Uzbekistan Case Study

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1. Introduction

The Republic of Uzbekistan is an arid country remote from the sea, located in the center of Central Asia in the Aral Sea basin. Uzbekistan borders on Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Afghanistan. The territory encompasses 448900 km^2 with a total length of the borders of 6221 km. The landscape of Uzbekistan is extremely diverse in terms of relief forms with plateaus, low and foothill plains (70%), mountain spurs and mountain ranges (20%). The average amount of precipitation in the desert zone of the country is less than 200 mm/year, and in the foothills and mountains it varies from 400 to 800 mm/year with a maximum in the highlands up to 2000 mm/year. The country has a variety of natural resources, including fertile agricultural soils, forest resources, water resources, mineral resources and an amazingly diverse flora and fauna. The population is more than 34.59 million people (01.01.2021), half of which is rural. Agriculture is the most drought vulnerable sector of the economy, as it directly depends on weather conditions and the availability of water resources. At the same time, it contributes 28.1% (2019) to the GDP. Today, irrigated agriculture, which accounts for only 9% of the total area of the country, already consumes about 90-91% of the countries total available water, and the demand for water will increase to ensure food security for a rapidly growing population.

According to the UNEP aridity index (from 0.05-0.20 to 0.65), the territory (excluding the foothill and mountainous parts) belongs to the arid zone affected by meteorological and soil moisture droughts and, accordingly, is susceptible to land degradation and desertification.

Based on national reviews and IPCC estimates, increases in mean annual air temperatures are observed; the difference in the average 30-year values between the beginning and end of the period 1950-2018 for the southern, central and northern zones of Uzbekistan was 1.01, 1.34 and 1.43°C, respectively. Throughout Uzbekistan, the number of days with high air temperatures continues to increase, for example, in 2019, the number of days with air temperatures above 38°C at Tashkent station exceeded the norm by almost 2 times.

The increased incidence of droughts caused by climate change is one of the most dangerous phenomena; they are protracted, widespread, and affect all population and economy.

In the last decade there has been an increase in the frequency of droughts in the country: droughts have become more frequent in summer and autumn, especially in the lower reaches of the Amudarya river and around the Aral Sea. For example,

while in the 1980s and 1990s drought was observed on average twice every ten years, in the period 2000 – 2012, extreme meteorological drought was recorded 4 times - in 2000, 2001, 2008 and 2011. According to the World Bank regional survey [3], losses caused by the agricultural drought of 2000-2001 in Uzbekistan amounted to US$130 million.

Droughts in Uzbekistan are regional in nature and, unlike other hazards, their impact is not clearly delineated. To take adequate measures and develop plans to combat drought and its impacts, it is necessary to identify the severity and spatial coverage of droughts and their frequency as well as to analyse the resulting deficit in water resources. We also need assessments of the impact on population, economy and environment.

The following drought types are typical for Uzbekistan:

- Atmospheric, or meteorological, drought is characterized by a long and significant lack of precipitation in comparison with the norm, high temperatures and a strong deficit of air humidity.
- Hydrological drought in Uzbekistan is a shortage of water resources caused by snow accumulation in the mountains.
- All other types of droughts, such as soil moisture drought, agricultural drought, and socio-economic drought, are the consequences of atmospheric and hydrological droughts.

Despite significant efforts by the government, Uzbekistan still faces the need to find solutions to combat desertification, land degradation and drought, and aims to develop responses and actions to prevent and mitigate drought risks to ensure sustainable livelihoods and food security in the country.

2. Drought Indicators. Approaches to Estimate and Forecast Drought in Uzbekistan

Drought estimates and forecasts in Uzbekistan are carried out by Uzhydromet, based on data from systematic observations of the characteristics and parameters of the climate system. Uzhydromet has an extensive network of meteorological, hydrological, agrometeorological observations (which is a stable basis for early warning and effective response. The observation network is being modernized and remote sensing and reanalysis data are also used for drought assessments and forecasts.

Analysis and review of numerous publications [5, 6, 7, 8, 11, 12, 14, 16, 27, 36, 37, 38], made it possible to identify a variety of drought indices used in the country both within the framework of scientific research and implemented in international projects, both for forecasting and assessing the degree and intensity of droughtsg (Table 1).

Table 1. Drought indices applied in Uzbekistan

№	Drought index	Type	Drought degree and intensity			
1.	Vapor-pressure deficit, (E), gPa	A	50-60 gPa	61-70 gPa	71-80 gPa	> 80 gPa
			weak	average	strong	very strong
2.	Aridity index	A	AI<0.03	0.03<AI<0.20	0.20<AI<0.50	0.50<AI<0.65
			Extra-arid	Arid	Semi-arid	Dry sub-humid
3.	Water flow availability for vegetative period (April-September)	H	80 % < P < 95 %		P > 95 %	
			moderate		strong	
4.	Snow accumulation as criterion (index) of year water availability	H	< -0.2		< -0.4	
			moderate		strong	
5.	Standardized precipitation index (SPI)	H	-1.0- -1.49	-1.5-1.99	-2 and less	
			moderate	strong	extreme	
6.	D.A.Pedya index or hydrothermal coefficient HTC (HTC of Sazonov)	H	0.7≤HTC≤1.0	0.5≤HTC≤0.7	0.4≤HTC≤0.5	<0.4
			weak	average	strong	very strong
7.	Reduction of soil moisture reserves in the soil layer 0-20 cm thick to 4 mm, for clay-rich semi-desert soils - 10 mm	S	Depending on soil			
8.	NDVI (vegetation condition)	A	Open soil	Oppressed vegetation	Sparse vegetation	Dense vegetation
9.	Number of days with air temperature exceeding 40°C	A				

A - atmospheric drought
A – agricultural drought
S – soil moisture drought
H - hydrological drought

Atmospheric drought – a number of days with vapor-pressure deficit in the air ≥50hPa. As an additional criterion, the number of days with air temperature of more than 40°C is used. Although this criterion is not a direct indicator of drought, the

temperature above 40°C negatively affects population health, growth and development of agricultural crops, and causes high transpiration from plants.

To assess atmospheric drought, field monitoring data from 32 representative meteorological stations are used and results are published anually.

An effective drought management is possible only with appropriate preparedness, on the basis of carefully developed proactive mitigation measures. Important in this context are skillful long-term forecasts of meteorological parameters like air temperature and precipitation, which are the basis for predicting atmospheric and hydrological droughts.

However, despite globally ongoing efforts, the effectiveness and justification of long-term and ultra-long-term forecasts is still low. Justification of monthly and seasonal forecasts of temperature and precipitation anomalies is slightly higher, but also insufficient for making effective and timely decisions. Particular difficulties in long-term forecasting arise in continental regions of moderate latitudes, where the natural variability of temperature and precipitation is high, which is also typical for the Central Asian region. In modern conditions, long-term forecasts of climatic parameters is a symbiosis of the traditional synoptic method with numerical and statistical forecasting methods. In Uzhydromet, the official method of long-term weather forecasting is synoptic-statistical, and additionally, statistical methods of forecasting for the season are used as advisory methods, which makes it possible to find general patterns in the formation of weather conditions for long periods of time.

Hydrological drought is estimated and projected based on river flow and water availability forecasts for the vegetation period (April-September). The basis for hydrological forecasts is information on the formation of snow cover and accumulation of precipitation in the mountains. Hydrological drought indicators criteria are given in Table 1.

Estimates and forecasts are carried out on the basis of field and satellite data using the Automated Information System for Hydrological Forecasts (AISHF). Realistic modeling results allow using this system to estimate the response of water resources to possible climate change, based on climate scenarios [27].

The results are given as:

- Information about accumulation of precipitation and snow reserves in the mountains (early January and February).
- Preliminary forecast for early March.
- Forecast of river flow (early April).
- Forecasts are specified with forecasts for the second and third quarters and forecasts of average monthly water discharge [8].

Agricultural drought. Agricultural drought monitoring is based on a comprehensive assessment of the impact of hydrological and meteorological drought on agriculture, taking into account the precipitation deficit, actual and potential evapotranspiration, changes in the level of groundwater and the level of reservoirs.

Based on the results of agrometeorological observations with a step of one decade, databases are created for assessing dry conditions, taking into account their main components (atmospheric and soil moisture droughts), and bulletins are published, including:

- number of days with relative air humidity <30%;

- number of days with maximum air temperature> 40°;
- reserves of productive moisture under winter crops and cotton in soil horizons 0-20, 0-50, 0-100 cm.

Remote sensing data is widely used for:

- agricultural land monitoring;
- operational assessment of the degree of agricultural and pasture land degradation;
- operational assessment of snow cover in the zone of Amudarya and Syrdarya.

To assess impact of climate change on water resources and formation of dry years, the climatic scenarios REMO-0406 and REMO-0507 developed by the German Research Centre for Geosciences in Potsdam are used, which make it possible to project the distribution of the expected future air temperature and precipitation values for the period up to 2099 with a daily resolution [16]. Climatic scenarios show consistent trends in air temperature increase relative to the base period (1971-2000) throughout Uzbekistan and practically unchanged precipitation with an increase in their natural variability [16].

At present, work is also actively underway on the possibility of using/verification global data, surch as ERA-5 reanalysis data - temperature, precipitation, relative humidity, and vapor pressure deficit (VPD) for calculating drought indices [13] and SPEI.

3. Drought Early Warning System

The Drought Early Warning System (DEWS) developed by Uzhydromet is a tool for assessing, monitoring, warning, alerting and decision-making in the event of low water and drought in the basins of the main Central Asian rivers: Amudarya and Syrdarya. DEWS allows to determine the volume of expected water flow in the upper reaches of the mountain rivers of Uzbekistan, located in the zone of natural flow formation. Predicting water content of rivers in the zone of intensive use of runoff is a rather complicated issue, since the river is experiencing a strong anthropogenic load. For this, new methods and approaches for DEWS have been developed [37-39].

The objective of DEWS is to provide decision makers and the public with information about possible droughts in advance. With the support of UNDP, the DEWS was tested in the flow formation zone (Kashkadarya region) and is currently being adapted for the flow dispersion zone (Karakalpakstan) of Uzbekistan [16, 17].

At present, it allows to obtain a qualitative assessment of the expected river flow, and to determine whether sufficient water resources will be available or drought is expected, and to define quantitative characteristics of water reserves for a particular object [17].

The degree of expected low water and drought is a criterion for the adoption of certain action plans to mitigate consequences of the expected drought. The reliability and timeliness of forecast information should be sufficiently high, since in the event of large-scale droughts, large areas of the country may be at risk, and in addition, on the basis of this information, the authorities will be able to adjust the strategy for managing available water resources, which will incur significant costs.

In general, the structure of the DEWS [9, 16, 17, 37-40] includes the following components:

- Biophysical data of the territory.
- Estimates and forecast of low water and drought.
  - Indices: Pedya Index, SPI, Snow Reserves Index,
  - Models of snow cover formation, runoff from glaciers, and runoff transformation.
- Awareness and data dissemination.
- Recommendations for mitigation.

4. Physical and Socio-economic Characteristics of Uzbekistan

4.1 Physio-geographical Profile

The Republic of Uzbekistan is located in the center of the Eurasian continent, within the Amudarya and Syrdarya rivers. It shares borders with Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Afghanistan. Total length of the borders is 6221 km, total area is 448.9 thousand km^2.

The country occupies a large territory with a complex variety of surface and relief. Desert areas make up 78.8% of the territory, which includes the Kyzylkum and Aralkum deserts formed as a result of degradation of the Aral Sea. In the east and southeast of the country, the plains pass into the spurs of the Tien-Shan and Gissar-Alay mountain systems with highly dissected relief - these are 21,2% of the country's area.

The climate of Uzbekistan is arid and continental, with hot and dry summers and short cold winters, characterized by large temperature differences between day and night, winter and summer.

Distribution of atmospheric precipitation over the territory is extremely uneven, closely related to the location of mountain systems, the altitude and the exposure of slopes (Fig. 1). An increase in precipitation is observed in the foothill and mountain areas, especially on the windward slopes. However, in general, the whole area of Uzbekistan belongs to the arid zone.

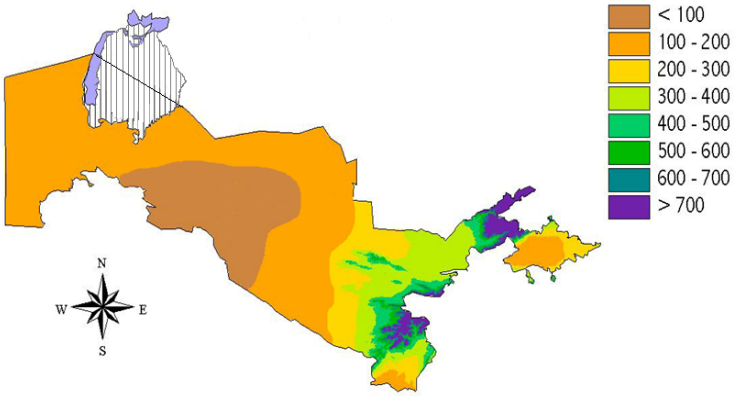

Figure 1. Distribution of annual precipitation amounts over the area of Uzbekistan (in mm).

Climate features are caused by a combination of three main factors - solar radiation, general atmospheric circulation and topography. In the warm season, a high level of solar radiation in Central Asia creates conditions for the formation of vast heat areas, especially over the deserts (Karakum and Kyzylkum). The strongly heated air over the plains of Uzbekistan is dry, therefore, in the summer period of the year the conditions for drought formation are often created. The absolute maximum air temperature in summer in the desert regions of Uzbekistan can reach 45-49°C and more. The average annual air temperature in the plains of Uzbekistan at present time (1990-2018) is on average 14.9°C, the warmest month is July (28.8°C), the coldest month is January (0.9°C). The increase in air temperatures over the area of Uzbekistan occurs against the background of high natural variability, which causes significant interannual fluctuations (Fig. 2).

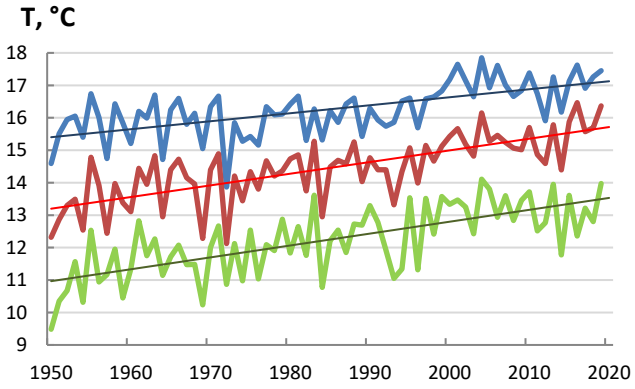

Figure 2. Change in average annual air temperatures since 1950 in the southern (blue), central (red) and northern (green) zones of Uzbekistan. Zones are defined based on latitude, therefore the central zone includes the foothills of the Western Tien-Shan and Fergana Valley.

Although the rate of increase in average annual air temperatures somewhat slowed down, the difference between the 30-year average values at the beginning and the end of period (1950-2018) for the southern, central and northern zones of Uzbekistan was 1.01, 1.34, and 1.43°C, respectively.

The increase in the number of days with high air temperatures throughout Uzbekistan continues. For example, in 2019, the number of days with air temperatures above 38°C at Tashkent station exceeded the norm by almost 2 times.

The increase in amount of hot days and the decrease in air humidity cause more frequent adverse weather phenomena, such as droughts, strong winds with a speed of 15 m/sec and more, and dry winds, which cause an increase in dust storms. The number of days with dust storms in the plains ranges from 10-30 to 50-64 days a year.

The country's **aquatic ecosystems** represent a single hydrographic network of permanent and temporary watercourses flowing from the spurs and ridges of the Western Tien-Shan and Pamir-Alay, groundwater resources and a unique combination of desert and humid territories, united by common sources of water supply - the Syrdarya and Amudarya rivers.

Surface runoff of rivers. The main water resources of Uzbekistan are surface runoff of the Central Asian transboundary rivers - Amudarya and Syrdarya, their tributaries and Kashkadarya and Zarafshan rivers. River runoff of Amudarya and Syrdarya is characterized by significant intra-annual and long-term irregularities, and in a dry year it is 23 km^3 less than in a year of average water availability. High-water years come periodically after 6-10 years and have duration of 2-3 years, but more often there are low-water periods observed after 4-7 years and having a protracted nature - up to 6 years. The main flow of the Amudarya river is formed on the territory of Tajikistan and of the Syrdarya river on the territory of the Kyrgyz Republic. This is the reason for Uzbekistan's dependence on transboundary water sources. The average long-term water resources of the national (internal) rivers of Uzbekistan are estimated at about 11.5 km^3/year, which satisfies about 18% of total water demand of all economy sectors.

The volume of available water resources of Uzbekistan for the conditions of seasonal regulation of the Amudarya runoff and long-term regulation of the Syrdarya runoff (taking into account 11.5 km^3 of the runoff of its own rivers) is 63.02 km^3 according to the interstate Agreement between Kazakhstan, Kyrgyzstan, Uzbekistan, Tadjikistan and Turkmenistan[1]. The cyclical nature of fluctuations in the river runoff and long periods of low water complicate the economic use of water sources, especially for irrigated agriculture in the lower reaches of the Amudarya river [19].

Lakes and reservoirs. In addition to small rivers, also lakes belong to the inland water resources. There are about 520 natural lakes on the territory of Uzbekistan, mainly with water surfaces not exceeding more than 1 km^2. Natural floodplain and deltaic lakes are located in the valleys of local rivers, most of which owe their origin to the erosion-accumulative activity of rivers. Mountain lakes, usually of dammed or glacial-moraine origin, are located at an altitude of 1700 - 4000 m above sea level and are a potential reserves of clean, fresh water, the volume of which is estimated 60 km^3 [45].

As a result of the development of irrigated agriculture, many artificial reservoirs have been formed due to collector-waste waters. Over 269 desert depressions with the area of 739 km^2 in the middle and lower reaches of the Amudarya river are filled with

[1] **Agreement between the Republic of Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan and the Republic of Uzbekistan on Cooperation in the Field of Joint Management on Utilization and Protection of Water Resources from Interstate Sources http://www.icwc-aral.uz/statute1.htm**

drainage water. In the middle reaches of the Syrdarya river, there is the largest system in Uzbekistan, the Arnasay system, which unites Aydarkul, Tuzkan and Upper Arnasay lakes. The volume of water in these lakes of anthropogenic origin is estimated 40 km^3; water in the lakes is mineralized, however, suitable for fishery and maintaining biodiversity.

The largest natural lake, the Aral Sea, half of which belongs to Uzbekistan, was the fourth largest lake in the world until the 1960s. Currently, there are two fragments of the sea left - in the north and west with a remaining water volume of about 10% compared to 1960. Mineralization of water increased tenfold and reached 25-30 g/l in the Northern part of the sea and 100 g/l in the Western one, and became unsuitable for habitation of most of the endemic species. The Aral Sea disaster, the result of many years of anthropogenic activity, is not only an ecological, but also a socio-economic problem for communities living along its former banks.

In Uzbekistan, there are 56 water reservoirs [45] operated to solve irrigation, energy and fishery problems. But since water reservoirs represent the flow of rivers redistributed within a year, they are not classified as water resources.

Groundwater is a significant component of Uzbekistan's water resources. Groundwater is widespread in the mountainous regions, and artesian basins are found on the plains. The sources of groundwater supply and formation of their resources are filtration canal losses from watercourses, infiltration of irrigation water and atmospheric precipitation. Operational reserves of fresh and brackish groundwater in Uzbekistan are around 6.147 km^3/year. Groundwater is used in the national economy as the main source of drinking water supply, water supply to industry, for irrigation of pastures, and partly for land irrigation. The volume of groundwater used is estimated to 5,319 km^3/year, which is on average 10% of the total water consumption.

Return water is an additional source of available water resources, but on the other hand, its quality poses a serious threat to aquatic and terrestrial ecosystems. The largest volume of return water is generated from irrigation. In 2017 and 2018, the collector-drainage flow, respectively, was 28.7 km^3 and 23.5 km^3. The share of collector-drainage runoff in the total volume of return water from all consumers and water users is about 90% in the Amudarya basin and over 55% in the Syrdarya basin. The main contribution to return waters come from irrigation in the Amudarya river basin - 87.9%, in the Syrdarya river basin - 56.2%. Such high volume of return water from irrigation is caused by large filtration losses from canals and irrigated fields.

Water resources available for use. The distribution and management of the resources of Amudarya and Syrdarya transboundary rivers, and keeping principles of regional water allocation and proportions of the established water intakes, are ensured by the regional Agreements on Cooperation signed by the Heads of State in the Aral Sea basin. The responsibility for making decisions on management and distribution of water resources is entrusted to the Interstate Commission for Water Coordination of Central Asia (ICWC), which coordinates activities of the Basin Water Association “Syrdarya” and Basin Water Association “Amudarya”, in accordance with the adopted Agreements [48, 49].

In accordance with interstate water allocation, the yearly water resources allocated to Uzbekistan are 59.2 km^3 (including 24.1 km^3 for the Syrdarya basin and 35.1 km^3 for the Amudarya basin) (Table 2).

Table 2. Approved volume of water resources for Uzbekistan, km^3

River	River trunk	Small rivers	Total	Groundwater	Collector-drainage flow	Total
Syrdarya	10.49	9.42	19.91	1.59	2.60	24.10
Amudarya	22.08	10.41	32.49	0.30	2.31	35.10
Total	32.57	19.84	52.41	1.89	4.91	59.20

Source: Scheme of IWRM in the Syrdarya (1983) and Amudarya (1984) river basins, Sredazgiprovodkhlopok taking into account the clarification of the Vodproekt association (1996)

When the water content of the rivers is higher than the calculated supply of excess water, the volumes of water in excess of the specified limits must be accumulated in water reservoirs and directed to improve the ecological situation in the Aral Sea basin regions. When the water content of the rivers is lower than the calculated water supply, water intakes of the countries of Aral sea basin are subject to proportional reduction.

According to the State Committee on Statistics, total land resources of the country amount to 44.896,9 thousand ha, of which 44.410,3 thousand ha are in use by enterprises, organizations and citizens. The land, like other natural resources of Uzbekistan, is a state property and a nationwide wealth, as well as a subject to rational use and it is protected by the state.

The division of land resources of the Republic according to economic purpose is due to differences in functions that the land performs for certain purposes. The main categories of land use in the Republic of Uzbekistan are given in Table 3.

The largest categories of land used are (i) agricultural land (46.1%); (ii) forest land (21.7%),
(iii) reserve land (27.6%) within three types of ecological landscapes - deserts, steppes and mountains, covering about 95% of the country's territory. Agricultural land occupies 25.6 mln.ha, of which 21.6 mln.ha are occupied by low-productive pastures and hayfields, located in desert and semi-desert zones and are very sensitive to water shortage. Irrigated arable land, the most valuable and multifunctional category of land and the main means of agricultural production, accounts for 4.3 mln.ha, and 0.745 mln.ha are boghara. The main products of irrigated crop production are cereals, cotton, vegetables, potatoes, melons, fruits, berries, grapes and other types of products. Two crops dominate among the others - cotton and wheat, but for the period 2010-2017 cotton sowing decreased by 55.2 thous.ha, and the area under orchards and vineyards, vegetables, fodder and other food crops increased significantly.

Table 3. Land use categories of Uzbekistan

№	*Land use categories*	Total area

		Thousand ha	%
1	Agricultural purpose	20481,1	46,1
2	Settlements	214,1	0,5
3	Industry, transport, communication, defense	914,5	2,1
4	Environmental, health and recreational purposes	75,9	0,2
5	Historical and cultural purposes	6,2	0
6	Forest fund	9636,9	21,7
7	Water fund	831,4	1,9
8	Reserve land	12250,2	27,6
	Total	44410,3	100,0

Source: 3NC (2016), according to data of the State Committee on Statistics of the Republic of Uzbekistan

The natural ecosystems of the country's arid and semi-arid regions are historically prone to natural salinization and are threatened by the spread of moving sands, dust storms and dry winds, exacerbated by the lack of water resources.

The main systems in land use are grazing, irrigated and rainfed agriculture. Pasture farming is based in regions with low natural resource potential, and its technological cycle is extensive and completely dependent on natural forage conditions. It is multicultural in structure and concentrated mainly in the desert and semi-desert (81%) and piedmont semi-arid regions (12%), and the rest falls on mountain (5%) and alpine (2%) pastures. Pasture lands are characterized by low productivity of 2-3 c/ha; the yield is unstable and depends on the amount and mode of precipitation, therefore it fluctuates over the years and seasons.

Forests in Uzbekistan are characterized by low forest cover (6.8%), differ significantly in their composition and are subdivided into sandy (84%) and mountainous forests (12%), and only 2% of the area falls on floodplain and valley forests. Forests are the most important factor in maintaining biological diversity, sequestration and storage of carbon dioxide with a potential of 2.53 million tons per year [6]. According to data of the State Committee on Statistics during 2000-2018, the forest area has increased by 2.44 times due to increase in desert forests (saxaul and shrubs), and reforestation on desert land (about 39% of the total reforestation).

The most serious environmental problems threatening the country's natural ecosystems are increasing soil and water salinization, wind and water erosion, grazing of pastures and deforestation, loss of species and agrobiodiversity. Land degradation, soil erosion and over-cultivation lead to atmospheric CO_2 accumulation and affect regional climate. Increasing dangerous phenomena, including droughts, become more frequent and increase instability of agricultural production and negatively affect the life of rural population.

Special attention should be paid to **the problems of the Aral Sea and the Aral Sea region**. The Aral Sea is located in Central Asia, on the border of Kazakhstan and Uzbekistan. The water resources of Central Asia are concentrated in two largest transboundary rivers: Amudarya with an average discharge of 78.5 km^3/year and

Syrdarya - 37.1 km^3/year. These rivers originate in the mountains and descend into the plains, crossing the deserts towards the Aral Sea.

Shrinking of the Aral Sea is considered one of the most serious anthropogenic ecological crises of the 20th century. The problem that arose during the life of one generation, in terms of environmental, climatic, socio-economic and humanitarian consequences poses a direct threat to the regions sustainable development, health, gene pool and the future of livelihoods in the region. The causes of the Aral Sea disaster are a significant population growth, intensive development of irrigation agriculture, land development, construction of large hydrotechnical and irrigation facilities without taking into account environmental consequences. As a result, over the past 50-55 years, the following consequences can be observed:

- The water volume has been reduced by more than 30 times
- The sea area has decreased almost 9 times
- The sea level has dropped by more than 29 m
- The coastline has receded by hundreds of kilometers.

The Aral Sea crisis zone directly covers the territories of Turkmenistan, Kazakhstan and Uzbekistan, as well as indirectly - Tajikistan and Kyrgyzstan. In Uzbekistan, the Republic of Karakalpakstan and the Khorezm region are in the ecological disaster area, corresponding to 38.7% of the total area of the country.

On the exposed part of the Aral Sea on the territory of Uzbekistan and Kazakhstan, on the northwestern extremity of the Karakum and Kyzylkum deserts, a new Aralkum sandy-saline desert, with an area of 38,000 km^2, has appeared [46]. During drought years, population and ecosystems are particularly stressed in this area.

4.2 Socio-economic Profile

The population of Uzbekistan is 33.9 million people as of January 1, 2020, of which 50.3% are men, 49.7% are women. The urban population is 50.5%, the rural population is 49.5%. From the total population of the Republic, 30.3% are younger than the working age, 59.5% are in the working , and 10.2% are older than the working age.

In 2017, the "Strategy of Action for Five Priority Areas of Development of the Republic of Uzbekistan in 2017-2021" was adopted according to a Presidential Decree. It is the most important program document for the development of all economy sectors, including agriculture, for the medium- and long term.

Over the past 15 years, there has been a growth in the gross domestic product (GDP) in the country, so in 2019 the GDP of the Republic of Uzbekistan in current prices amounted to 511 838.1 billion soums compared to 2018. In 2019, GDP growth was 5.6% against 5.4% in 2018 and 4.5% in 2017, while the growth of the GDP deflator index slowed down to 19.2% in 2019 against 27.5% in 2018 and 19.4% in 2017. The structure of the country's GDP according to type of economic activity is given in Table 4.

It should be noted that the economic sector most vulnerable to drought is agriculture, which jointly with forestry and fishery, contributes 28.1% of gross added value to the GDP [50]. The export of agricultural products brings about 20-25% of the total export income to the Republic. Currently, more than 180 types of agro-food products are

exported to 80 countries of the world, thereby contributing about 10% to the external income of Uzbekistan [51].

Agriculture provides about 27% of employment of the economically active population [52]. In the aggregate incomes of citizens, the share of income from agriculture in different regions ranges from 35 to 60%, and in rural areas this figure exceeds 70% everywhere.

Table 4. Structure of the country's GDP acoording to type of economic activity

Economic activity	2000	2010	2013	2014	2015	2016	2017	2018
Gross added value of industries	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Agriculture	34,4	19,8	19	33,8	34,1	34,0	34,0	32,4
Industry	16,2	26,7	25,9	20,2	20,2	20,6	22,2	26,3
Construction	6,9	6,6	6,5	5,7	6,0	6,0	5,7	5,7
Services	42,5	46,9	48,6	40,3	39,7	39,4	38,1	35,6

Source: State Committee on Statistics of the Republic of Uzbekistan, www.stat.uz

The industry is demonstrating sustainable growth rates. The volume of agricultural production in 2019 amounted to 215.7 trillion soums, or 102.7% to the corresponding period of 2018 (Table 6).

Due to the arid, continental climate, crop production almost entirely depends on irrigation. Today, irrigated agriculture, which accounts for only 9% of total area of the country, already consumes over 95% of total water intake. Besides that, the demand for water to ensure food security for the 34 million citizens will increase due to high population growth. As a result of population growth, the area of arable land per capita has decreased from 0.195 ha to 0.129 ha over the past 25 years. More than half of farms are engaged in cultivation of wheat and cotton, the rest are engaged in livestock production, vegetable growing, melon growing, viticulture, horticulture, beekeeping, etc. Uzbekistan is one of the world leaders in cotton production and the main producer of fruits and vegetables in Central Asia. In 2015, Uzbekistan became one of 14 countries to receive awards for achieving the Millennium Development Goals in the field of food security.

5. Drought Characteristics

To assess ***atmospheric drought***, Uzbekistan uses the number of days with a vapor-pressure deficit of ≥50 hPa, calculated on the basis of ERA-5 reanalysis data [13].

Figure 3 shows the number of days with atmospheric drought relative to the average over the period. We can see how the average value changed relative to these two periods, on average the number of days increased by 8 days, which also demonstrates a long-term trend. If we take the years with an excess of the relative average value as dry years, then the most prolonged droughts occur in 2014-2015 and 2017-2018 [54].

On average, the number of days with atmospheric drought in Surkhandarya region is 75 days, Bukhara region - 55 days, Navoi region - 50 days, Kashkadarya region - 25 days. A large number of days a year with air temperature above 40°C is also observed in these regions (Figures 4 and 5) [54].

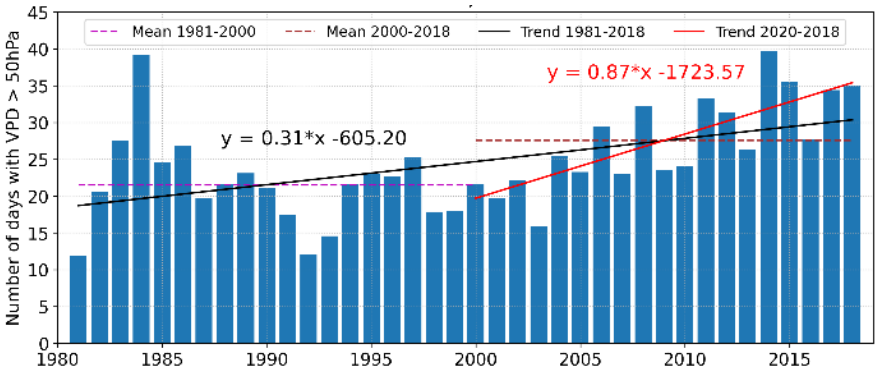

Figure 3. Dynamics of the average number of days with drought in Uzbekistan per year [54]

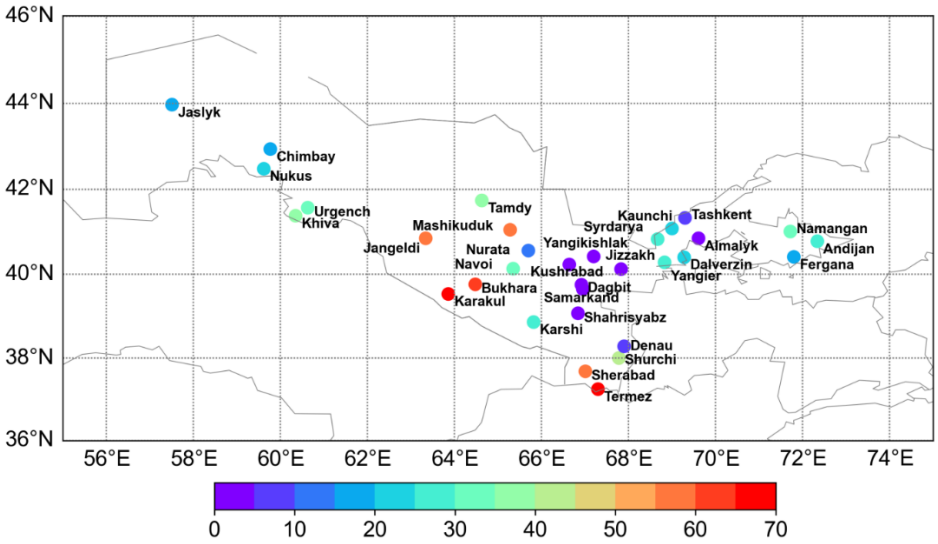

Figure 4. Number of days with a vapor-pressure deficit of ≥50 hPa averaged over the growing season from 1980 to 2018 (according to ERA-5) [54]

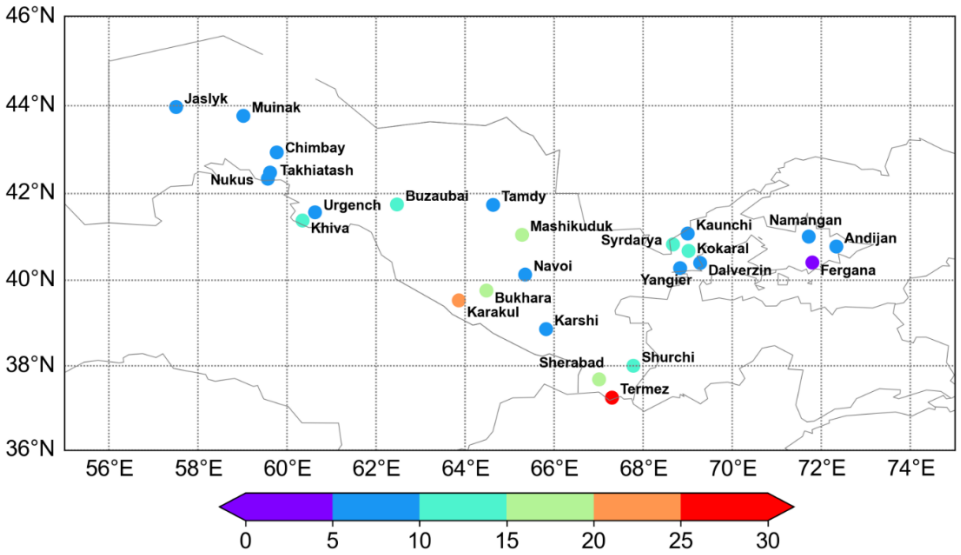

Figure 5. Number of days with air temperature ≥40°C averaged for the period 1980-2018 (according to ERA-5) [54]

Hydrological drought. Due to fact that the flow on the rivers in Uzbekistan is predominantly regulated headwaters with a minimal anthropogenic impact were analysed for the period 1960-2016/2017.

The indicator of "water availability in %" was taken as the indicator of hydrological drought, which demonstrates the degree of aridity.

Figure 6 shows, for example, long-term series of water availability for the basins of the Surkhandarya and Kashkadarya rivers, where we can see more frequent cases of droughts.

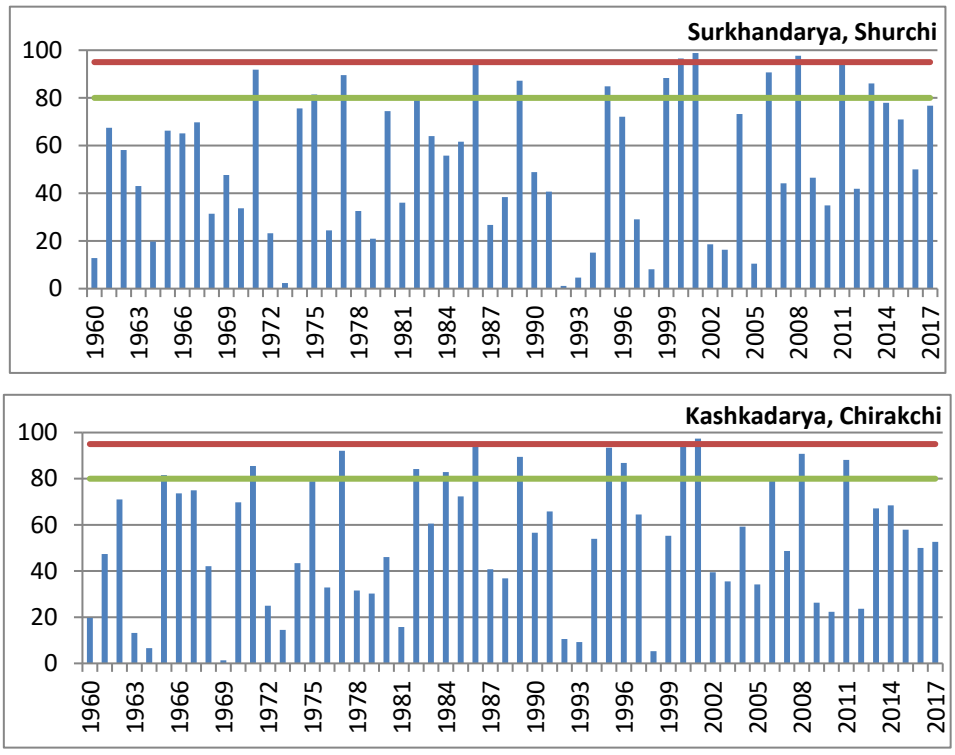

Figure 6. Trends in the drought index (water availability) for the period 1960-2017

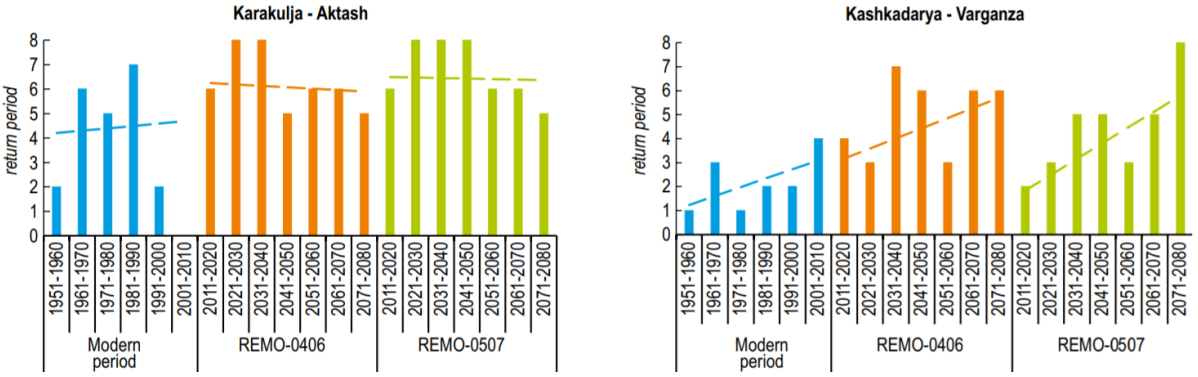

Figure 7. Frequency of low water on the Kashkadarya and Karakulja rivers in the modern period and according to climatic scenarios [16]

Figure 7 shows the results of a scenario analysis estimating the recurrence rate of dry years at present and in the future [16, 39]. The results of this approach showed that under the conditions of warming expected according to climatic scenarios against the background of increased natural variability, a decrease in runoff is likely, and there is also a tendency for the increase in extreme water content years in the basins of some rivers.

For assessing vulnerability and risks of desertification and drought the following analysis was performed:

- Zoning of the territory according to aridity index [41]
- Assessment of areas prone to desertification, land degradation and drought [15, 41]
- Assessment of agriculture and water sector vulnerability to climate change.

Zoning of the territory according to aridity index [41]. To assess the drylands of Uzbekistan, the Harvgreaves method was chosen based on the classification shown in Table 1.

As shown in Figure 8, almost the entire territory of country is located in the arid area, with 25% of the land in the extra-arid zone, and 68% in the arid and semi-arid zone.

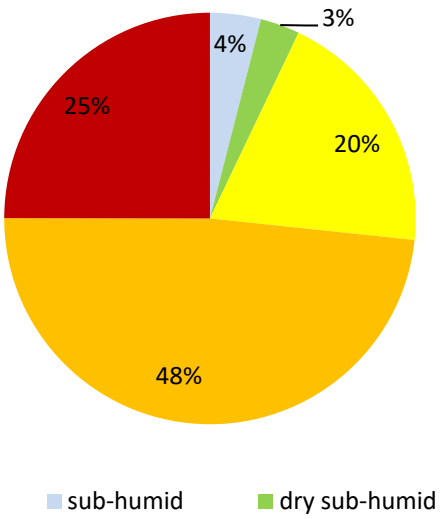

Figure 8. Distribution of the territory of Uzbekistan accroding to aridity classes [41]

The main part of the extra-arid zone falls on the Republic of Karakalpakstan (14%) and the Navoi region (7.5%), while the arid and semi-arid zone accounts for 23.1% in the territory of Karakalpakstan, and 17.4% in the Navoi region (Fig. 9).

An assessment of areas prone to desertification, land degradation and drought was performed by Rhakmatova[15].

The assessment is based on indicators of soil erosion, soil salinity, fertility, aridity, precipitation, and vegetation vigour (NDVI). A score-based approach was used to assess the integral component. Each indicator was mapped and graded on a five-score scale. Then the cumulative amount of these indicators for all classified factors allowed creating an algorithm for assessing type and degree of desertification. Taking into account the obtained values, an integral/complex map was obtained on susceptibility to desertification, land degradation and drought (Fig. 9).

As follows from the figure, more than half of the territory of the Republic (51%) is affected by desertification and drought. These areas are located in the steppe zone, but most are in the desert or semi-desert zone.

25% of the territory of Uzbekistan undergoes a strong degree of desertification and drought, it includes the areas of sandy deserts, the Aral Sea region and western part of the Ustyurt plateau.

The areas characterized by weak and insignificant degree of desertification and susceptibility to drought occupy 8% of the entire territory and are located in the foothill and mountainous regions.
1/6 of the country is moderately affected by desertification and drought. As a rule these correspond to the irrigated zones of the plains.

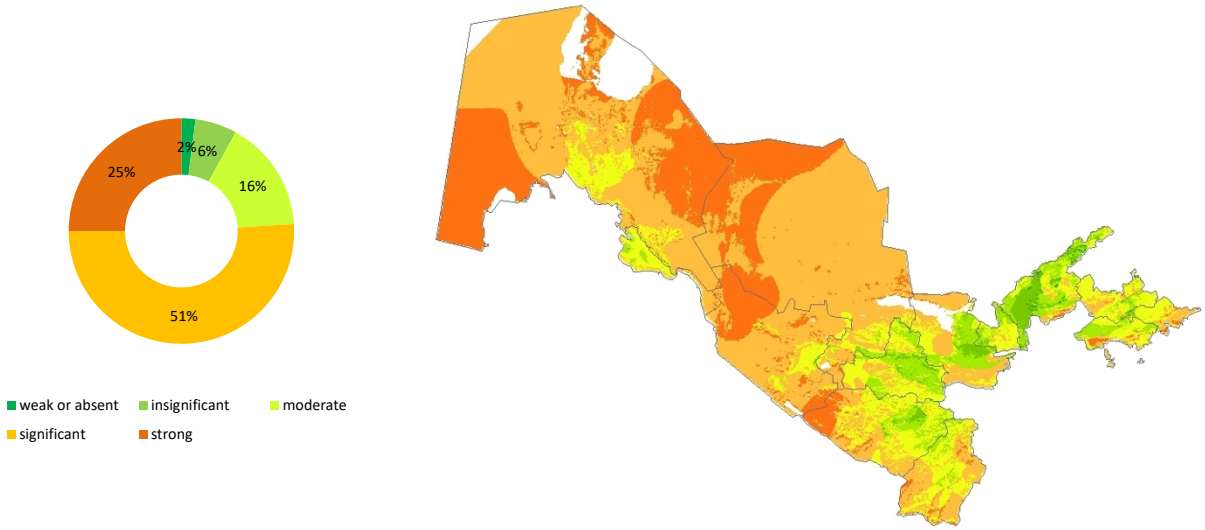

Figure 9. Map of the territory's susceptibility to desertification and drought [15]

Assessment of the vulnerability of the agricultural and water sector to climate change [42]. In terms of agriculture and water, vulnerability is influenced by a range of social, economic and environmental factors that influence the ability to withstand the effects of changing conditions. To assess the vulnerability, this study adopts a combined index approach known as the Climate Change Vulnerability Index [43], based on indicators reflecting a variety of vulnerability aspects. The following most significant indicators were selected for the assessment:

- trend of climate change,
- vegetative cover,
- mineralization of irrigation water,
- land fertility,
- salinization area,
- erosion,
- degradation of pastures,
- percentage of irrigated land,
- arable land area per capita,
- rural population,
- population density,
- use of water for irrigation,
- public health,
- percentage of the working-age population,
- GDP per capita,
- crop yield.

Each of these indicators has its own units of measurement and scales. For comparability, indicators were normalized from 0 to 1 as input to the combined vulnerability index (Fig. 10).

In all planning zones, agriculture and water sectors are vulnerable to climate change in varying degrees. On 40% of the territory, vulnerability is assessed as high and very high, on 55% as medium and high. A very high degree of vulnerability is typical for the Aral Sea region, which is due to the increased climatic impacts as a result of degradation of the Aral Sea. For certain areas of the Fergana Valley, increased vulnerability is determined by high sensitivity as a result of heavy load on natural resources and shortage of land resources due to population density (maximum 1188

people/km^2 in Asaka district of Andijan region). The areas located in the foothill part (Tashkent, Samarkand, Kashkadarya and Surkhandarya regions) are characterized by a reduced vulnerability.

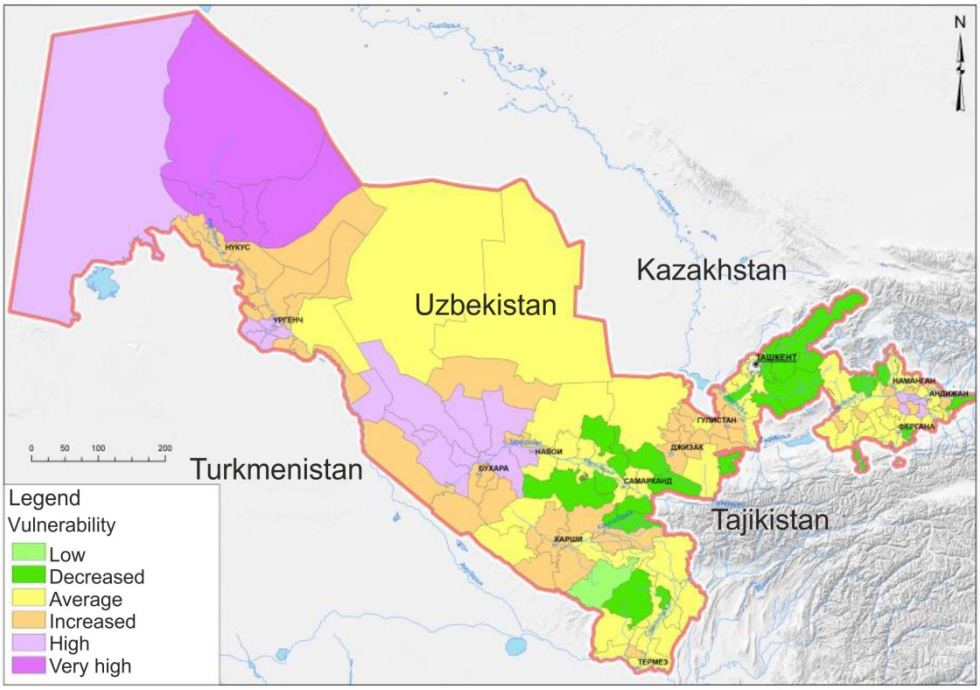

Figure 10. Vulnerability of agriculture and water resources to climate change [42]

Based on these assessments, the most vulnerable zones are the Aral Sea area and theKhorezm and Bukhara regions. A high or significant degree of vulnerability is also found in some areas of Fergana Valley, while the most favorable areas are Tashkent, Samarkand, Kashkadarya and Surkhandarya regions.

6. Drought Impacts

Due to its geographical location Uzbekistan is significantly vulnerable to the impact of climate change. In recent years, we witnessed more and more severe droughts with negative impacts on all types of water bodies, which disrupts their natural functions, as well as the health and well-being of the population and economy. The agriculture sector is especially vulnerable.

According to Third National Communication on Climate Change of the Republic of Uzbekistandata (2016) [6], climate change will inevitably aggravate the current situation in terms of drought frequency and impacts, including (i) a reduction of glaciation and seasonal snow cover in the mountain river basins; (ii) an increased flow variability; (iii) an increased region/volatilits, which will lead to water losses in irrigated areas and affect irrigation rates. A decrease in available water resources and an increase in water consumption are expected in all sectors.

Water resources. From 1957 to 2010 the rate of reduction in the area of glaciation varied from 0.1 to 1.65% per year. This degradation process, even if it accelerates

as a result of increasing summer temperatures, will continue for several decades, since the ice reserves are significant (567 km^3) [1,9,21].

The melting of glaciers results in a temporary increase of the available water resources [22, 35]. However, by 2050, reductions of 2-5% in the Syrdarya river basin , and of 10-15% in the Amudarya basin are possible, as well as an increase in the interannual variability of runoff in the river basins. In extremely warm and dry years the runoff in the basins of the Syrdarya and Amudarya rivers may decrease by 25-50%. The expected reduction in river runoff will lead to an acute water deficit especially in dry years.

Low runoff, high temperatures and resulting moisture deficits have a negative impact on ecosystems: desertification processes are aggravated, water resources are reduced, and the quality of water in terms of salinity and hydrobiological indicators is significantly deteriorating. A change in the hydrological regime disrupts the aquatic biota of lake systems and wetlands, and reduces the productivity of terrestrial ecosystems, which is clearly visible on lakes and wetlands in the lower reaches of the Amudarya river and the Aral Sea region, which in turn makes the delta tugai forests vulnerable.

The main threat to the preservation of wetlands of the Amudarya delta is the unstable hydrological regime and absence of outflow, resulting in the drainage and degradation of water and near-water ecosystems, the disturbance of the ecological balance and the loss of socio-economic functions. The hollows of the Big Aral have turned into salt lakes. In autumn 2009, satellite images showed the complete disappearance of the Big Aral eastern basin. In recent years, water in the eastern basin of the Aral Sea appears for a short time when water is discharged from the Small Aral basin and large inflows through the Amudarya watercourse happen.

The analysis of the consequences of the 2000-2001 drought of the Karakalpakstan and Khorezm region shows that the most dramatic declines in agricultural production occurred due to insufficient planning, forecasting and control over water resources at the regional, republican and local levels [21, 26].

In fact, the 2000-2001 drought formed gradually, was unusual due to a lack of precipitation combined with high levels of evaporation caused by hot weather over several years. Precipitation levels reached only 40-60% of the norm, which led to an extreme reduction in river runoff (35-40% of the average). River runoff in the lower reaches of the Amudarya river was recorded low - which led to decrease in water supply in Karakalpakstan by 20-30% and in Khorezm region by 35-80%, compared to the approved water limit.

The 2000-2001 drought was a catalyst for desertification and environmental degradation. By the end of 2001, the lake systems and wetlands in the northern part of Karakalpakstan, with an area of about 160 thousand ha, were almost completely dry. As a result of the disappearance of the wetland habitat, 46 species were entered in the Red Book of Uzbekistan in 2000-2001. The groundwater level in areas affected by drought dropped to 10-15 meters, as a result, most artesian wells run dry. The quality of water has deteriorated [21].

Hydrological and socio-economic effects of drought were felt until the end of 2003, while precipitation and agricultural production returned to normal in most areas in 2002 [21, 27].

Agriculture. As already mentioned, agriculture is one of the most significant sectors of economy for Uzbekistan, with a contribution of 28% to the country's GDP. 50% of population are rural residents. In 2017, 3.7 million people worked in the agricultural sector (27.2% of the total number of employees) [23]. Crop production is almost completely dependent on irrigation, and over 95% of the sown area is irrigated land, with 3.4 mln.ha occupied for growing annual crops (cereals, barley, wheat, rice, corn, cotton, potatoes, vegetables) [22] . Cotton and grains are the most important agricultural crops in Uzbekistan. Fruits and vegetables are grown in significant volumes. Besides that, milk, silk and livestock are produced.

Due to the increased incidence of droughts, local communities and farmers experience significant problems associated with searching of and additional costs for alternative sources of water and yield losses, which lead to a decrease in income. The Urban population is experiencing the impact of drought as an increase in agricultural products' prices.

In the event of droughts, crops are suppressed, crop shortages and/or loss of crops occur over large areas. The measures taken in 2000-2001 were of an extraordinary nature; one of the forced measures was to ban cultivation of rice as the most water-intensive crop in some areas. Losses of grain crops during the years of severe drought in 2000-2001 accounted for 14-17%, and for other crops - on average from 45-52% to 75% (the lower reaches of Amudarya). Orchards and vineyards are particularly susceptible to reduced yields when water is scarce.

The expected loss of yield of major agricultural crops by 2050, , will average 35-50% according to 2016 Third National Communication on Climate Change of the Republic of Uzbekistan estimates [6]. Due to increased evaporation cotton yield losses will vary from 4% (2030) to 10% (2050). For winter wheat, rice and other food crops, yield losses will range from 4% (2030) to 7-14% (2050). For rainfed agriculture in unfavorable weather conditions, the crop yield will decrease to 50% or more. Due to the rise in air temperature, the spring-summer vegetation of all types of vegetation on desert pastures will begin 5-10 days earlier and the total evaporation will increase, which will lead to a more rapid decrease in soil moisture reserves and, accordingly, biomass.

By 2050, a complex of negative factors can lead to a shortage of agricultural products by 10-15% compared to the modern period. Population growth, combined with a decline in soil fertility and declining water resources due to climate cha give reason to expect a future aggravation of problems in the agricultural sector and hence a reduction in food security [28,10].

Cattle breeding. Pasture-based cattle breeding is concentrated mainly (81.4%) on desert pastures, the productivity of which is very low (0.1-0.27 t/ha). In unfavorable years, the yield of pastures decreases by 2-3 times, while the load on pastures is especially increasing.

The impact of drought on the cattle breeding sector is manifested through changes in pasture productivity, fodder stocks, grazing conditions and animal health. During the 2000-2001 and 2011 severe droughts, overgrazed pastures around rural settlements and villages were completely deprived of water supply. As a result, the harvesting of forage grasses has been reduced by more than half. In some of the affected areas of Karakalpakstan, drought has forced farmers to sell a significant portion of their herds or agricultural equipment [18, 19, 21].

The expected increase in air temperatures will further intensify heat loads in summer and increase their duration, which will cause a decrease in weight gain, and from a certain level even weight loss in animals.

The cattle breeding sector in Uzbekistan is developing at a rapid pace with a growing livestock population, which entails an additional load on pastures, overgrazing, a decrease in feed capacity and a degradation of vegetation. Consequently, the cattle breeding sector will need to make decisions with a focus on the main risks (supply of feed, condition of pastures; availability of additional stocks of feed; heat stress), assess its vulnerability and identify priority mitigation measures.

At present, the Government's efforts are aimed at further developing the agricultural sector by reforms and transformations to mitigate land degradation and drought, and by improving the reclamation of irrigated land, reconstructing irrigation and drainage infrastructure. Particular attention is given to diversifying agricultural production (with transition to drought-resistant and less water-intensive crops, creation of value chains), as well as the restoration of pastures and forests. In this respect, the agricultural vulnerability assessment needs to be updated, taking into account the latest changes in the sector, using new methodologies and approaches, and the analysis of the 2018 drought impacts. This should involve all stakeholders and local communities, and identify targeted mitigation measures to increase the preparedness and resilience to droughts.

Fishery. During drought years in the Amudarya delta the loss of the bioproductivity of biocenoses and aquatic biota of reservoirs as a result of critical changes in water regime led to total death of populations of commercial fish in the region, undermining the resource base of fisheries. In the entire history of fishing, the smallest catch of fish in the Amudarya delta was in years following the drought 2003 and 2004. Fifty farms of Karakalpakstan were on the verge of bankruptcy, leasing over 60 thous.ha of lake systems.

Social impacts. In addition to environmental and economic damage, droughts have significant social impacts. In years of drought, the rural population is especially vulnerable to the lack of water. Combined with high temperatures this leads to the death of plants, a decrease in yield, the drying up of small reservoirs and the pestilence of fish, problems with grazing and, accordingly, a drop in income. The population is prone to exacerbation of cardiovascular diseases, acute intestinal diseases and skin melanoma.

Social assessments identify a need of local communities to improve the quality of drinking water and water for cooking and sanitation during periods of severe drought ADB (2005). All of them have to spend a significant share of their income on purchase and storage of drinking water. In addition to monetary costs, the population bears significant social costs, which are expressed in serious health risks, poor nutrition, etc. [30, 31].

According to UNDP (2007) [32], the following population groups are extremely vulnerable to water scarcity:

Farmers downstream. Farmers located in the lower reaches of rivers, as well as in the end spots of the irrigation network and/or remote from the irrigation network. The most vulnerable are dekhkan farms on soil of poor quality and land difficult to reclaim, and in sufficient access to irrigation water.

Women are predominantly rural residents. Water scarcity, especially during

periods of severe drought and environmental degradation, greatly increase their vulnerability. Old-age pensioners, disabled people, single mothers, pregnant women, families with many children are also in a vulnerable position. It is especially difficult for these populations to cope with water scarcity and adaptation measures.

According to UNDP estimates, during the years of severe drought in 2000-2001 the most affected population in the regions of Uzbekistan (about 600,000 people) needed food, drinking water, assistance in the supply of agricultural resources, the cost of which amounted to US$19 million. The analysis shows that in 2001, about 79,000 farms in Karakalpakstan and 21,000 farmers in Khorezm were unemployed, and migration outside Uzbekistan in search of better living conditions increased.

7. Drought Management

7.1 Existing Drought Policy and Legislation

In response to extreme droughts and climate variability affecting the country's territory, the government is making significant efforts to prevent and mitigate the consequences. Activities are carried out at international, regional and national levels. Uzbekistan is a party to the following international agreements directly or indirectly affecting drought issues:

- United Nations Framework Convention on Climate Change (UNFCCC)
- Paris Agreement
- UN Convention to Combat Desertification, Land Degradation and Drought (UNCCD)
- UN Convention on Biological Diversity (UN CBD)
- Convention on the Conservation of Migratory Species of Wild Animals
- Ramsar Convention on Wetlands
- Vienna Convention for the Protection of the Ozone Layer
- Montreal Protocol on Substances that Deplete the Ozone Layer.

In 2015, the Government of Uzbekistan made commitments to implement the global 2030 Agenda for Sustainable Development. In October 2018, 16 National Sustainable Development Goals and 125 Targets were adopted. The government is working to integrate the Sustainable Development Goals and Targets into national, regional and sectoral development strategies and programs. To date, out of 125 national SDG targets, 105 (or 84%) have been covered in more than 190 regulatory, programmatic and strategic government documents. In the field of ecology, Uzbekistan prioritizes mitigation and adaptation to climate change (including under the Paris Agreement) with a special focus on the Aral Sea region, conservation and careful use of water, land and energy resources, as well as biodiversity conservation (SDG 13, 14 and 15). Uzbekistan also adopted a National Action Plan for implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 [54].

The SDGs include SDG Target 15.3, which calls for “combating desertification, restoring degraded land and soils, including lands affected by desertification, drought and flooding, and striving to achieve a land degradation neutrality - LDN by 2030”.

Uzbekistan, under Goal 15, Target 15.3, adopted a voluntary target "Share of land that degrades (irrigated and not irrigated) over the total land area".

The Government of Uzbekistan supported the provisions of the joint WMO/UNCCD/FAO Programming Document "National Drought Management Policies" and “Best Practices for National Drought Management Program". Implementation of this document will shift the emphasis from response measures (actions in a crisis situation) to proactive measures to ensure preparedness for drought.

Uzbekistan participates in a number of initiatives on regional level in the field of disaster risk reduction and emergency prevention [34]:

- Action Plan for implementation of the Sendai Framework for Disaster Risk Reduction
  2015-2030 in Central Asia and South Caucasus region, December 2016
- Climate Adaptation and Mitigation Program for Aral Sea Basin, April 2016
- Call for action by the participants of the Second Central Asian Conference on Climate Change, 3-4 April 2019
- EC and WB "Strengthening Financial Resilience and Accelerating Risk Reduction in Central Asia" Program, 2019-2023
- Subregional Action Program of the Central Asian Countries to Combat Desertification in the Context of the UNCCD
- Framework of Cooperation on Strengthening Regional Cooperation of Disaster Management Authorities of Central Asian and South Caucasus region, January 30, 2015.

In terms of drought policy, after signing the UN Convention to Combat Desertification and Drought in 1999, the National Action Program to Combat Desertification was developed and implemented, which was updated in 2014.

The updated National Action Program (NAP) to Combat Desertification (2014) aims to prevent and reverse land degradation and drought, and, where possible, restore DLDD-prone land in order to support the country's efforts to improve prosperity and ensure food and environmental sustainability.

The objectives of the NAP are aimed at:

- Increasing national awareness of DLDD issues and their impact on socio-economic development.
- Ensuring response measures and actions to challenges, threats and restrictions associated with land degradation, desertification and drought.
- Compliance with the priorities and coordinated responsibility of key organizations in decision-making and effective implementation of the country's obligations under the UNCCD in the context of combating DLDD.
- Development of national capacity to integrate DLDD issues into national and sectoral plans and monitoring system to implement coherent action with local population to address factors causing DLDD.

The updated NAP includes a strategy to combat desertification, land degradation and drought, an integrated financial strategy (IFS) and an action plan for the implementation of the NAP in the short and medium term.

At the national level, the priority during the period of ongoing economic reforms is to ensure reliable social guarantees and measures for social security and environment protection. The strategic framework for the harmonious development of reforms and transformations in all sectors of the economy is provided by Decrees of the President and Resolutions of the Cabinet of Ministers of the Republic of Uzbekistan, as well as by special laws, regulations and norms governing their implementation. The main approaches and priorities for ensuring environmental protection and nature management and the implementation of international agreements are integrated into strategies, national programs and sectoral action plans.

In order to improve the efficiency of the work to combat desertification and drought, the Resolution of the President “On measures to increase the efficiency of combating desertification and drought in the Republic of Uzbekistan” was adopted February 22, 2019 (#PP-4204 dated 22.02.2019). On the basis of this Resolution, a “Roadmap” was developed for combating desertification and drought in the Republic of Uzbekistan for 2019-2023, approved by the Cabinet of Ministers of the Republic of Uzbekistan (#03/1-670 dated April 26, 2019). The Roadmap aims to achieve the following objectives:

- planting of greenery on the drained bottom of the Aral Sea;
- organization of cultivation of forest, decorative and desert-pasture seedlings;
- development of criteria and indicators to combat desertification and identification of degraded lands;
- identification of territories affected by DLDD processes and taking timely measures;
- updating and developing the National Action Program to Combat Desertification and Drought for 2023-2030;
- development and implementation of a project for the construction of the Bukhara green shield to protect residential and agricultural land of the Bukhara region from sanding;
- planting pistachio forests in the foothills of the Nurata ridge in the Navoi region;
- creation and reconstruction of forest protection plantations in order to reduce wind and water erosion;
- organization of seed production of pasture crops in Karakalpakstan.

The main strategic document of the country's development is the "Strategy of Actions for Five Priority Directions of Development of the Republic of Uzbekistan in 2017-2021" adopted by the Decree of the President #UP-4947 dated 07.02.2017. The Strategy of Actions laid down a comprehensive framework and activities, including a set of regulatory, technical, agro-technical, institutional and adaptation measures and solutions, and their integration into agriculture and water management

to mitigate drought risks and expand sustainable land management (SLM) in various agricultural landscapes of the country.

An important priority of the Action Strategy is the strategic direction "Modernization and intensive development of agriculture", including: (i) introduction of modern resource-saving agricultural technologies, (ii) new varieties of crops, (iii) adoption of systemic measures to mitigate the negative impact of global climate change, etc.

Key approaches and measures to combat desertification, land degradation and drought are integrated into a number of national programs, strategies and projects.

An important document of environmental policy until recently was the Program of Action for Environmental Protection of the Republic of Uzbekistan, which was updated every five years (1999-2005, 2008-2012, 2013-2017). It included measures aimed at improving the ecological state of the environment, including afforestation and improving soil fertility and the use of water resources, etc.

The government of the country has taken and is implementing measures to reform the economy associated with the development of market relations and private ownership in the rural area. Significant results have been achieved in improving efficiency of land use, reclamation of irrigated land, reconstruction/modernization of irrigation and drainage infrastructure, etc.

The State Program for Irrigated Land Reclamation for 2008-2012, 2013-2017, 2018-2019, implemented in the country since 2008, aims to form a systematic and integrated approach to the implementation of measures to increase the productivity of irrigated land through the construction and reconstruction of reclamation systems, reducing problems of salinization and waterlogging. Under the Ministry of Finance of the Republic of Uzbekistan, a Fund for Irrigated Land Reclamation was created. As a result of the work performed, the processes of waterlogging and soil salinization have significantly decreased, and land reclamation has improved on the total area of about 2 mln.ha. Farmers have been provided with equipment and techniques for land reclamation. Particular attention is paid to water-saving irrigation methods. The area with drip irrigation has reached 25 thous.ha, improved methods of surface irrigation are used on an area of 75,600 ha, incl. 34,000 ha using mobile flexible irrigation pipes and 45,600 ha irrigation of cotton along furrows shielded by foil. By 2019, it was planned to introduce drip irrigation systems on 22060 ha, and increase the area with improved surface irrigation methods for crops by 109,600 ha.

In order to ensure the achievement of national goals and objectives in the field of sustainable development for the period until 2030, by the Decree of the President #PF-5863 dated October, 30, 2019, ***the Concept of Environmental Protection of the Republic of Uzbekistan until 2030*** was approved. Based on this it is expected that by 2030:

- the area of forest plantations on the Uzbek part of the dried bottom of the Aral Sea is brought to 60% of its territory, creating a "green belt" around Nukus, Urgench and Khiva towns with local trees and shrubs [54];
- the losses of water resources in agriculture are reduced by 10%;
- the water consumption in agriculture (per specific hectare) is reduced by 15%;
- the efficiency of wastewater treatment is increased up to 80%;
- the forest area covered with forests is enlarged to 4.5 mln.ha;

- the protected natural areas of I - V categories are enlarged up to 12%.

By Decree of the President of the Republic of Uzbekistan dated August 23, 2019 #PQ-4424
“On additional measures to increase the efficiency of forest management in the republic”,
the Forestry Development Program for 2020-2024 was approved, which aims to create forests on the territory of 2.78 mln.ha [54]/

The Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020-2030
is the most important program document in the field of future development of the agri-food sector. The main goal of this Strategy is to radically improve state policies aimed at deepening the ongoing reforms aimed at increasing competitiveness of the agri-food sector, and covers the following strategic priorities: (i) stimulating an increase in the share of high-yield crops/breeds; (ii) providing access to large foreign sales markets; (iii) facilitating the inflow of foreign and domestic investment; (iv) modernization and innovative development; (v) creation of modern infrastructure, including water management, transport, science and education; (vi) providing access to financial and insurance instruments, etc.

Particularly vulnerable to drought is the Aral Sea region, where the most significant damage to ecosystems is observed due to drying up of the Aral Sea and Amudarya delta. Uzbekistan is making significant efforts to mitigate consequences of the Aral Sea crisis for population of the Aral Sea region and the entire Aral Sea basin. A number of programs are being implemented in the country aimed at supporting local population, protecting and preserving ecosystems, and mitigating negative consequences:

The ***Program of measures to eliminate consequences of drying up of the Aral Sea and prevent a catastrophe of ecosystems in the Aral Sea region*** provides for the implementation of the following important measures in the field of combating consequences of the Aral Sea crisis:

- Creation of conditions for living, reproduction and preservation of a gene pool in the Aral Sea region. Improving the management system and economical use of water resources.
- Maintenance of the system of natural reservoirs in the water area of the Aral Sea.
- Implementation of large-scale measures to plant forest on the drained bottom of the Aral Sea and prevent desertification in the region.
- Conservation of biodiversity, restoration of biological resources, protection of flora and fauna.

The government of Uzbekistan and the world community pay great attention to solving problems associated with the Aral Sea disaster - a special charitable foundation "Muynak-2019" has been created. Within the framework of the "Comprehensive program for mitigating the consequences of the Aral Sea disaster, restoration and socio-economic development of the Aral Sea region for 2015-2018” with the support of the IFAS Executive Committee and the Charity Fund for the Protection of the Aral Sea Gene Pool, measures were taken to improve the

management and economical and rational use of water resources in the region. To ensure a coordinated approach to solving the problems of the Aral Sea region in Uzbekistan, under the auspices of the UN, a Multi-Partner Trust Fund for Human Security for the Aral Sea Region (MPTF) was created. The purpose of this fund is to develop international cooperation and mobilize funds from the donor community for implementation of projects to improve the environmental and socio-economic situation in the Aral Sea region.

The main body of the MPTF is the Steering Committee, which makes decisions on mobilization and allocation of funds and the management and supervision of the Fund's activities. The Co-chairs of the steering committee are the Government of the Republic of Uzbekistan and the UN Office in Tashkent.

The ***State program for the development of the Aral Sea region for 2017-2021*** is aimed at improving the conditions and quality of life of the population residing the Aral Sea region, which also provides for the development of water supply systems and an increase in the level of clean drinking water supply to the population, improvement of sewage systems, sanitation and waste disposal.

As mentioned above, the agricultural sector is the most vulnerable sector. In recent years, this sector has undergone significant reforms supported by the following documents.

Recently, the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan "On measures to accelerate the creation of "green coverings " - protective forest plantations on drying up territories of the Aral Sea bottom " (#132 dated 15.02.2019) was adopted, which provides for the allocation of **100 billion soums** in 2019 for the creation of forest plantations on the area of **500 thousand ha** of dried seabed.

The ***Program for the integrated development and modernization of drinking water supply and sewerage systems for 2017-2021*** is focused on problems in the Republic of Karakalpakstan and the Bukhara, Jizzakh, Kashkadarya, Surkhandarya and Khorezm regions. The program outlines the need to create convenient and comfortable social and living conditions for the population, residing especially in rural areas, to achieve the supply of consumers in all places of residence with high-quality drinking water, to increase the efficiency of water supply and sewerage services.

The ***Strategy for Conservation of Biodiversity in the Republic of Uzbekistan for the period 2019-2028*** provides for the implementation of the following priority tasks:

- expanding the area of protected natural areas to 12% of the country's territory;
- afforestation of the drained bottom of the Aral Sea, bringing the forest area to 1.2 mln.ha;
- breeding gazelles in the Bukhara specialized nursery "Jeyran" and increase if their number to 1,000 species;
- creation of a unified monitoring system for biodiversity components with a central link to the reference ecosystems of state reserves;
- creation of a unified information database for state monitoring and a state cadastre of biodiversity based on modern geoinformation technologies (GIS-technologies);

- conducting an annual geobotanical survey of the vegetation of natural pastures and hayfields in the volume of 2 mln.ha;
- integrating biodiversity conservation issues into all sectors of the economy.

In order to implement ***the Sendai Framework Program***, the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan #299 dated 12.03.2019, which approved the Strategy for achieving goals of the “Sendai Framework for Disaster Risk Reduction for 2015-2030” and the National Action Plan for implementation of the Strategy for achieving goals of the “Sendai Framework for Disaster Risk Reduction for 2015-2030” for the period 2019-2030. The main goal of the Strategy is to increase the effectiveness of the ongoing reforms in the field of comprehensive protection of population and territories from disasters, to significantly reduce the number of fatalities and injured people by 2030, as well as direct economic damages from disasters.

From the implementation of the Strategy by 2030 it is expected to:

- prevent the emergence of new and reducing the threat of known natural disasters’ risks;
- reduce to a minimum the number of victims, the level of mortality, the amount of social, economic and environmental damage from emergencies;
- increase the efficiency of the State system of warning and actions in emergency situations, ensuring full coverage of the territories by specialized response services;
- improve monitoring and forecasting of emergencies, information exchange, notification and informing the population;
- ensure maximum coverage of population with the early warning system;
- create and develop life support systems for the population affected by emergencies;
- improve the system for training specialists of the management level and population for actions in emergencies.

United Nations Development Assistance Framework (UNDAF) 2016-2020. The program provides for assistance in raising awareness and strengthening national capacity to support rural communities in areas prone to natural disasters, etc. The UNDAF program aims to (i) apply proactive methods to reduce the risks of increased droughts associated with climate change and (ii) provide additional vulnerability assessments; and (iii) promoting development patterns that are more resilient to climate change, and (iv) implementing climate change adaptation and mitigation activities.

Strategy for the Transition of the Republic of Uzbekistan to a "Green Economy" for the period 2019-2030 approved by the Presidential Decree # PQ-4477 dated October 4, 2019, The priority areas of the Strategy are to increase energy efficiency of the basic sectors of economy; diversification of energy consumption and use of renewable energy sources; climate change adaptation and mitigation; increased efficiency in the use of natural resources and conservation of natural ecosystems; development of financial and non-financial mechanisms to support the "green" economy.

Target indicators for the implementation of the Strategy also provide for climate change mitigation measures, including increasing the efficiency of water use in all sectors of economy, introducing drip irrigation technologies on the area of up to 1 million hectares and increasing yields to 20-40% of crops cultivated on them, achieving a neutral balance of land degradation.

Third National Communication on Climate Change, 2016. The Country Report focuses on assessing the impact of climate change on agriculture and forestry, biodiversity and possible adaptation measures.

In general, drought management policies have become part of an integrated development policy in the country, policy instruments and legal frameworks reflect issues of regulation of activities to combat desertification, land degradation and drought; regional agreements were adopted to improve water availability, a set of measures and actions to mitigate drought, etc.

7.2 Institutional Framework for Drought Response

Currently, Uzbekistan has developed an institutional structure that allows monitoring dangerous phenomena and taking measures to prevent or mitigate their consequences.

A clear assignment of powers and obligations in the risk management process is essential to ensure its continued effectiveness. This process requires a strong and sustained commitment from the responsible ministries and agencies, as well as careful and strategic planning to achieve commitment at all levels.

Powers and obligations

The State System for Prevention and Action in Emergency Situations (SSES) has been created in the country (Resolution of the Cabinet of Ministers of Republic of Uzbekistan #242 dated 24.08.2011), which unites governing bodies, forces and means of republican and local authorities, enterprises and organizations, whose powers include the organization of emergency response measures, including those related to meteorological conditions. The system includes the following departments and ministries: Ministry of Emergency Situations (MES), Centre for Hydrometeorological Service (Uzhydromet), Ministry of Health, Ministry of Agriculture, Ministry of Water Resources, State Committee on Ecology and Environmental Protection, etc., whose functions and actions are clearly identified. The basis for the activities of the State Emergencies Service are the estimates and forecasts of Uzhydromet.

SSES consists of territorial and functional subsystems and has three levels: republican, local and facility level.

Emergency situations in Uzbekistan include the following:

- Threat of agrometeorological drought, causing air moisture deficit and leading to disruption in water balance of plants, their oppression and death with possible significant material damage.
- Threat of dry wind (persistence for 5 days or more at air temperature of +45°C and above strong wind and air humidity of 30% or less), leading to significant

material damage during oppression and death of agricultural crops and posing threat to human health.

- Threat of low water and shortage of water resources, which can lead to disruption of the vital activity of population and significant economic damage of agriculture and some other sectors of economy.
- Threat of intense heat (air temperature exceeding +40°C for several days), leading to significant economic damage when agricultural crops are damaged and posing threat to human health. In some cases, it poses threat to the normal functioning of certain sectors of economy.

The SSES mandate includes the following main tasks:

- implementation of state policy, development and implementation of regulatory legal acts in the field of protection of population and territories from emergency situations in peacetime and wartime;
- forecasting possible emergencies on the territory of the republic, assessing their socio-economic consequences;
- development and implementation of targeted and comprehensive scientific and technical programs aimed at preventing emergencies, ensuring safety of people, reducing the risks of hazardous technologies and industries, increasing sustainability of functioning of economic sectors and other organizations;
- ensuring constant readiness of command-and-control bodies, forces and means intended for prevention and elimination of emergencies;
- collection, processing, exchange and issuance of information in the field of protection of population and territories from emergencies;
- preparation of population, officials of the management bodies, forces and means of the State Emergency Service for actions in emergency situations.

Stakeholders can be divided into two large groups:

(i) government bodies that are involved in planning, management and monitoring of the environment and nature management within the framework of their public responsibility, and which have influence and/or authority to make decisions on activities related to drought management and monitoring at local, sub-regional and national levels;

(ii) primary stakeholders who are directly or indirectly affected by desertification, land degradation and drought, and who may be beneficiaries of activities carried out by the relevant Agreements, programs and projects (or will participate in various ways).

The main beneficiaries at the national level are low-income and wealthy agricultural producers, women, local communities and households, agricultural workers, suppliers of agricultural inputs, procurement organizations, organizations financing agricultural production, construction organizations, central and local authorities, and

organizations engaged in drinking water supply, water, land, biological resources, and environment management.

At local level, water resources provide livelihoods for the majority of population, whose security, as well as their livelihoods, are threatened without adequate and reliable irrigation and water supply during and after drought. In fact, there are no local organizations that do not have any responsibility to ensure reliable supply of acceptable water quality for consumption and production.

7.3 Response Measures and Actions

Response measures to combating drought and desertification in Uzbekistan are implemented as climate change mitigation in the context of crisis management, and include: (i) prompt measures to reduce water use limits during growing season, comply with the discipline of water use, ban rice cultivation as the most water-intensive crop, use of water from drainage collectors for irrigation, and (ii) mitigation measures and actions to overcome risks and protect population and areas in the Aral Sea zone.

In crisis situations, special committees for drought management are additionally created.

GEF international full-scale projects, GEF Small Grants Program projects, FAO projects, World Bank projects, etc. are being implemented aimed at operation and implementation of water-saving technologies, introduction of drought- and salt tolerant crops, and adaptation of the DEWS for various regions of the Republic.

The country has accumulated positive experience in using FAO approaches to mitigate the risk of drought. In particular, to raise awareness of local farmers in Syrdarya and Kashkadarya regions (2002-2004) and South Karakalpakstan (2005-2009), within the framework of FAO and WB projects, UNDP (2014-2021) [22, 44], farmer field schools were created.

The Council of Farmers, Dekhkan Farms and Owners of Homestead Farms conducts explanatory work among farmers on ongoing basis. It promotes dissemination of best land use practices, including in drought conditions, introduction of alternative energy sources, as well as innovation and information and communication technologies. Self-government bodies of citizens assist in implementation of control over the sanitary and ecological state of the corresponding territory, water supply sources, dwellings, educational institutions.

Rural communities, family farms, individual farmers, upstream and downstream farms, and private sector - all have definite and well-identified interests in ensuring effective management of limited water resources. There are many different categories of water users.

In Uzbekistan, a financial mechanism has been developed and operates to mitigate drought and other natural hazards which is insurance. Currently, the only company specializing in insurance of risks in agriculture provides agricultural producers with affordable insurance services that meet their needs (about 40 types).

The main types of agricultural insurance include: voluntary insurance of agricultural crops against overseeding; voluntary insurance against crop shortages; voluntary insurance of orchards and vineyards against crop shortages; voluntary insurance of

farm animals, etc. The insured risks are damage or death of crops, animals and equipment as a result of drought, harmssel (dry wind), mudflow, flooding, low water or dryness, hail, rainfall, storm, hurricane, frost, snow, lodging of crops as a result of prolonged rains, lightning, fire, landslide, rising groundwater level, etc.

Based on the experience of agricultural insurance in foreign countries, a number of innovations are being introduced into the insurance practice. In particular, significant benefits were provided to farms on crop shortage insurance: due to simplification of the terms of the insurance contract, the number of insured risks increased, for some of them insurance rates were established, which were differentiated by region, the system for considering insurance claims was simplified, and in absence of insured events, the insurance rate was reduced.

Uzbekistan is making significant efforts to mitigate the consequences of the Aral Sea crisis, including mitigation of stress during drought years for the population of the Aral Sea region and the entire Aral Sea basin.

A number of programs have been implemented and are being implemented in the country aiming to support local populations, protecting and preserving ecosystems, and mitigating negative consequences:

- Comprehensive program to mitigate consequences of the Aral Sea disaster, recovery and socio-economic development of the Aral Sea region for 2015-2018.
- State program for the development of the Aral Sea region for 2017-2021 aimed at improving the conditions and quality of life of the population in the region.
- International innovation centre of the Aral Sea region was created under the President of Uzbekistan.
- The Multi-Partner Human Security Trust Fund for the Aral Sea region in Uzbekistan (MPHSTF) has been established under auspices of the UN.
- International conferences and forums are held, such as "Development of cooperation in the Aral Sea basin region to mitigate consequences of the ecological disaster" (Urgench, October 28-29, 2014); "Joint actions to mitigate consequences of the Aral Sea disaster: new approaches, innovative solutions, investments" (Tashkent, June 8-9, 2018); International high-level conference "Priaralie - Zone of environmental innovations and technologies", Nukus, October 25, 2019; "Innovative approaches to promote sustainable management and social stability in the Aral Sea basin" (Samarkand, October 16-18, 2018), etc.
- In the region, the International Fund for Saving the Aral Sea (IFAS) functions, aimed at enhancing actions in the region for the ecological improvement of areas affected by the Aral Sea disaster.

8. Options and Pathways to Increase Resilience and Minimize Drought Risk

It is very important to develop a National Action Plan for Drought Management, which should be developed in the near future. The plan should take into account both general issues for the whole country:

- Development of the monitoring system as a basis for early warning of drought through updating and developing the technical basis
- Introduction of modern methods and tools for forecasting droughts
- Improvement of vulnerability and risk assessment techniques to ensure targeted planning and drought management
- Increasing knowledge or capacity by informing and educating the population, taking into account both the issues of early warning and mitigation measures, including early introduction of resource-saving technologies, landscaping, and the use of drought-resistant plant varieties, etc.

As discused in this case study, some of the mentioned capacities have already been developed in the country. Examples are the implementation of numerous pilot projects demonstrating "best practices" for adaptation and/or mitigation and the introduction of sustainable financing mechanisms such as the UN Trust Fund for the Aral Sea region.

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