 1962). The suspended sediment composition upstream of the THC reservoir inflow can be described with a particle content of 15.5 percent sand, 22 percent silt, and 62.5 percent clay.

8.6.5.2.4 Conclusion on sediment flow

With the increased maximum flow of the Amu Darya, as result of the more extreme maximum precipitation and the land degradation, the turbidity (sediment flow) is expected to increase.

8.7 Evaporation from the Tuyamuyun Hydrocomplex reservoirs

Open water evaporation from reservoirs is influenced by a number of indicators. Climate and surface area to volume relation are the key elements.

Climate

Temperature, wind and humidity change are main climatic elements that influence open water evaporation. The for future projections, the climatic factor with the highest relevance for increasing evaporation at the Tuyamuyun Hydro Complex (THC) is the increasing temperature.

Two models are applied to estimate open water evaporation losses for the Tuyamuyun reservoir: Free evaporation based on the Blaney Criddle method mostly used for reference crops, and open water evaporation based on the modified Penman method. The latter is assumed to be more accurate for a water reservoir.

The Blaney Criddle method is a simplistic approximation of evapotranspiration, used when only air-temperature datasets are available for a site, and utilizes the following formula

$ET_o = p \cdot (0.457 \cdot T_{mean} + 8.128)$

With: ET_o is the reference evapotranspiration [mm/day] (monthly)

T_{mean} is the mean daily temperature [°C] given as $T_{mean} = (T_{max} + T_{min})/2$

p is the mean daily percentage of annual daytime hours

As the Blany Criddle formula is intended for grassed areas, and not open water, the results are expected to underestimate open water evaporation and could be increased by at least 30% based on the authors experience.

The modified Penmen method is more scientific based, considering evaporation energy- and vapour removal requirements. More details are e.g. described by Linacre (1997). The following formula was used:

$E_0 = (700*T_m/(100-A)+15*(T-T_d))/(80-T)$ [mm/day]

With $T_m = T + 0.006h$

h is the elevation (metres)

T is the mean temperature

A is the latitude (degrees)

T_d is the mean dew-point

Values given by this formula typically differ from measured values by about 0.3 mm/day for annual means, 0.5 mm/day for monthly means, 0.9 mm/day for a week and 1.7 mm/day for a day. The formula applies over a wide range of climates.

Monthly mean values of the term $(T - T_d)$ can be obtained either from an empirical table or from the following empirical relationship, provided precipitation is at least 5 mm/month and $(T - T_d)$ is at least 4°C:

$(T-T_d)=0.0023*h+0.37*T+0.53*R+0.35*R_{ann}-10.9$ °C

With R is the mean daily range of temperature

R_{ann} is the difference between the mean temperatures of the hottest and coldest months.

Using the above formula, the evaporation rate can be estimated from values for the elevation, latitude and daily maximum and minimum temperatures. An assumption that had to be made in this regard, is that the mean daily range (R) of temperature is set artificially to 10°C and assumed not to change with climate change. Site elevation was set to 140m.

Applying these methods for the Tuyamuyun Hydro Complex results in the following increases for future climate change projections:

Table 21 Change in increase of evaporation for THC as percentage of the historical evaporation based on RCP4.5 and 8.5 following the Blaney-Criddle and Penman method (historical period covered – 1960-1990, forecasted period for RCP 4.5 and 8.5 scenarios – by 2050)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
RCP4.5 Blaney Criddle	9%	5%	5%	4%	4%	4%	4%	4%	5%	6%	5%	10%	5%
RCP4.5 Penman	21%	12%	11%	9%	11%	14%	14%	14%	14%	14%	12%	23%	13%
RCP8.5 Blaney Criddle	11%	8%	5%	5%	5%	5%	5%	5%	6%	7%	7%	11%	6%
RCP8.5 Penman	27%	17%	12%	12%	14%	15%	16%	17%	18%	18%	16%	25%	16%

As expected, the Blaney Criddle based results are rather low and the Penman values seem more applicable. Overall it is concluded that under RCP 4.5 and RCP 8.5 climate scenarios the increase of evaporation can be expected to average 13% for RCP4.5 and 16% for RCP8.5 scenarios, resulting in respective reservoir water losses.

Surface area to volume relation

The percentage water loss as result of evaporation in relation to the total storage volume is strongly dependent on the reservoir shape. Deep incised reservoirs typically have small surface areas as compared to their volume, while rather wide and flat reservoirs typically have a larger surface area compared to their volume. The lower the surface area to volume relation, the lower the percentage evaporation losses. The storage volume of the Tuyamuyun reservoir is expected to decrease over time due to sedimentation. As a result surface area to volume relation is increasing, and as such the evaporation percentage in relation to the total storage increases, i.e. the % losses are getting higher. Depending on the shape of the reservoir, the relation between surface/volume and evaporation is not linear but requirs specific calculations based on the reservoir bathymetry.

9 CLIMATE CHANGE ADAPTATION FOR THE TUYAMUYUN HYDRO COMPLEX

9.1 Approach for climate change adaptation

The private sector, businesses, industry and services sectors, and individual citizens will be confronted with the consequences of climate change and can play an essential role in adaptation measures.
Action is needed by the public sector to stimulate the private inclusion or to raise their effectiveness, e.g. adapting spatial and land use planning to risks of flash floods; adapting existing building codes to ensure that long-term infrastructure will be proof to future climate risks; updating disaster management strategies, early flood and forest fire warning systems.

Adaptation is one of the best investments in the future, with an average benefit-cost ratio of 4-9 and an investment return period in case of monitoring and early warning of less than a year.
Adaptation will, therefore, offer new economic opportunities, including new jobs and markets for innovative products and services, such as:

- New markets for climate-proof building techniques, material and products;
- Tourism would be expected to shift to spring and autumn, where tourist resorts may become too hot during summers, while favorable climate conditions during summer mountain areas would turn into potential new tourist destinations;
- Adapting local agricultural management practices to longer growing seasons or earlier timed seasons and serving new markets with other products;
- The insurance sector could develop new insurance products for reducing risks and vulnerability before disasters strike. Insurance premiums anticipating climatic changes could provide incentives for private adaptation actions.

There is a whole network of relations on adaptation measures on local, regional, and national levels that support or influence each other (figure 40).

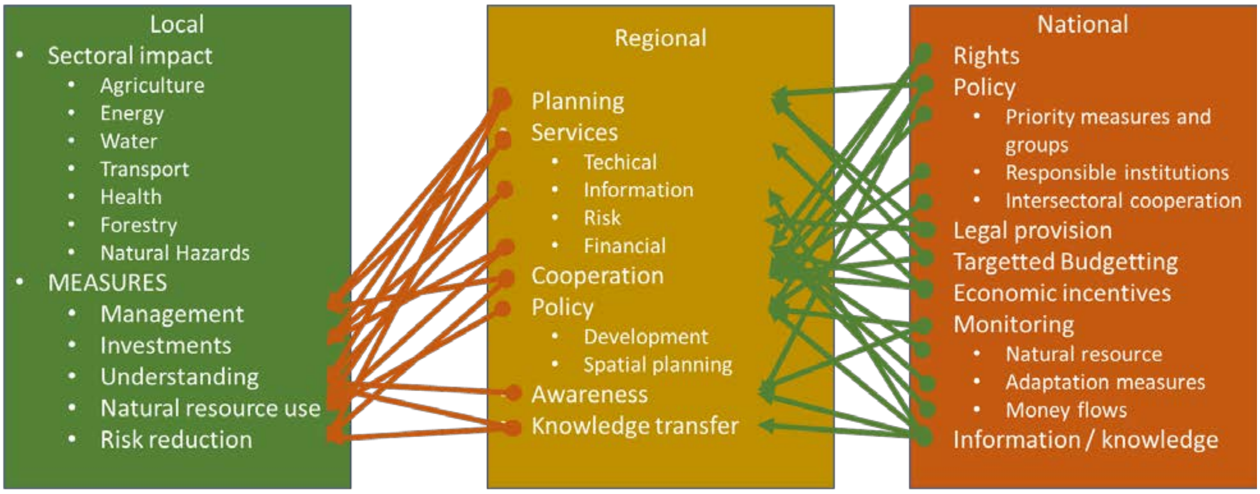


Figure 39: Scheme of related and conditional climate change adaptation measures on different levels

Therefore, adaptation measures are presented on these three levels.

9.2 Recommendations for climate change adaptation[40]

9.2.1 General recommendations

The effectiveness of climate adaptation lies in intersectoral and multi-level cooperation. Thus, the cooperation between in the case of Tuyamuyun Hydro Complex between agriculture, water management and the energy sector. But also, the cooperation between local, regional and national level and, in this case transboundary between Uzbekistan and Turkmenistan.

9.2.2 Sectoral recommendations on a local and regional level

Major sectors under the Tuyamuyun Hydro Complex influenced by climate change are agriculture, water and energy.

9.2.2.1 Adaptation in agriculture – local level

Climate adaptation is expected not to be sufficient for sustainable climate-resilient agriculture. It is better to speak about a transition to climate-resilient agriculture. This means a transition to other crops, better soil management, a low water economy, and increased processing and marketing to increase income. This will only be successful when local level adaptation measures will be supported by regional and national level.

[40] For more details the following reports: Recommendation on adaptation options for Uzbekistan and for Turkmenistan

Key institutions: Council of Farms and Dekhkan Farms and Owners of Household Lands of Uzbekistan, Regional and district departments of agriculture, Regional basin departments of water management

Supporting institutions: Ministry of Agriculture. Ministry of Water Resources, Committee for Environmental Protection, Hydrometeorological Center of the Republic of Uzbekistan.

Stakeholders: Local Council of Farms and Dekhkan Farms and Owners of Household Lands of Uzbekistan, Water Use Associations, Agricultural clusters, farms and dekhkans, household plots.

For effective adaptation, agriculture must be divided into arable farming, livestock farming and horticulture. Each of them is differently impacted by climate change but also offers alternated adaptation options.

Long-term weather forecasts, early warning, hydrological information, and climate change information in open access are essential in transforming climate-smart agriculture. Digital information services, etc, are essential in this transformation. (see cross-cutting measures on regional and national level).

On local, regional and national level, the most critical climate change adaptation measures for the agriculture sector are:

Vulnerability Agriculture
- Heat, drought, extreme precipitation, shift in precipitation
- **Misharvest / production**
- **Lower productivity**
- **Land degradation**

Measures - Local
- Management
  - Selected breed / new crops
  - Soil : low/no-tilt, Soil cover
  - Pasture rotation
  - Drip irrigation
- Understanding
  - Adapt management
  - Business planning
  - Digit info climate weather, water, market
  - Ownership, responsibility
- Investment
  - Equipment, Drip irrigation, under-cover horticulture
- Risk reduction
  - Community DRR plan / land use plan

Regional
- Planning
  - Development / riskplan
  - Processing, marketing
- Services
  - Repair/parts, rent, contractor, sale, lease, marketing
- Financing
  - Guarantees, interest, governmental incentives, grants
- Rights
  - Land / water rights
- Risk management
  - Insurance, Land degradation
  - Natural hazards
- Knowledge
  - Extension, business planning, information market, climate
- Cooperation
  - Pasture degradation

National
- Policy Priorities
  - Measures
  - Groups
  - market
- Rights
  - Land, water, market rights
- Legal arrangements
  - Crediting
  - Nature protection
- Financing
  - Incentives, tax, guarantees, budgets
- Knowledge
  - Agri research, Monitoring, Open access,
- Monitoring
  - Effect
  - Cost benefits

9.2.2.1.1 Arable farming

Arable farming is of significant importance for the THC. Heat and drought are major issues—the area mainly dependents on irrigation. Above 37 °C all crops experience heat stress. Adaptation approaches can be found in adapted breeds of crops that are more heat resistant or ripening earlier in the season, and improved soil management. Investing 50% more in **seeding material** can offer 30% more harvest in dryland. On a small scale, **shaded agriculture** is an option. Adapted and proofed seeds and planting should be made available, as the **need for knowledge.**

Deeper rooting, increased organic matter in the soil for soil humidity and less evaporation are options. **Crop rotation** is essential to maintain soil fertility. It helps increase the organic matter and nutrients in soil and reduces the development of pests and diseases. Or apply **organic fertilizer and local waste** to increase the organic matter in soil, fertility and soil organic life. Other options are using **mycorrhiza or gel to deepen the rooting** and increase the soil water-binding capacity. Especially in dryland, this measure is earning itself back twice or more in the same growing season.

Buffer strips of trees, shrubs, or grass will stop runoff erosion due to heavy rain. The buffer strips need a width of 6-10 meters to be effective. By grape cultivation, it can be applied every 2nd row. In flood irrigated land, a buffer strip at the low end of the field prevents topsoil from ending up in the drainage channels. Using grass buffer strips can be replaced every 3-5 years by which the fertility is added to the cultivated land. The width between the strips depends on the slope of the field and the vulnerability of erosion. It may also be applied for **shaded cropping** to reduce heat impact. **Green cover** in between crop growing will also eliminate erosion in between growing seasons. It adds humus to the soil and allows the next crop with deeper rooting. Heavy erosion-sensitive soil **mulching** made be applied, especially in vegetable crops. As a result, run-off reduction of 80% and more can be reached.

Speaking about **alternative crop choice,** the **shift from annuals to perennials like aromatic herbs** comes in scope. For new crops, new markets must be opened. Another alternative is the switch to livestock fodder, requiring less water and increasing the income from the surrounding arid area.

Most pest and diseases development are connected to the **summary degree days** (also mentioned growing degree days). This is the sum of daily temperatures above a base value of 2, 5, or 10 °C. It takes a minimum summary degree day for a disease or pest to develop. The higher the summary, the earlier the pest gets a chance, or more generations of pest can develop. The actual value of the summary degree days can be used to predict and take timely actions against pests and diseases and advised to be taken up in the agricultural weather monitoring. There is a need of national research in this field to finetune global knowledge. For farmers developing their calendar of summery degree days in the growing season can strongly reduce the risk by improved understanding of them at almost no cost.

9.2.2.1.2 Livestock and pasture management

Livestock and pasture management is of significant importance to Uzbekistan. It is most under the pressure of heat and drought. Pasture degradation is the most pressing human influence.

Solutions for **local drinking water supply** for the livestock, and **corrals** to stay safely overnight in summer, are critical to reducing the daily migration time and spreading the livestock more evenly over the pasture territory. **Rotational pasturing** is the adaptation measure with the highest economic benefits. An increase of 30-300 % productivity can be expected due to the vegetation's deeper rooting, reducing drought vulnerability. The social dimension of moving from free pasturing grazing to rotational grazing is a significant bottleneck. **Community pasture rights** in combination with pasture management planning, are essential tools to enable this measure. Forestry is an essential partner in this process. Portable electric fencing and the introduction of trained herder dog use are two solutions to overcome the issue of rotational grazing that would need increased manpower. This needs demonstration and investment support. The low status of herders is another issue. The increase of productivity by rotational grazing and hazard reduction are significant arguments to stimulate rotational grazing.

More sustainable mixes of livestock with low goat percentage or single livestock herd are helpful in the adaptation. **Pasture management (see also horticulture) cooperative** might support the improvement of pasture and rangeland. **Agricultural management of nature protection** and **natural management of steppe pasture** is a successful and proven tool to build corridors between (and join) nature-protected areas and increase their quality at the lowest cost (see also forestry). It is profitable for both agriculture and nature protection.

For farm-hold livestock, the adaptation options can be found by **low water requiring fodder** to increase the water efficiency. Providing shade is essential to reduce heat stress. It is known that **trees** can reduce the field temperature by up to 10 ^{o}C. **Optimal access to drinking water** is necessary to prevent dehydration.

In drought, haymaking for emergency fodder supply is lucrative and may compete with arable farming to sustain the fodder reserve. Here, cooperation with arable farming and horticulture also come into focus, as fodder production requires much less water, is less vulnerable to drought, and can offer relatively high benefits as the fatted livestock is relatively more valuable. In an emergency drought by a lack of fodder, the best economic solution is very timely selling of livestock.

Another way to reduce the livestock pressure is to reduce the quantity of livestock and focus on **higher-quality markets**, where more profits can be reached.
An increase of small livestock like ducks, rabbits, and goats will add to the income, strengthen the position of women, and may help reduce the pressure of large animals on the pastures and, most importantly, reduce the impact of drought heat on the environment household.

9.2.2.1.3 Horticulture

Horticulture is usually a more intensive and smaller scale form of agriculture than arable farming, with higher profits. This allows more investments in adaptation measures. However, horticulture is most sensitive to climate change. In arid areas, the risk of horticulture is increasing as a result of increasing droughts.

Horticulture and drip irrigation focus on reducing heat and drought (and extreme precipitation) sensitivity undercover. In comparison with flood irrigation, regularly applied to increase the water efficiency and reduce the water need by 50- 80%. It can result in an additional harvest of 50-100%. Alternative, **less water requiring and more heat resistant crops** is a measure for which market development is needed.

Higher-value agricultural products offer better options for climate adaptation.

9.2.2.2 Adaptation in agriculture – regional level

To enable local agriculture to implement adaptation measures there is a **need for services, knowledge, cooperation and planning**. **Services** are understood as repair, parts, sale, lease, rent, contractor, financial, insurance. These services will enable access to new and adapted equipment necessary for adapted management in agriculture. Service cooperative is a successful tool in setting up services where private ones are lacking. Besides services cooperative, pasture management would optimize the pasture and rangeland productivity and quality.

In the field of knowledge, **regional extension services, state or commercial, education and awareness-raising** need to be organized to allow understanding of climate adaptation measures and feed the sector with new information on climate risks and adaptation options. To allow **new breeds and crops** to be successful, **new value chains must be developed**.

Insurance products and early warning systems for heat and drought hazards must be developed for active risk management. Further also regional risk management **monitoring and planning** need to be implemented.

Marketing services are a regularly underestimated part of the value chain. Good marketing facilities, like providing fodder and water for livestock commodities, support a fair price for the livestock. **Regional specialization** is here a critical approach in the adaptation. On a regional level, **access of smallholders to the processing industry** can be stimulated. Support of **contracting horticulture** is a tool in relation to the value chain of smallholders. These contracts can, in principle, also be used as **collateral for loans**. Other tools are **collecting points or cooperative trade** to increase the adaptive capacity.

Development of the processing industry and **value market** can also be part of the adaptation measures. **Processing and storage facilities** allow products to be sold at other times with better profits. Therefore, investment facilities and market support are crucial adaptation measures.

9.2.2.3 Adaptation in energy sector

Key institutions: Uzbekgidroenergo JSC, Inspectorate for Supervision in Electric Power Industry (UZENERGOINSPEKTSIYA), Uzbekenergo JSC, Regional departments of Uzgosenergo supervision, UZENERGOENGINEERING JSC, National Energy Saving Company JSC

Supporting institutions: Ministry of Energy, Ministry of Water Resources, Ministry of Emergency Situations, Ministry of Economy and Industry, Ministry of Finance,

Stakeholders: "Thermal Power Plants", "National Power Grids of Uzbekistan", "Regional Power Grids", Regional Administrations of Uzgosenergo Supervision, Inspectorate for Supervision in Electric Power Industry (UZENERGOINSPECTION)

The energy sector can be divided into three levels: production (fossil and hydro), transmission and demand. However, while the impact is on the local level, the management and, thus, also adaptation measures are organized on a regional and national level. As presented in the CRVA, the energy sector is most vulnerable to heat and drought. The cooling capacity is affected most; hydropower is most affected by water availability and extreme discharge (through extreme precipitation). Therefore, climate change has to be included in the **energy balance**.

For fossil power generation, it is the cooling capacity that is affected most. This counts for the gas-powered Dashoguz power plant.

Hydropower of the Tuyamuyun Hydro Power is most affected by water availability and extreme discharge (through extreme precipitation). This requires climate included **remodelling the water reservoirs management** to prevent extreme water levels and flooding (see also water).

The transmission capacity is impacted by extreme heat, causing a reduction in the energy transmission capacity during heat waves. Damage usually is automatically prevented by a reduction of voltage. In the planning, the reduced transmission capacity has to be included. In addition, natural hazards may impact energy infrastructure. Reallocation or preventive measures based **on risk mapping** has to be assessed.

The request of energy is strongly increasing as a result of heat. First measures could therefore be taken in energy saving. Internationally, it is expected that due to the growth in air-conditioning use, the request of energy may increase by 25%. Therefore, considerable adaptation potential can be expected from increased **energy efficiency** and related building requirements to reduce the increase of air-conditioning as a significant energy consumer in times of heat and in some areas in times of cold. Main local measures are **greening of the settlements** and **better insolation of the housing**.

Climate adapted modelling of the river discharge, and reservoir management is an essential instrument to reduce the risk of flooding due to heavy precipitation and assess buffer capacity in times of drought.

The cooling of fossil power generation is mainly built for a water temperature of a maximum of 25 °C. Increased surface water temperature reduces the cooling capacity and limits energy production. Adaptation requires a higher cooling capacity.

Transmission capacity is reduced in times of heat. This requires **increased overall transmission capacity**. **Like solar and wind, local renewable energy** can be a good alternative for remote areas and stabilize the energy supply.

On local, regional and national level, the most critical climate change adaptation measures for the energy sector are:

Vulnerability
Energy
- Heat
- Drought
- Extreme precipitation

- **Water quantity reduced**
- **Peak discharge**
- **Transmission capacity reduced**

Measures - Local
- Management
  - Buffer capacity in reservoir
  - Energy saving
- Understanding
  - Energy efficiency
- Investment
  - Cooling capacity
- Policy
- Risk reduction
  - Early warning

Regional
- Planning
  - Modelling discharge and reservoir management
- Services
  - Reserve capacity natural hazards
- Rights
- Cooperation
  - Energy saving
- Risk management
  - Early warning
  - Risk identification
  - Balanced power production
  - Local power generation

National
- Priorities
  - Renewable energy
  - Energy saving
- Rights
- Legal arrangements
- Budget
  - Energy saving
  - Balanced power capacity
  - Incentives renewables
- Knowledge
  - Awareness energy saving
  - Modelling discharge
- Monitoring
  - Water buffer

9.2.2.4 Adaptation in Water sector

Key institutions: "Amurdarya" basin water management association, Tuyamuyun Hydro Complex management, Regional and district departments of water management. Canal management, Water intake facilities.

Supporting institutions: Ministry of Water Resources, Committee for Environmental Protection, Hydrometeorological Center of the Republic of Uzbekistan, Ministry of Agriculture, Ministry of Emergency Situations.

Stakeholders: Agricultural clusters, farms and dekhkans, household plots.

Drought and heat are increasing the water request. Measures taken on local level are **water efficiency and adapted cultivation techniques** (see also agriculture). Water efficiency requires, besides adapted management, investment and knowledge in the higher efficient water supply to the crops, and alternated crop choice.

Water leakage reduction is the first measure to be taken. Here the most results can be gained. **Water efficiency** in relation to the economic benefits is crucial for agriculture. **Drip irrigation** (possibly in combination with undercover cultivation) is an example of this.

Crucial for the communities and cities is the drinking water supply, which has to be guaranteed. Increased drinking water requests and lower water reserves increase the risk of shortage. Increased infiltration using swale and infiltration ponds, (underground) water storage, closed water resources, and **water-saving** are recommended adaptation measures. As an alternative, local household or community water sources usage can reduce climate impacts.

Water reservoir management is affected by water availability (drought) and extreme discharge (resulting from extreme precipitation). This requires **remodelling the management of water reservoirs** to prevent extreme water levels and flooding (see also water) and thus an average lower storage capacity of the reservoirs. This cannot be solved on a local level but is part of the regional or national water management.

A significant factor impacting the Tuyamuyun Hydro Complex is the sedimentation in the reservoirs. As the water resources for the THC are from upstream, her major measures need to be taken. Some measures can be taken inside the THC reservoirs, making use of Nature-based Solutions. This includes a sediment trap in the upper part of the main Ruslovoe reservoir. This means a network of designed islands, channels and sediment pits to increase the local, more concentrated, sedimentation and as result decrease the sedimentation elsewhere in the reservoir. A 200 ha pit area is able to consolidate 200.000 – 500.000 m3 sediment per year is the experience. A higher solid fraction than 12-17% will deliver higher sedimentation. The whole construction can be prepared with local material. These measures will also support the biodiversity and ecological quality of the reservoirs.

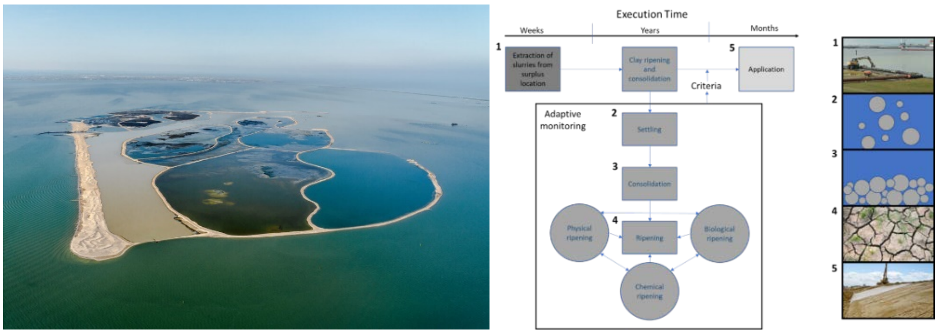


Figure 40 Marker Wadden, sediment trapping by islands and channels and clay ripening for further usage

This can be combined with a ripening facility the increase the use of the collected sediment.

Adaptation Upstream of the Tuyamuyun Hydro Complex

Upstream of the Tuyamuyun Hydro Complex, the following measures are recommended in relation to THC management.

Riverbank protection is an inert or living construction providing bank fixation and an obstacle for the lateral connection of the river. Eliminating it consists of removing some parts of the bank protection, especially the inert one, to enhance lateral connections of the river, diversify flows (depth, substrate, and speed) and habitats, and cap floods in the mainstream. It is a prerequisite for many other measures like re-meandering or widening, as well as initiating later channel migration and dynamics

Major floodplains roles have thus been lost due to land drainage, intensive urbanization and river channelization. The objective is to them their retention capacity and ecosystem functions by reconnecting them to the river. **Restoring the floodplain** roles requires measures such as:

- modification of the channel, removing of the legacy sediment, creation of lakes or ponds in the floodplain, new/modification of agricultural practices, afforestation, plantation of native grasses, shrubs and trees, creation of grassy basins and swales, wetland creation

Riverbank represents both natural and artificial terrain following the river flow. In the past, lots of artificial banks were built with concrete or other types of retention walls, limiting rivers' natural movements, leading to river degradation, increased water flow, increased erosion, and decreased biodiversity. **Riverbank re-naturalization** consists of recovering its ecological components, thus reversing such damages, especially allowing banks to be stabilized and rivers to move more freely. Nature-based solutions such as bioengineering are preferable, but civil engineering must be used in solid hydrological constraints.

Widening the river space by **reconnecting wetlands** or creating overflow areas increases a stable flow and reduces flood risk (see also natural hazards).

Wetland restoration and management can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); small-scale technical measures such as clearing trees; changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. **Creating artificial or constructed wetlands** in urban areas can also contribute to flooding attenuation, water quality improvement and habitat and landscape enhancement.

Seasonal streams or intermittent rivers are rivers for which surface water ceases to flow at some point in space and time. They comprise a large proportion of the global river network and are characterized by dynamic exchanges between terrestrial and aquatic habitats. These habitats support aquatic, semi-aquatic, and terrestrial biota. Seasonal streams provide essential ecosystem services to society, including flood control and irrigation. The abundance and distribution of seasonal streams, and their natural intermittent flow regimes, are being altered by climate change, water abstraction and inter-basin transfers. Despite their values and ongoing alterations, seasonal streams are chronically under-studied and protective management is inadequate. **Restoring and reconnecting seasonal streams** with the river consists in, therefore, favoring the overall functioning of the river by restoring lateral connectivity, diversifying flows and ensuring the proper functioning of these seasonal streams for better water retention during floods. As a result, peak flow reductions of 15-30% can be reached.

There is a need to include **climate impact considerations in river basin management plannin**g, just as the **risk for natural hazards**, resulting in alterations of the natural flow. **River Basin Management** is the tool to integrate the water nexus, water quality, quantity and risk management, and the stakeholders. Therefore, it needs legal strengthening and enforcement of the river basin management planning (see national adaptation measures).

On local, regional and national level, the most critical climate change adaptation measures for the water sector are:

Vulnerability
Water

- Heat, drought, extreme precipitation, shift in preciptation to spring and lower altitude

- **Increase request**
- **Evaporation**
- **Peak discharge**
- **Drought reserve**
- **Natural hazards**
- **Pollution of open wells**

Potentional Measures
Local

- Management
  - Water efficiency (also econiomic)
- Understanding
  - Water risks
- Investment
  - Water efficiency
- Policy
  - Community land use / risk plan
- Risk reduction
  - insurance

Regional

- Planning
  - Natural resource planning: RBM, Risk, development
- Services
  - Water management
- Rights
  - Water user rights
  - WUA - RBM
- Knowledge
  - Extension service
  - Water modelling
- Intersectoral Cooperation
- River Basin Management
- Risk management

National

- Priorities
  - Nature based solutions flooding
- Rights
  - Water, land, financing
- Legal arrangements
  - RBM
- Budget
  - Water management
  - Reservoirs, River Basin Management
- Knowledge
  - Risk monitoring earth observation
  - Risk modelling
- Monitoring
  - Weather, climate , hydro, land
  - CCA efficiency

9.2.2.5 Adaptation to Natural hazards – local and regional

The main natural hazards are slow onset large scale hazards being heat and drought. Main tasks to answer these are in the specific sector like agriculture, water, and energy and the health sector.

Heat

Heat is one of the natural hazards with the highest economic cost, just like drought. As the impact is widely spread, it does not attract similar attention as floods, for example. A large-scale event can be prognosed in advance by using respective models for a long-term weather forecast.

The adaptation towards heat depends on the sector and is discussed under the sectors above.

In addition, the Health sector can be mentioned. According to the CRVA, the health sector is most impacted on local level by heat and drought. The calls into hospitals are on average increase per degree C above 25°C. The impact is strongly related to cardio- and respiratory diseases and obesity level. Besides that, the elderly are more vulnerable than the youth. There is also a direct relationship between accidents and heat for labor and in traffic.

The most straightforward adaptation measure on local level is the availability of **shade** (greening of the settlement and housing) and the **availability of water** to prevent dehydration. **Greening of the settlements**, when correctly planned, offers additional savings of energy. **The insolation of houses** reduces the risk of overheating. Besides the measures mentioned before, the best is the structural supply of reliable drinking water to prevent dehydration**.** As an alternative during heat and drought, the **supply of bottled drinking water**, both in a combination of **awareness-raising** on the need to prevent dehydration is proposed.

There is a direct relation between call into hospitals and temperature. Internationally, with every degree of temperature increase, the number of calls into hospital raise by 2,5%. This requires **increased staffing**, **reserve capacity for heatwaves**, transport facilities, and emergency budget etc. To reduce the calls into hospitals, **awareness-raising and water supply** on local level has to be organized, to prevent overheating and dehydration as significant causes. **Greening of the environment and improving insolation of houses** must be promoted as adaptation measures. The number of road accidents increases with the temperature and increases medical pressure (see also transport). **Nationally, funds for climate-induced emergency** has to be brought in place (see national adaptation).

Awareness raising and early warning are essential tools in the adaptation to climate extremes. The risk of natural hazards is also impacting health (see natural hazards).

Drought

Drought effects are similar to the effects of heat. The position and strength of the significant climate systems are indicative of the longer-term risk of drought. **Significant drought impact is on agriculture, water management and health (see above under heat).** (for measures see under these sectors)

9.2.3 Adaptation measures on national level

National measures are required to enable or support the local and regional adaptation measures.

Adaptation on a national level is mostly policy and planning related, providing the actual environment for successful adaptation. Incentives, guidance on national level are essential tools for successful adaptation on local and regional level. However, lack of intersectoral cooperation and harmonization is a major bottleneck.

9.2.3.1 (Inter)national framework

The international framework for climate change adaptation is formed by a range of international conventions closely related and overlapping each other.

The main one for Climate is the United Nations Framework Convention on Climate Change.

The UNFCCC is a “Rio Convention”, one of two opened for signature at the “Rio Earth Summit” in 1992. Its sister Rio Conventions are the UN Convention on Biological Diversity and the Convention to Combat Desertification. The three are intrinsically linked. In this context, the Joint Liaison Group was set up to boost cooperation among the three Conventions, with the ultimate aim of developing synergies in their activities on issues of mutual concern. Moreover, these three conventions are major policy documents to build adaptation on. Both Uzbekistan and Turkmenistan signed these UN conventions.

Other critical related ratified international conventions signed by both Turkmenistan and Uzbekistan guiding climate adaptation are:

1. Sustainable development - Sustainable Development Goals
2. Do No Harm Rule – in accordance with the Charter of the United Nations
3. The Beijing Declaration and Platform for Action on Gender equality
4. UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters Environmental information (Aarhuus convention)
5. Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) and related Protocol on Water and Health, jointly serviced by UNECE and WHO-Europe.
6. Sendai Framework for Disaster Risk Reduction

Both Turkmenistan and Uzbekistan have a basic policy in place to enable the national measures. However, for both countries the national intersectoral coordination is hampering (see national CCA reports for Turkmenistan and Uzbekistan, and the policy assessment for both countries.

For Turkmenistan it is the Land Degradation Neutrality which is a central policy, for Uzbekistan it is focusing on soil productivity and water efficiency.

9.2.4 Intersectoral cooperation

The effectiveness of **climate adaptation policy** and measures largely depends on the **sectoral implementation.** Therefore, the sectors' capacity to implement cross-cutting issues has to be further developed and institutional settled in the desk or department. Furthermore, to **harmonize between**

sectors, a permanent National Platform on Climate Change and Disaster Risk Management in which all sectoral authorities participate is essential to harmonize and prioritize the adaptation measures.

To enable this, Uzbekistan and Turkmenistan have a major policy structure in place to build on. It is about practical **activation of the intersectoral cooperation in climate change adaptation** and **sectoral implementation**. And the **communication and supporting measures** (**incentives and guidance**) to the lower authorities and private sector.

Sectoral capacity needs to be built and institutionalized to enable effective sectoral implementation.

Effective adaptation requires, besides the **intersectoral cooperation on a governmental level, business cooperation down the value chain**, **ownership** on the measures and a **multi-level authority approach** and last but not least **NGO involvement to include local households**.

Building regulations, standardizations in different sectors need to be adapted into an integrated multi-sectoral approach. Also, climate adaptation has to be included in sectoral legislation like the Code for Architecture or the Law on safety of hydraulic structures. The new environmental code offers an essential tool for these approaches to be included in the sectoral legislation and regulation. For example, a regular for example **5 years review of all sectoral legislation and regulation on climate change** is advised.

To increase the effectivity following the climate adaptation strategy, a roadmap including clear targets, budget, and responsible actors for implementation needs to be developed, including all sectors, and centrally monitored and publicly communicated (see monitoring).

Other important adaptation tools on national level include[41]:

- Financial incentives to stimulate authorities, businesses and households to take their share in adaptation – these include a range of tools that stimulate adaptation like **tax incentives, grants, subsidies, guarantees for loans, climate financing, attracting global resources, bonds and equity for the capital market, interest restrictions and support, limitation to collaterals for loans, ownership rules enabling its use as collateral for loans.**
- Insurance for recovery from disasters
- Spatial planning - to stimulate the economy (to bring supporting economic sectors together), reduce risks for natural hazards, stimulate necessary infrastructure and stimulate sustainable development. By excluding risky natural hazard zones, significant disaster cost can be avoided.
- Compensation for the impact of climate change adaptation

[41] See for more details “Recommendations on adaptation options for Uzbekistan and Turkmenistan”

- Monitoring – monitoring of natural resources inclusive hydrology, meteorology, disaster risk monitoring, monitoring of the effectiveness of climate adaptation measures, monitoring of the effectiveness of budget flows and open, timely and free availability of environment and natural resource information
- Research and education
- Stakeholder involvement
- Advisory on climate change adaptation
- Sectoral policy on priority measures and groups, targeted subsidies and budgets aiming to support climate change adaptation

10 BENEFITS, BARRIERS AND RISKS OF CLIMATE CHANGE ADAPTATION

10.1 Benefits of adaptation

The major climate vulnerability for the Tuyamuyun Hydro Complex, as mentioned above, are heat and drought duration and extreme precipitation. Where heat and drought are pressing most on agriculture, water and health, the increase of extreme precipitation are most pressing through the water, natural hazards and infrastructure.
This means that by climate adaptation, most benefits can be reached for these sectors.

The information mentioned in this chapter is indicative and based on global resources of international organizations like World Bank, FAO, UNECE, IPCC, Global Commission on Adaptation, IEA, and other. It aims to give directions on the benefits of adaption and its importance for the country.

In agriculture, climate change will increase the heat stress of crops, cause increased evaporation, increase disease and pest risk, decrease the accessible water stock in soils, and thus increase the water need. The economy of Uzbekistan is for approx. 28% based on the agriculture sector, or in GDP PPP a value of 70 billion USD. In total, a decrease in agricultural production between 1-13% by 2050, depending on the region, may be expected by non-adaptation. Therefore, a 4% average decrease of agro production would mean an economic loss of 2800 million USD (PPP). For Turkmenistan by non-adaptation, a decrease in productivity of 4-5% may be expected, resulting in a cost of 350 million USD PPP.

Improvement of the monitoring of weather, climate, and natural resources offers the highest benefit, not only for agriculture but also for most other sectors, with a benefit average of 9 or more USD for each dollar invested. The most can be reached by giving free access to the data, which will result in increased economic use of up to 15 times. The loss of fee-based income will largely be compensated by increased tax from economic use of the data.

More heat-resistant breeds of crops will give release and offer a 50% more investment in selected seeds and a 30% additional harvest, especially in rainfed arable farming. This counts especially where the water availability is limited. Strip cropping, wherein one field more crops in strips are cultivated, in combination with crop rotation, will reduce the risk of diseases, stimulating the soil health and shade to each other. It will increase the average yield against minimal cost. No-tilt and low-tilt cultivation on rainfed land will increase the organic matter in soil, but seen the investment level delivering profit only but steadily after a couple of years. Permanent land cover (green fertilizer) will increase the soil organic matter, resulting in deeper rooting and more water availability. This can be further improved by root growth supporting fungi preparate. It is the most beneficiary on soil with limited access to water. Using legumes for intermediary crops will also increase the Nitrogen and free available Phosphate in soil, contributing to the following crops. Improved soil can result in doubling the root depth and triple or more access to water and minerals. The ploughing under of straw will give an additional positive effect. In this case, the first years, a higher N gift is required to balance the C/N coefficient. But after 2-3 years this is earning fully back, thus an investment in time.

Altitude cultivation and cropping deliver at hardly any additional cost high reduction of run-off and land erosion.

Water efficiency measures will result in water-saving and reduce the risk of salinization and save soil fertility. Drip irrigation is the most effective measure, especially for high-value crops like vegetables and fruit. It offers, besides water-saving, increased productivity. In combination with under cover cultivation a doubling of the yield can be expected by a water saving of up to 80%. In the longer term, the benefit is 4 – 5 USD for each dollar invested (Global Commission for Adaptation under IPCC)

In areas with limited water available and or higher salinity, permanent crops, especially fodder crops, are advised. Well-selected fodder crops require less water and offer more stable productivity, thus reducing risk. All these measures in the longer-term will be earned back with a benefit of 3 to 4 USD for each USD invested.

Improved processing and storage capacity will contribute to more stable income from agricultural production and a higher added value.

For livestock, it means besides heath stress, additional need for water and fodder, which will be less available in non-irrigated areas. In non-irrigated areas pasture rotation, with compact herding, permanent access to water and local shading provided, for example in the form of agro-forestry, can increase the (degraded) pasture productivity easily by a factors 3 or more. It is wise to produce a stock of fodder crops to overcome drought risk and fatten the livestock before selling, which will earn double back in the first drought / heat period. In irrigated areas, provision of shade and permanent water access are most important and be earned back with a benefit of 4 dollars for each USD invested.

The benefits of land degradation neutrality are higher than average. The cost for the economy are estimated for Uzbekistan at 3% of the GDP or 7.5 billion USD (PPP) and 4-5% for Turkmenistan or 350 million USD (PPP). Therefore, a benefit of 5-6 USD for every dollar invested can be expected. The benefits are found in land productivity, wood production, reduced cost of water management (less sedimentation, increased peak flow), increased energy productivity (increased buffer capacity, sedimentation of reservoirs and turbidity of cooling water) and especially in disaster risk reduction (flooding, mudflow, flashflood and landslide risk) (UN LDN).

Agriculture is by far the most water-consuming sector, reaching of 80% and more of the available resources. Measures as mentioned above, combined with reduction of leakages (estimated around 50 percent, can reduce the water consumption by 30% or more. A benefit of 4 – 5 USD for each dollar invested can be expected when applied in a combined approach with agriculture. Here the risk of more limited water availability is further increasing the long-term benefits. On top of this, the land degradation neutrality benefits can be added (ICWC / GCfA under IPCC).

The energy sector is facing a reduction in capacity between 3-5% due to higher water temperature. Thus less cooling capacity, lower transmission capacity, increased peak flow and sediment flow into reservoirs and increased risks of natural hazards. Increased temperatures, extreme precipitation and increased peak discharge, are major climate-induced causes. A fossile generation capacity of 254 MWt and a hydro capacity of 150 MWt means a potential reduction of generation capacity 12-16 MWt. On the other hand, benefits can be expected from increasing cooling capacity, climate-based modelling of river flow and improved climate monitoring (IEA).

The benefits of the health sector, in need of an increased capacity of 10% or more, can be counted by the increased labor availability and social investment done by the community in the patient's lifetime. 10 years of shorter life results in a loss of at least 10 times the gross national income per capita, which is 7.000 USD (PPP) for Khorezm and the republic of Karakalpakstan in 2019 or 16.000 USD (PPP) for Dashoguz province. This means a total of 70.000 USD resp. 160.000 USD value for the society to be saved, added by 25% of the social investment education, etc. This investment in the medical sector to increase the capacity to match the changing climate is readily earned back. This calculation does still not include the social value for family and community. In average the death rate by 3 °C temperature is expected to increase with 73 additional death per 100.000 inhabitant. For the provinces included in the THC area this could mean 3,700 additional death per year. The first heat wave will earn back a special fund for extreme weather and reserve capacity. Measures like mentioned above, like the greening of sub-urban areas, creating shade and decreased temperatures of 3-4 °C, or supplying save drinking water in times of health, or better permanent save drinking water supply, will create a benefit of 4 -5 USD for each dollar invested (UN / Worldbank/ WHO).

Besides the production of wood, Forestry has a major role in the protection of natural resources like grassland and erosion. The benefits of forestation (land regeneration) ranges from 5 USD and up for every dollar invested, depending on the protection for other sectors like infrastructure, urban settlements, water management or drinking water supply. Their contribution is also necessary to green the area for climate adaptation and revegetation of degraded land as mentioned above.

Monitoring natural resources, e.g. by earth observation, would benefit 9 and up per dollar invested. The second one is land regeneration and reforestation as mentioned above with a benefit of average 5 and up.

Thus, all the adaptation measures mentioned in the chapter above have a positive benefit-cost ratio. In average, the adaptation measures have a cost-benefit ratio of in average 1:4 or higher. Open and free information on climate and environment has the highest cost benefit ratio of average 1:9-15. In other words every dollar invested offers an economic benefit or avoids losses with a value of at least 4 dollars up to 15 dollar. Adaptation is therefore well worth to invest in. Governmental incentives and initiatives will be picked up quickly when awareness is raised and capacity build.

Following the Nature-based Solution approach, the benefits may raise with another 30-35% due to the multi sector impact.

Adaptation has a triple benefits. Besides profit and avoided losses, especially when applying nature-based solutions, will offer cross sectoral benefits, health and wellness, and biodiversity.

As climate change is developing step by step, measure needs to be adaptable and prepared in advance step wise. Developing adaptive pathway, especially by authorities is a suitable tool for longer term economic and management planning. When prepared in a harmonised way, climate change adaptation

will create economic benefits, create new employment opportunities, and reduce future cost. Adaptation is of interest for the private sector but needs public incentives.
The public sector must support by guidance, demonstration and incentives, local climate adaption, and national measures to make local adaptation successful.

Further details and examples can be found in the report on benefits and cost of climate change adaptation.

10.2 Risks

The success of climate change adaptation includes risks that have to do with the planning (also budgetary), awareness and understanding, which in the main part can be avoided by taking them into account by the preparation. In specific can be mentioned:

- Significant risk for climate adaptation is that the cost is developing with time, earlier actions will cost less.
- Lack of public involvement bring adaption in risk

Risks are not understood. Even when risks are understood, knowledge is often lacking on proper solutions—what works, what does not, and the costs and benefits of specific options to reduce vulnerability.

10.3 Barriers

As a barrier to adaptation, action can be mentioned:

- Most decisions do not internalize climate change. Decisions by a city official undertaking land-use planning, a utility deciding where (and whether) to build a new power plant or a farmer planning the next cropping season should all consider the many ways climate puts expected outcomes at risk. Even when risks are understood, knowledge is often lacking on appropriate solutions—what works, what does not, and the costs and benefits of specific options to reduce vulnerability.
- Human behavior does not favor taking the initiative when the location and timing of hazards are uncertain, when benefits of action may be years away, or when more immediate priorities take precedence.

In addition to knowledge gaps and short-term biases, fragmented responsibilities, poor institutional cooperation, and lack of resources hinder action. Governments lack incentives and funding for agencies to grapple with knowledge gaps, collaborate across silos, and implement innovative solutions.

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