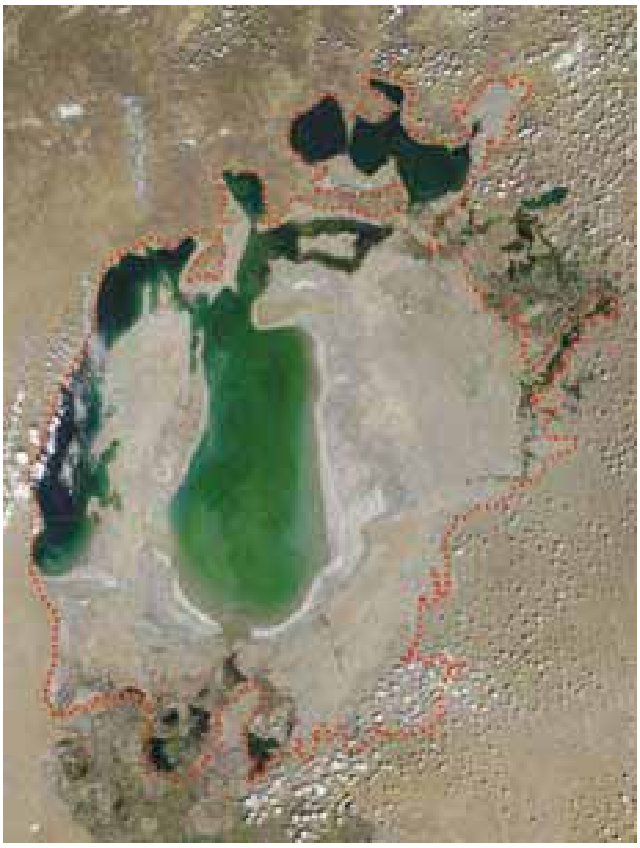
Eurasian Development Bank

Executive Board of the International Fund for Saving the Aral Sea
Regional Center of Hydrogeology

IMPACT OF CLIMATE CHANGE TO WATER RESOURCES IN CENTRAL ASIA

(Consolidated Report)



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Introduction

The global climate change over the past decade has taken a tenable place among the major environmental problems challenging the world community.

Particularly acute is the impact of climate change on water resources in the Central Asian region, which requires more detailed study from a regional perspective.

Given the great importance of water resources for socio-economic development of Central Asian countries, the Executive Committee of IFAS together with the Regional Center of Hydrology (RCH) initiated the preparation of regional reports covering the most important aspects of the impact of climate change on water resources in the region and assessment of their vulnerability, and developed the adaptation activities, and applied to the Eurasian Development Bank (EDB) to fund the preparation of this report. In December 2008, EDB approved the application and as a technical assistance, provided the necessary funds to carry out the work.

This initiative was supported by the International Conference "Problems of climate change, water management, leadership and capacity development in Central Asia", which was held within the framework of the preparatory process to the 5th World Water Forum (WWF) on 28 - 29 May 2008 in Bishkek, Kyrgyz Republic.

The relevance of this issue and the need for integrating processes in the water-energy sector of the Central Asian states is analyzed in the Declaration and the Resolution of the International Conference on the reduction of natural disasters related to water, held within the "Water for Life" International Decade (2005 - 2015), on 27 - 28 June 2008 in Dushanbe, Tajikistan.

Water in Central Asia is an essential element of national and regional security. Water resources of Central Asia are used by many sectors of the economy of the region, but the main water users are the irrigated agriculture and hydropower facilities. More than 90% of water resources in the Aral Sea basin are used by irrigated agriculture, which produces approximately 30% of the gross domestic product and provides employment for more than 60% of the population of the region. Share of hydropower comprises 27.3% of the total electricity consumed by the region. In some countries (Tajikistan and Kyrgyzstan), this figure is over 90%, indicating a clear dependence of these economies on the availability of water resources. Therefore, any changes affecting water resources will have an immediate impact on other aspects of life in the region.

Countries, located within the region, are interconnected by the transboundary water systems. Any change in water use by one of the countries would inevitably affect the interests of other countries. Tajikistan and Kyrgyzstan, where the main flow of the Aral Sea Basin (80%) is formed, are interested in the use of available water resources for hydropower production, and the downstream countries - Kazakhstan, Turkmenistan and Uzbekistan - intend to continue the use of same resources for irrigation. In doing so, the upstream countries are interested in maximizing the discharge of water during the winter period, when demand for electricity is very high, but the downstream countries need the maximum discharges of water during summer for irrigation purposes.

The situation is aggravated by rise of the water-consumption, which is associated with population growth and intensive development of the region's economies. The expected reduction of flow in the near future due to changes in climate makes this problem even more acute.

Melting glaciers will create additional risks for sustainable development and regional food security. Retreat of the glaciers results in the threat of short-term floods, and in the long term perspective – in decline of water-supply in Central Asia.

These factors determined the need for a regional analysis of the current situation of water resources in the light of climatic changes, trends in the development of this process, population growth, economic development and the environment protection requirements with respect to water. In turn, this could be the basis for the development of new strategies for water use, taking into account the interests of all countries in the region, based on generally recognized principles.

The main purpose of this paper was to assess the current situation of water resources in the region in light of climatic change and to identify the trends in development of this process. This report is a fundamental instrument for achievement of sustainable management of water resources in Central Asia, which will considerably reduce the risk of potential conflict situations in this area. Pure water supply will determine the quality of life and the future development of the region. The need for a common system of modern water management in Central Asia is raised by the nature itself and requires the creation and development of a cooperation mechanism, based on an integrated approach.

The primary data for development of the report was that collected through the many-year observational studies available to NMHSs of the region, as well as the results of studies conducted by the countries of the region for the preparation of national reports on climate change. When analyzing the situation in Turkmenistan, the materials of the First National Communication of Turkmenistan for UNFCCC were used.

1. Analysis of changes in the hydrological cycle of the Aral Sea Basin through the analysis of data from the basic (reference) hydrological posts

The Aral Sea is one of the largest inland water reservoirs of the globe. It is located in the zone of deserts of Central Asia - in the Turan lowland, at the eastern edge of the Ustyurt plateau. Two Central Asian rivers flow into the Aral Sea - the Amu-Darya and Syr-Darya rivers, the waters of which have traditionally been used for irrigation. The rivers of the Aral Sea basin virtually all are transboundary watercourses.

The Amu Darya river joins the basins of Surkhandarya, Sherabad, Kashkadarya and Zarafshan rivers; the Kashkadarya and Sherabad river basins are entirely located within the territory of Uzbekistan. The main flow of Amu-Darya is formed within the territory of Tajikistan.

Syr-Darya river basin is located within the territory of 4 countries: Kyrgyzstan, Uzbekistan, Tajikistan and Kazakhstan. Water reserves of Syr-Darya are mainly formed in Kyrgyzstan (Naryn river) – that is over 74%, about 14% is formed in Uzbekistan, about 3% in Tajikistan, and the share of Kazakhstan is accounted for 9% (rivers Arys and Keles).

The main watershed of Amu Darya and Syr Darya rivers is located in the mountainous and highland areas. The predominant feeding source for most rivers are the seasonal melt water of snow cover, less specific weight is generated by glacier water, as well as rainwater. Depending on the altitude, the extent and timing of watershed watering with rain, the share of those or other sources in the river feeding may vary significantly, and as a result of this, the flow regime also changes to some extent.

Syr-Darya flow formation area is located within the territory of Kyrgyzstan. The nature of the regime relates these mountain rivers to the Kyrgyz Tien-Shan type with two pronounced phases: spring-summer flooding and autumn-winter drought period, with two flood peaks observed: one in spring (April-June), associated with the period of seasonal melting of snow in the mountains, and one in summer (July-September) due to melting of the glaciers and upland snows.

A distinct feature of mountain rivers' discharge record is the uneven distribution of runoff within a year or even within a single day. The proportion of river runoff in the growing season averages in 74% of the annual volume, and in the autumn-winter and early-spring periods its 26%. In Kyrgyzstan, 20-25% of the river runoff is used for domestic water consumption, while the remaining part enters the territory of neighboring states.

Analysis of conditions of maximum river water discharge generation in Kyrgyzstan has demonstrated that these are caused by various excesses over the average, depending on the genesis:

a) with abnormally high temperature or in case of heavy precipitation, the excess reaches 2-3 times;

b) with mud discharge resulting from the convergence of high melting and rainfall discharge - about 5.0 times;

c) in case of breached lakes and reservoirs - 7-10 times, and in some cases (in cases of breaking large lake reservoirs) much bigger - 100 (basin of Adygine river, Alaarchinsky basin) and 500 times (Yaschinkul lake, Isfayram-Say river basin).

For all the rivers of Kyrgyzstan, the draught periods fall to the cold time of year, when melting processes are slowed down and river runoff is formed with groundwater. Draught period is featured with stable and low consumption of water, gradually declining to the beginning of flooding, and is graphically displayed as a curve of depletion of underground water in the zone of active water exchange. The minimum water consumption is observed during the pre-flooding period - in spring (March and April).

There are 1923 lakes in Kyrgyz Republic, with a total surface area of 6.84 square kilometers. The largest lakes are Issyk-Kul, Son-Kul, Chatyr-Kul. The freshwater resources concentrated in the lakes are estimated at 1745 cubic km. The largest lakes in Kyrgyzstan account for more than 55% of the surface area of lakes in Central Asia. Since the middle of the XIX century, the water level in Issyk-Kul lake fell about 12 meters and its basin became a closed basin. According to the instrumental records, kept since 1927, the lake level decreased by 3.2 m. The drop was particularly intense in the 60-70-ies of the last century – during that time the shoreline in shallow areas retreated at speed of 20 m/year. Results of calculations of water balance of the lake for different periods - from one to several decades – is unambiguous - the balance is negative, i.e. there is a trend to decrease of the level. The negative balance is primarily caused by an increase in evaporation from the surface of the lake. Due to the increasing air temperature, increase of evaporation is clearly observed, particularly in Balykchy (Rybachye) meteostation.

Mean annual runoff of rivers in Kyrgyzstan, which for the period up to 1973 comprised 48.9 cu. km, increased to 51.9 cu. km for the period of 1973-2000.

The western and north-western parts of Syr-Darya and Amu-Darya river basins, where the mountain ranges of Pamir-Alai and Tien-Shan change over to the plains, located on the territory of Uzbekistan. This is the reason why the rivers in Uzbekistan have relatively low water content, as compared to that in Tajikistan and Kyrgyzstan. In total, there are 17,777 natural waterways in the Republic, mainly made up by small rivers less than 10 km in length. There are about 505 lakes in Uzbekistan, and these are mainly all small reservoirs with an area of less than 1 km^2. Currently there are 53 reservoirs built in the country for irrigation purposes. Today, Uzbekistan like other Central Asian countries faced the need to find ways to address, minimize and, if possible, prevent water problems, caused by water scarcity, pollution and depletion of water sources. In present conditions and in future, the shortage of water reserves is one of the main factors limiting the development of the country.

There are 525 mountain glaciers, with the total area of 154.2 km^2, i.e. these glaciers are mostly small forms, with the average area of a glacier just 0.293 km^2, located within the territory of Uzbekistan, upstream several rivers, like Surkhandarya, Kashkadarya, Pskem. We know that almost all the water resources of the region are generated by the snows and glaciers, located on the territory of Kyrgyzstan and Tajikistan. Irrigated agriculture is concentrated in the densely populated valleys of the Amu-Darya and Syr-Darya rivers, carrying their water to Uzbekistan, Kazakhstan and Turkmenistan. For the past two decades, the countries living downstream of the Syr-Darya and Amu-Darya rivers suffer from the lack of water and its socio-economic impacts.

Currently, the series of long-term observations of runoff on the territory of Uzbekistan do not demonstrate coherent trends that would point to the already observed decrease in water resources. Expected future changes in the natural water resources are determined, predominantly, by the change in the climate system.

The mean annual run-off of Aral-Syrdarya river-basin scheme of Kazakhstan (total surface water reserves in vivo) was 26.1 km^3 per year, including: those formed in Kazakhstan - 3.5 km^3 per year, the remaining part – 22.6 km^3 per year – coming from the adjacent territories of neighboring states: Uzbekistan and Kyrgyzstan.

During the period of 1965 to 1985, there was a cascade of reservoirs with cyclic storage and seasonal regulation built on Syr-Darya river – the Toktogul (Kyrgyzstan), the Shardarinskoe (Kazakhstan), the Kairakkum (Tajikistan), the Charvakskoe and the Andizhanskoye (Uzbekistan). To regulate the flow and to use of water, there were Kyzylordinskaya, Kyzylkumskaya and Kazalinskaya irrigation systems created.

As a result of these activities, the runoff of Syr-Darya river was fully regulated. Downstream the Syr-Darya river, due to the increased water intake, the flow has dramatically decreased, resulting in the catastrophic situation of the Aral Sea. In circumstances of stable water consumption, the Syr-Darya river water inflow to the territory of Kazakhstan comprises 14.5 km^3 per year, while the total reserves are 18.0 km^3 per year. The natural regime of the river in the territory of Kazakhstan is totally upset.

Until 1990, Toktogulskoye reservoir was used mostly for irrigation. The discharge of water from the reservoir occurred mainly in spring-summer period and reached 75% of the total discharge. In the mid 90-ies of the last century, discharge regime of Toktogulskoye water reservoir has changed dramatically. In the last decade, in order for Kyrgyzstan to develop the necessary electricity, main discharge of the water is occurring during the winter months, when the discharged volume comprises about 60% of the total. As a result, the distribution of intra-annual flow of Syr-Darya river has significantly changed: instead of the relatively low winter drought period, there are significant winter floods, which have resulted in the formation of hanging dams and ice blocks. All this leads to floods downstream the Syr-Darya river in the region of Kyzylorda. Particularly high water discharges from Toktogulskoye reservoir were occurring in early 2000-ies.

The river flow to the Aral Sea Basin, as well as to the other basins, is featured with phases of different water content, duration of which ranges from 2-3 to 4-5 years. In the basin of Syr-Darya river, in Kazakhstan's territory, we can particularly highlight the abounding year of 1969.

Analysis of normal values of the annual flow, specified in the first (until the mid twentieth century) and in the second half of the period reviewed for the rivers in Kazakhstan, including Syr-Darya river basin, has shown that there is no significant differences in these values. The exception is the only the rivers of Balkhash lake basin, where run-off for the second half of the period was slightly higher, and based on the available data has increased by up to 8%, mainly due to additional melt water generated as a result of degradation of mountain glaciers. Thus, in the second half of XX^{th} - beginning of the XI^{st} century, there were no significant changes in natural flow under the influence of climate.

Headstream of Amudarya river is located in the south-east, the most elevated part of the Central Asian region. High mountain ranges divide the territory of the Republic of Tajikistan into a number of hydrographic areas of river basin formation for rivers Panj, Vakhsh, Kafirnigan and Zeravshan.

In addressing the socio-economic issues, the crucial place is occupied by Amu-Darya river basin, which has about 60% of water and 70% of hydropower resources of the region.

Due to the elevation of the major watersheds of the largest rivers of the Republic, the main source of their feeding is the seasonal snow melt water (60-70%), significantly smaller role is played by glacier and groundwater (10-30%) and a small part is generated by rain water (5%). In the low-altitude watersheds, the proportion of snow feeding falls to 40-50%, while the proportion of groundwater and rainwater feeding increases respectively to 40% and 15%.

The highest specific water content is in the rivers, which watersheds are favorably oriented in relation to the water-saturated air streams. The highest annual flow (about 45-50 l/s from 1 km^2) is a feature of Vakhsh, Karatag, Sherkent and Kafirnigan river basins.

Annual flow of river basins in the Pamir ranges as follows: in the east of the Pamirs from 2.0 l/s (Bartang river) to 10 l/s km^2 (Lyangar river).

The rivers of western branches of the Academy of Sciences ridge (rivers Yazgulem, Vanch, Obihumbou, Obikhingou with feeders) are more open to the water-saturated air masses. The annual flow of medium and small rivers reaches 20 l/s - 30 l/s km^2. Small rivers of foothills and low-mountains are essentially periodic flows of mud.

During a sufficiently long observation period (more than 50 years) there was no significant transformation of intra and inter-annual variability detected with respect to the river flow with glacier-snow feeding, i.e. hydrological regime of the main rivers of Amu-Darya basin does not change.

Periods of high and low river flow water-content are evenly divided both within the territory, and in time, in groups of 2-3 years.

Continuous periods of high and low water content with the duration of 4-6 years have been observed three times, being relatively evenly distributed over the period of 1930-1960; the most prolonged periods of low water contents last up to 8 years.

Review of the dynamics of the runoff volumes by decades revealed a general trend to reduced runoff during the 1971-80 in the rivers of snow-glacier (11-14%) and snow-rain (8-21%) feeding type. In the period of 1981-1990, the volume of runoff decreased (1-11%) in the rivers of glacier-snow feeding type and increased (6-25%) in the rivers of snow-glacier and snow-rain feeding type.

In Syr-Darya river basin there is still no clearly observed decrease of water reserves under the influence of climatic factors. Changes in water resources and their inter-annual redistribution are caused by anthropogenic activities in the region. In the territory of Kyrgyzstan, there has even been some increase in water resources.

In Amu-Darya river basin, there have been no significant changes found in the hydrological regime and in water resources.

2. Analysis of atmospheric precipitation and air temperature changes in the Aral Sea Basin based on the analysis of data from the basic (reference) meteorological stations

Occupying an extended (approximately: 35-55°N and 50-85°E) and orographically complex area combining vast lowlands and the highest mountain uplifts in the south and south-east, Central Asia (CA) is characterized by the diversity of climatic conditions. However, the climate of the Central Asian countries has a common regional feature – its very continental, characterized by large amplitude of air temperature fluctuations during a year and low precipitation. The northern plains of Central Asia are steppe landscapes, the central and southern are semi-desert landscapes.

All the local types of climates in Central Asia could be divided into three categories:

1. Temperate climate zone (approximately up to 41-42°N at the south).

2. Dry subtropical climate zone (south of 41-42°N).

3. Mountain climate of Tien-Shan, Pamir-Alai, the Pamirs and Kopetdag with a pronounced altitudinal belt zoning: 1) Valley-Foothill Zone (0.2-1.2 km), 2) Medium Altitude Zone (1.2-2.2 km), 3) High Altitude Zone (2.2-3.5 km), 4) Nival Zone (above 3.5 km.)

Systematic monitoring of the climate in Central Asia began in the late XIX century, in the mountainous areas most stations were established later, in the first third of XX century. The most dense network of stations operated in the 80-ies of the XX century, then for economic reasons, their number was decreased by one third, and in mountainous areas by about three times.

The main feature of climate change in Central Asia during the period of instrumental observations is the significant increase in surface air temperature. Thus, the average for the territory of each country temperature increased by:

- 0.26 °C/10 years in Kazakhstan (1936-2005);
- 0.08 °C/10 years in Kyrgyzstan (1883-2005);
- 0.29 °C/10 years in Uzbekistan (1950-2005);
- 0.10 °C/10 years in Tajikistan (1940-2005);
- 0.18 °C/10 years in Turkmenistan (1961-1995).

Temperature rise on the territory of Central Asia occurred unevenly. The highest rates of increase in mean annual air temperature were recorded in the lowland areas, and in the mountainous regions the rate of warming is slower, or even sometimes a slight cooling was observed. For example, in Kyrgyzstan, all the territory of which can be attributed as the mountainous, the average rate of warming has been minimal compared to the rest of Central Asia. In Tajikistan, in the high-altitude zone (above 2500 m), the trend of temperature change only in April, November and December had the positive values. In some low relief areas, there was also a lowering of temperature observed. For example, in Bulunkul lake basin (Tajikistan) during the period of 1940-2005, the lowering of the average annual temperature comprised 1.1 °C, which may be related to features of Eastern Pamirs climate.

In most parts of Central Asia, the most rapid rates of temperature increase was observed during winter months. For example, in Kazakhstan (Figure 2.1) the temperature of the winter period increased on average for the territory by 0.44 °C/10 years, summer - by 0.14°C/10 years. In Kyrgyzstan, the increase of winter temperatures comprised 0.03°C/10 years. In Tajikistan, the temperature of the winter period for the period of 1940-2005 increased by 1.3-3.0°C. In Turkmenistan, on the contrary, the increase in air temperatures of the winter season was only 0.1°C/10 years, and during the remaining seasons of the year – 0.2°C/10 years.

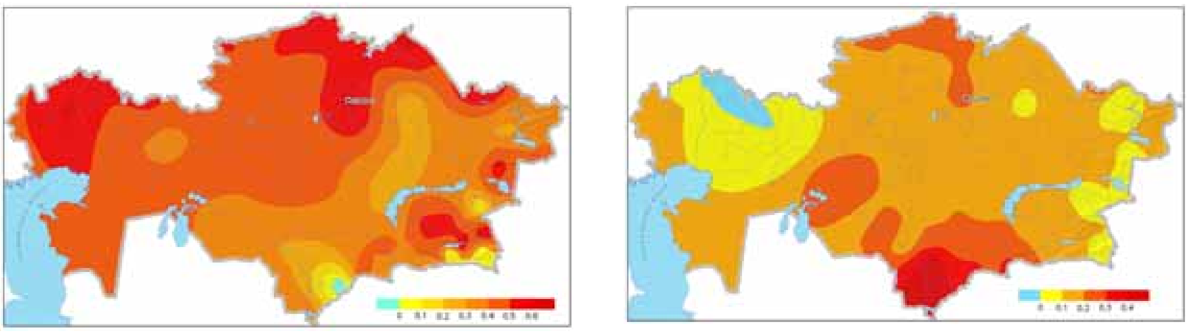

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Figure 2.1 - Spatial distribution of the linear trend coefficient for the surface air temperature in winter (a) and summer (b) periods (°C/10 years), calculated in Kazakhstan for the period of 1936-2005.

Increase of minimum temperatures was generally faster than the growth of maximum temperatures. For example, the average rate of warming for Uzbekistan (*(ΔT/10years*) of maximum temperatures in 1951 reached 0.22°C, minimum – 0.36°C (Figure 2.2). The exception is the area of the Aral Sea retreat, where a very high rate of increase of maximum temperatures was observed, but the minimum temperatures hardly increased due to the reduction of the sea.

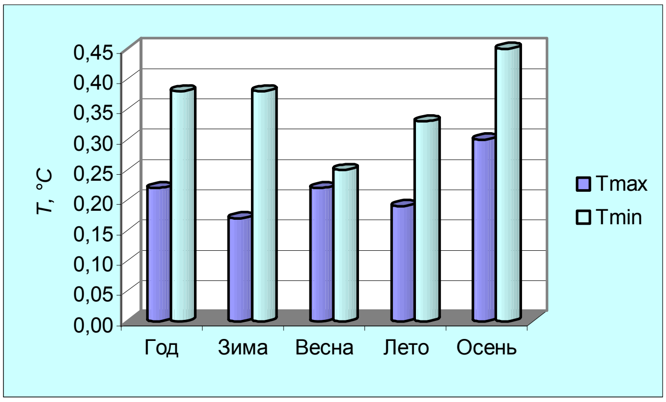

Figure 2.2. Averaged rate of minimum and maximum air temperatures increase in Uzbekistan (ΔT/10 years) since 1951

Changes in precipitation occurred unevenly throughout the territory of Central Asia and through the seasons of the year.

Thus, in most regions of Kazakhstan winter precipitation has increased slightly (Figure 2.3), but it has significantly increased in the region of the southern slopes of the Urals, in the valley of the river Esil, in the areas of mountain uplifts of Kazakh Upland, in the foothills and in the mountains of Southern Kazakhstan. In the area of Moyynkum sands and Zaisan lake there was a negligible decrease in annual precipitation. Spatial distribution of precipitation trends in the winter period coincides with the distribution of trends in annual precipitation. Changing in the amount of precipitation of the summer period (same for its decrease and for the increase) throughout almost the entire territory was insignificant.

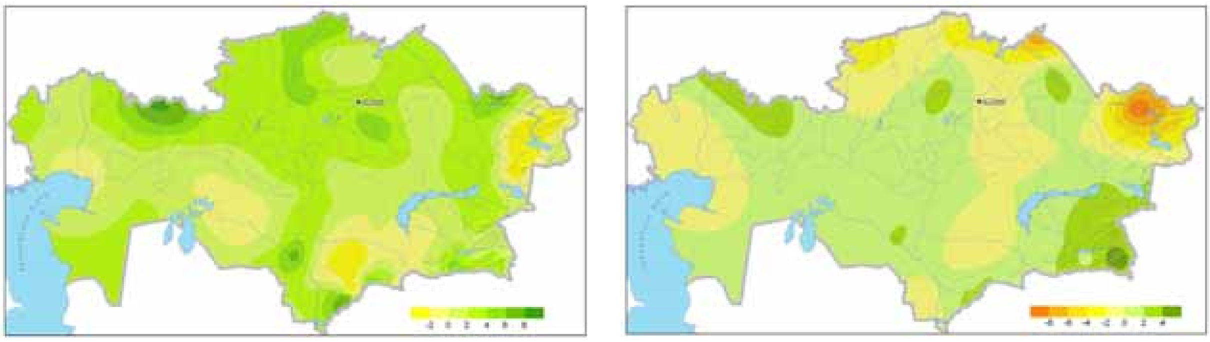

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Figure 2.3 - Spatial distribution of the linear trend coefficient for the amount of precipitation in winter (a) and summer (b) periods (mm/10 years), calculated in Kazakhstan for the period of 1936-2005.

Where in the northern regions in winter period there was an increase in precipitation, in summer, on the contrary, there was a tendency to decrease.

For the orographically complex Kyrgyzstan territory, the change in precipitation is also characterized with significant variability. For the North-Western Kyrgyzstan, the majority trends of annual precipitation amount fall within the range of 0.05-1.7 mm/year, but the High-Altitude Zones have negative trend values (about 3 mm/year). In the valley and foothill areas, there is some tendency to increased precipitation (0.1-1.7 mm/year). In South-Western Kyrgyzstan, the precipitation trends, just like in all high-altitude zones, have both positive and negative values; the maximum positive trends are in the foothill zone - up to 3.0 mm/yr, and the maximum negative are in the mountain zone – up to minus 3.2 (Chaar-Tash meteostation, western slope of Fergana Ridge). In the North-East of Kyrgyzstan, only the avalanche research station Jong-Ashuu observed negative trend (minus 1.1 mm/year), but the other meteostations report the precipitation trends within the range of 0.2-3.3 mm/year. For the Inner Tien-Shan, most meteorological stations, both in the foothills, and in the mountainous areas, have observed a negative trend, falling in the interval from minus 1.5 to minus 0.9 mm/year.

For the territory of Uzbekistan, there were significant fluctuations in annual precipitation recorded, while the average for the territory was slight tendency to increase (Figure 2.4).

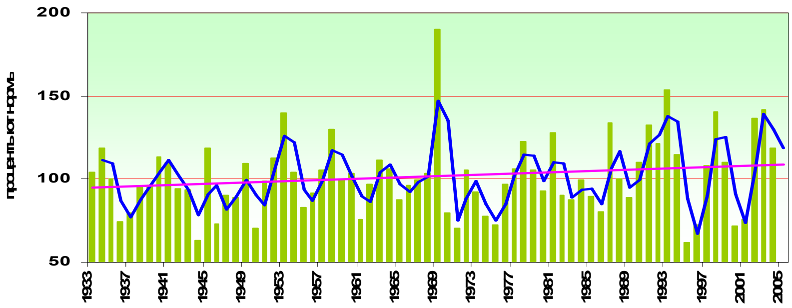

Figure 2.4 – Changing in annual precipitation amount for Uzbekistan

In Tajikistan, due to the mountainous nature of the territory, the distribution of precipitation, and their long-term changes are very different (Figure 2.5). Thus, in the Eastern Pamirs (mountain plateau with the height of 4000-6000 m above the sea level) the amount of precipitation generally decreased by 5-10%, with the maximum values observed in the Murgab - by 44%. A similar trend of reducing precipitation occurred in the southern lowland areas of the Republic (Kurgan-Tube, Shaartuz).

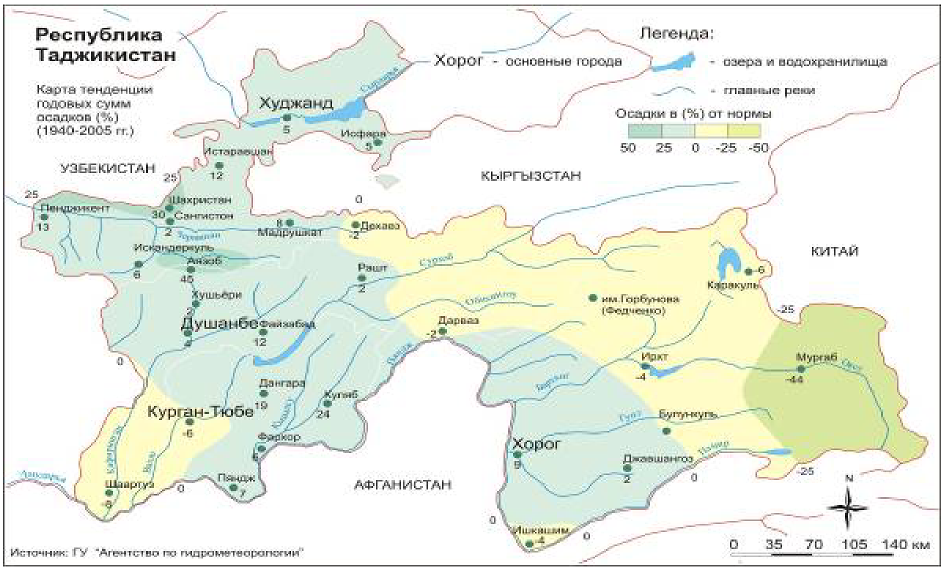

Figure 2.5 Changes in annual amounts of precipitation (%) in Tajikistan for the period of 1940-2005.

Annual amounts of precipitation have increased slightly in the territory of Tajikistan located below 2500 m (an average of 8%) and decreased slightly in the high-altitude areas (3%). The increase of precipitation was mostly observed in summer and autumn in the zone under 2500 m (37-90%), mainly due to intense rainfall (Figure 2.6).

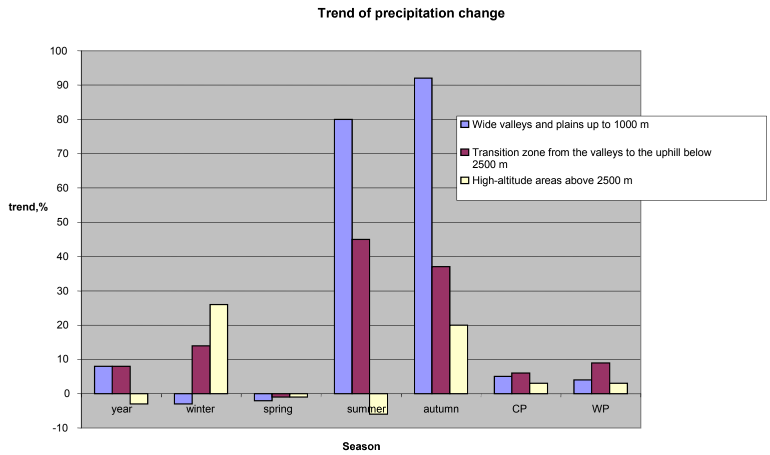

Figure 2.6. Change in the amounts of precipitation (%) by seasons of the year in Tajikistan for the period of 1940–2005.

In Turkmenistan, for the period of 1931-1995 there was an increase in precipitation in all seasons of a year, being most significant during winter and spring (by 1.6 and 1.3 mm/10 years, respectively). During summer, the amount of precipitation almost didn’t change. The annual average amount of precipitation in the territory of the Republic have been increasing by 12 mm/10 years (Figure 2.7).

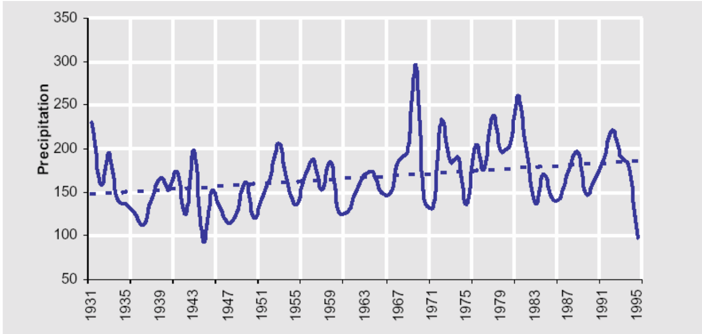

Figure 2.7. Interannual variability in the average amount of precipitation within the territory of Turkmenistan (solid line) and linear trend for the period of 1931-1995.

In many parts of Central Asia, the variability and intensity of precipitation has increased. The increased irregularity of precipitation in time, when torrential rains take turns with periods of drought, may have a negative effect on the territory of Central Asia, as this may cause the enhancement of soil erosion. In addition, in summer such type of precipitation does not provide for the adequate moistening of the soil, since because of heavy rainfalls the soil is not able to quickly absorb the moisture, part of which quickly runs off the surface, and high air temperature contributes to its rapid evaporation.

Significant increase of air temperature accompanied with decrease, or with, usually, an insignificant increase in precipitation, leads to increasing aridity of the climate in the plain areas of the deserts and semi-deserts of Central Asia, as well as in areas adjacent to them. Such a change in humidity conditions is confirmed by the data of approximately 60% of stations in Kazakhstan. Analysis of agrometeorological adverse events and the affected farms in Kazakhstan showed that in 2005-2007 major adverse events for Kazakhstan were: atmospheric (60% of cases) and soil (20%) drought. Only in some mountainous and foothill regions of Central Asia, where the increase of air temperature was less significant, we can talk about a slight decrease in aridity of the climate.

3. Analysis of mountain glaciers situation

Warming in high-altitude areas of the Pamirs, Tien-Shan, Gissar-Alai and other mountain systems corresponds to the regional and global trends. Glacial reserves concentrated in the mountainous regions of Central Asia and Kazakhstan are the most important source and multiyear reserve of clean fresh water. By producing melt water during the hot part of the year, when reserves of the seasonal snow are already depleted, they fill the deficit of irrigation water during the time when the demand for it is the highest. However, reserves of ice are not stable. Currently, the glaciologist researchers remark the widespread retreat of glaciers: small glaciers disappear, and large glaciers divide into parts. Tajikistan and Kyrgyzstan glaciers have played an important role in shaping Amu-Darya and Syr-Darya rivers - the major waterways of Central Asia and the Aral Sea Basin. In this arid region, the future impacts of climate change may directly affect the amount of glaciers, sources of feeding and water content of the rivers, and ultimately, the availability of water for the downstream areas and countries. Each year melting of glaciers in Tajikistan contributes on average 10-20% to the runoff of large rivers, and in dry and hot years, the contribution of glaciers to the water reserves of certain rivers during the summer can reach 70% (Figure 3.1). Water is essential for agriculture, hydroelectric power and related sectors of the economy of Tajikistan. Moreover, water reserves generated here are consumed mainly by the downstream countries.

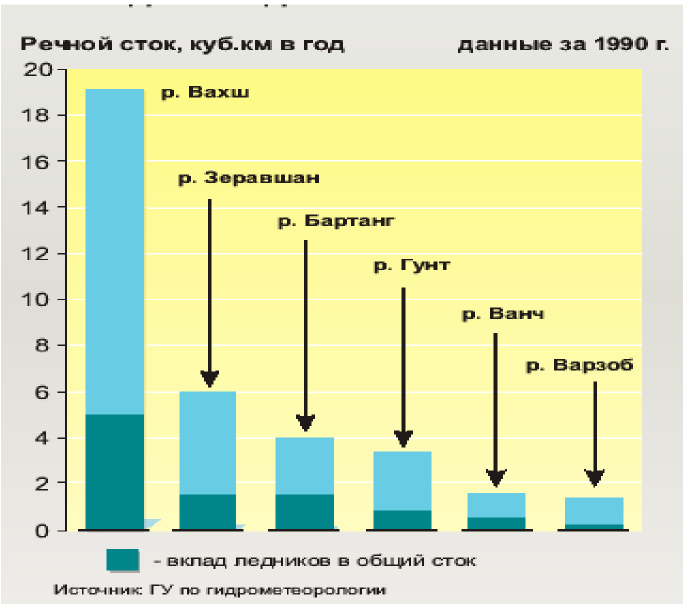

Figure 3.1 – River runoff in an average year in terms of water-content and the share of glacier feeding

Assessing the impact of global climate change on glaciers in the Pamir-Alai has shown that over the entire observation period, starting in 1930 (the first instrumental measurements), the total area of glaciers has decreased by about one third.

Changes in the area of glaciers are particularly great in regions with extensive glaciation (Bartang, Muksu, Fedchenko glacier system) in the center and south of the region, and not so noticeable in basins with smaller glaciation (south of the Fergana Valley, Surkhandarya and Kashkadarya rivers) - to the north and west.

During the twentieth century, the glaciers of Tajikistan, on average, have decreased by 20 - 30%. Glaciers of Afghanistan (left bank of Pianj river) – by 50 - 70%. In recent years, due to rising temperatures of the air, activity of pulsing glaciers has increased.

The area of glaciers in Tajikistan may reduce as compared to the present time by 15 - 20%, and water reserves in the glaciers - by the 80-100 km^3, but the larger glaciers and glaciation nodes will remain. The glacial runoff of Pianj, Vakhsh and the entire Amu-Darya river may increase due to the active glacial melting in the beginning, but in the long run, however, it will reduce due to depletion of ice. Adverse changes of the hydrological regime of rivers can have serious consequences both for the individual vulnerable communities and for the entire region (Figure 3.2)

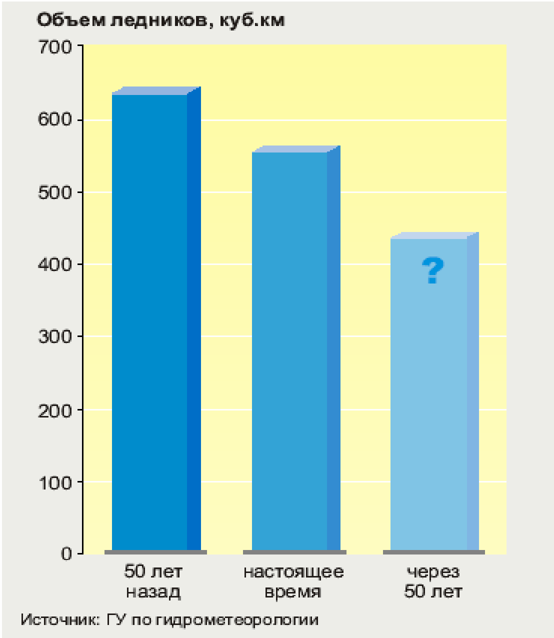

Figure 3.2 – Tajikistan glaciers volume change

If current rates of degradation of glaciers will continue in the next 30 - 40 years, many small glaciers in Tajikistan will completely disappear. The degradation of glaciers could severely affect the entire regime of Kafirnigan, Karatag, Obikhingou rivers. If the amount of atmospheric precipitations will continue to reduce, the surface runoff may reduce as well, leading to reduction of the area of lakes.

Assessment of changes in glaciation of Western Tyan-Shan (Pskemsky Ridge) allowed determining the rate of reduction of glaciers at the present time. Over the 20 years, the glaciation of the area had decreased by a total of 16.8%.

Evaluations of reaction of Gissar-Alai glaciation, located within the territory of Uzbekistan, on climate change, showed that if the precipitation would decrease twice and the temperatures would increase by 3 ºC, the firn line will rise by 700 m, and the area of glaciers will shrink by 86%, and the glacial runoff – by 96% .

In order to evaluate the changes of glaciers in Kyrgyzstan, the following major hydrological basins have been identified: **I** - Issyk-Kul Lake; **II** – Chu river; **III** – Talas river; **IV** – Syr-Darya river; **IVa** - Rivers of the Northern frame of the Fergana Valley (Syr-Darya river); **IVb** - Narin river (Syr-Darya river); **IVc** - Kara river (Syr-Darya river); **IVd** - Rivers of the Southern frame of the Fergana Valley (Syr-Darya river); **V** - Chatyr-Kul Lake; **VI** – Amu-Darya river; **VII** – Tarim river; **VIII** – Balkash lake; **BK** - the region as a whole.

Calculations to assess the parameters of the glaciers were performed separately for all the hydrological basins, as well as for the region as a whole. The calculation results are summarized in Table 3.1 and Figure 3.3.

Table 3.1 - Assessment of the main characteristics of glaciation in 2000. Changes, as compared to the situation in 60-ies of XX century, are given in parentheses, per cent

Basin	Number of glaciers	Area, km^2	Volume, km^3	Average thickness, m
I	614 (97.3 %)	538.11 (84.6 %)	24.224 (83.1 %)	45.02
II	715 (94.8 %)	582.12 (82.3 %)	26.377 (80.4 %)	45.31
III	177 (88.5 %)	112.91 (72.7 %)	4.643 (71.5 %)	41.13
IV	2965 (95.2 %)	1982.34 (84.1 %)	100.973 (83.2 %)	50.94
V	3 (100.0 %)	2.61 (93.4 %)	0.099 (92.6 %)	37.75
VI	277 (99.6 %)	604.36 (94.0 %)	42.158 (93.5 %)	69.76
VII	1693 (94.6 %)	2991.83 (85.3 %)	219.055 (84.8 %)	73.22
VIII	1 (100.0 %)	0.25 (82.3 %)	0.008 (80.4 %)	33.69
BK	6445 (95.2 %)	6814.53 (85.1 %)	417.537 (84.6 %)	61.27
IVa	107 (89.9 %)	39.41 (77.3 %)	1.460 (76.1 %)	37.04
IVb	1661 (94.2 %)	1098.08 (81.2 %)	55.657 (79.7 %)	50.69
IVc	269 (91.2 %)	74.18 (68.4 %)	2.735 (67.1 %)	36.87
IVd	928 (99.0 %)	770.67 (91.0 %)	41.122 (90.1 %)	53.36

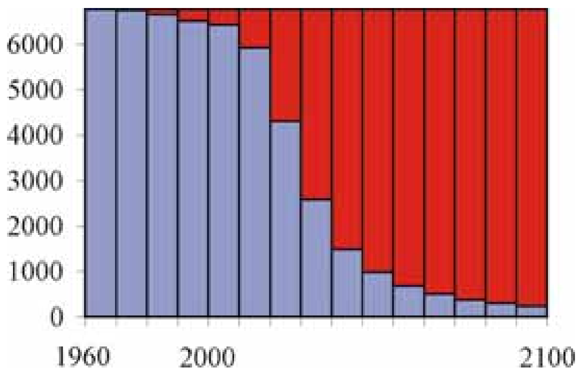

Figure 3.3 - Distribution of the ratio of quantities of remaining and disappeared glaciers by decades, based on the simulation developed for a most likely option of projected climate changes (**dT**=4.96°C, **m**=0.96). The blue identifies the remaining glaciers, and red – those that disappeared.

During the period of 1957 – 1980, the glaciers of the Aral Sea Basin had lost 115.5 km^3 of ice (≈104 km^3 of water), which represents almost 20% of the ice as of 1957.

Rivers of Balkash lake basin mainly originate in the glaciers of North and East Tien-Shan, and Jungar Alatau.

In Ile River Basin, the reduction of glaciation comprised 1254 km^2 (36.6%) and the average per year is 25.1 km^2 (0.73%). In the entire basin of Balkash lake, the decrease comprised 1 498 km^2 (36.9%) or in average per year - 30 km^2 (0.74%). Calculations showed that through the reduction of the multi-year ice stock and water reserves in glaciers, the rivers of Balkash lake basin additionally receive more than 10% water.

According to the opinion of glaciologists, derived from the evaluation of degradation of glaciation during the second half of XX century, in circumstances of today's global air temperature rise on our planet, the glaciers will totally disappear by the end of the XXI century. Studies have shown that due to the degradation of glaciers, the runoff of Ile river will reduce by 2.26 km^3 (11.6%) per year, and runoff in the basin of Balkash lake - by 2.54 km^3 (10.5%) per annum.

The annual decrease in river runoff, accompanied by the degradation of mountain glaciation occurs in proportion to its reduction in the basin of Ile river and Balkash lake. At the same time, it is partially compensated with the water contributed in the process of melting of the multiyear ice reserves. The overall decrease in river flow is formed as a result of the quantitative balance of these two processes: the increasing loss of river runoff by reducing the area of glaciers and the inflow of water from the melting of ancient ice reserves, decreasing with shrinking area of glaciation.

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Due to the degradation of mountain glaciers, the runoff during the low-water years will be reduced (at 25.4 – 27.9%) and during the abounding years it will increase (at 31.4 – 42.4%), the inter-annual distribution of river flow will also change significantly. Runoff in July, August and September will be reduced almost twice, and in April, May and June it will be increased (almost twice also). Assessment of changes in runoff and its inter-annual distribution at the expense of mountain glaciers' degradation was made by comparison of its values in the basins with both glacial and non-glacial feeding.

These calculations have shown that global increase of temperatures on our planet and the continued deterioration of mountain glaciers will lead to increased tensions in the use of runoff in the basin of Balkash lake. To compensate for this tension, water reservoirs on mountain rivers, mainly for seasonal regulation, as well as the flooding and mudflow-control hydraulic structures should be designed and constructed.

The mountain and foothill areas of Kazakhstan, occupying 15% of the territory, may be devastated by mudslides. The Ileysky Alatau, in terms of the mudflow activity, occupies one of the leading places in the CIS. According to the Kazselezaschita (Mudflow Prevention Body in Kazakhstan), mudflows threaten 156 human settlements (including Almaty) and more than 6000 sites of economic activity. Mudflows are formed as a result of a breakthrough of surface and groundwater reservoirs, glacial moraine complexes, intense and prolonged liquid precipitation, facilitated by strong earthquakes, unsustainable economic activity. In less than 100 recent years, there were approximately 1000 cases mudflows of different origin, many of which had a nature of disasters, involving human victims.

The main factors of mudflow formation are: geomorphological, geological and climatic. Assessing the significance of these factors showed that the geomorphologic factor contributing to the formation of powerful mudrock flow, will continue to exist for about 4 million years, geological factor in the centenary perspective may also be considered as unchangeable. The main determinant of mudflow activity on the northern slope of Ileyskiy Alatau is the climate.

Study of the climate change in the territory of south of Kazakhstan and of the geological structure of outcropped cones of the northern slopes of Ileyskiy Alatau demonstrated that during the glacial ages, the mudflow activity is almost equal to zero. Maximum mudflow activity occurred during the period when the air temperature exceeded the present values by 2-3ºC. It is very likely that the main mass of mudflows was formed in a few decades, and the foothill plains were filed with billions of cubic meters of loose debris rocks.

Catastrophic mudflows with rainwater genesis in the concerned region are usually formed with torrential rains in the environment with relatively high air temperatures. If the climate temperature raises by 2-3ºC, the top levels of watersheds will exceed 4000 m, and the areas of watersheds will increase by several times, i.e. all surfaces, as shown in Figure 3.4, will become the hotbeds for the generation of mudflows. The frequency of mudflow-forming precipitations, duration of mudflow risk periods, inclination of mudflow pockets will increase. Catastrophic mudrock flows, which in the XX century occurred once in a hundred years, will be formed almost every year.

Figure 3.4 - Typical picture of a high-altitude zone of Ileyskiy Alatau after precipitation in summer time. In today's climate, as it is well illustrated by the photograph, large amount of precipitation in the range of heights of 3400 m and more, in the overwhelming number of cases, falls as snow, corn or hail.

Climate warming in the XX century has led to rapid degradation of glaciers of Tien-Shan, during which the glacial moraine complexes formed surface and ground water reservoirs. Breakthrough of the latter led to the formation of catastrophic landslides, including those on the northern slope of Ileyskiy Alatau. These debris flows have caused great damage and deaths of hundreds of people. At present, the greatest danger to the city of Almaty would be a breakthrough of Lake No 6 on Manshuk Mametova glacier. The damage which may be caused by a mudflow, formed as a result of a breakthrough of the lake, is estimated at a minimum of 100 million dollars.

With warming of the climate by 2-3ºC, the steppe climate of the upper foothill stage of Ileyskiy Alatau will be transformed into desert climate. Loessial soil will disappear, brows currently covered with herbaceous and shrub vegetation will become badland (Figure 3.5).

Virtually all liquid precipitation will lead to formation of mudslides, deposits of which at the foothill plains will overlap the soil which is currently the most productive. The rapid increase of solid flow in rivers flowing into the Ile river, will create conditions for rapid silting of Kapshagayskoye reservoir, change of delta regime for Ile river and Balkash lake as a whole. There will be serious problems with the irrigation of crops due to the unsuitability of water for irrigation and siltation of irrigation systems with abnormal hard sediments.

The concept of mudflow protection of Almaty and other human settlements based on the notion that catastrophic mudflows are an extremely rare phenomenon. The catastrophic mudflows of the second half of XX century are the proof of erroneous of these perceptions. Multiplication of mudflow activity in the first half of XXI century demonstrated the need to develop a new strategy to protect against mudslides.

Figure 3.5 – Badland formation in the basin of Karaturuk river
(Ileyskiy Alatau ridge).

Rapid increase in mudflow activity should be expected in the mountainous regions of Central Asia currently under glaciation. Sustainable development of this region in the XXI century will largely depend on how timely and appropriately will the actions be undertaken to prevent the landslides, and to reduce the damage caused by the latter.

4. Study of changes in major climate-forming factors

One of the very important tasks at present is the prediction of climate – i.e., a statistical description of the future situation of the climate system in terms of averages and variability of different characteristics of its components over time. In order to assess the vulnerability of economic sectors and ecosystems to the climate change, there are scenarios of climate change developed.

Scenarios of possible greenhouse gases emissions, presented in the Special Report on Emissions Scenarios (SRES), are based on various socio-economic assumptions and involve various levels of future emissions of greenhouse gases and aerosols to the atmosphere. The SRES scenarios are built with no regard to additional initiatives related to climate change, and do not mention the degree of probability of events. Each scenario represents a specific quantification of one of the four storylines. Description of socio-economic assumptions in the six illustrative SRES emissions scenarios is as follows:

A1. Storyline A1 (family of A1 scenarios) describes a future world, which is featured with svery rapid economic growth, rapid introduction of new and more efficient technologies and growth of population of the world, peaking at mid-century, and then subsequent reduction. The main strategy of such development includes: gradual convergence among different regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. This family of scenarios is divided into three groups depending on the main directions of development of energy technologies: large proportion of fossil fuel (A1F1); non-fossil fuel sources (A1T) and a balance among all sources (A1B). This balance here is defined as absence of apparent dependence on any one particular energy source, assuming similar rates of efficiency improvement for all the technologies of energy supply and end use.

A2. Storyline A2 (family of A2 scenarios) describes a very heterogeneous world. The underlying principle is self-financing and preservation of identity. Birth-rate patterns across regions converge very slowly, which results in continuous growth of population. Economic development is primarily regionally oriented and technological change and economic growth per capita are more fragmented and slower than in other storylines.

B1. The storyline and family of B1 scenarios correspond to a single focus for the world development with the same as in A1 global population that peaks in mid-century, and then decreases. However, the rapid changes in economic structures are aimed at developing service and information economy, with a reduction of material intensity and introduction of clean and resource-saving technologies. The emphasis is on global solutions to economic, social (including improved justice) and environmental sustainability, but without additional initiatives related to climate.

B2. The storyline and family of B2 scenarios, similar to A2, are based on a strategy of local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population (with lower growth rate than in A2), intermediate levels of economic development and less rapid and more diverse technological changes than in storylines A1 and B1. This scenario is focused, same as B1, at environmental and social justice, but the attention it paid to local and regional levels.

In the six illustrative emission scenarios outlined in the Special Report of the Intergovernmental Panel on emissions scenarios, the projected concentration of CO_2 in 2100 would be 540-970 million^{-1} versus approximately 280 million^{-1} in the pre-industrial era and about 368 million^{-1} in the year 2000 (Figure 4.1).

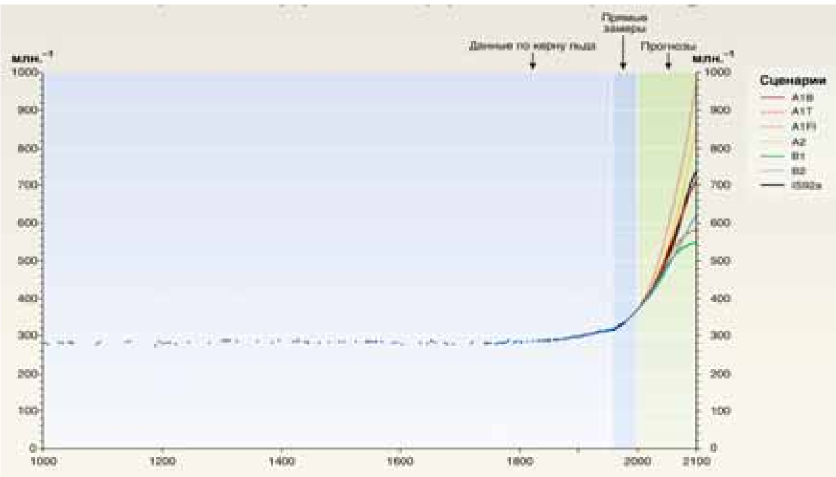


Figure 4.1 - Atmospheric concentration of CO_2 in the period of 1000-2000, determined on the basis of data obtained from ice core and direct atmospheric measurements over the few past decades. CO_2 concentration projections for the period of 2000-2100, based on the six illustrative scenarios from the Special report on emission scenarios and IS92a (for comparison with the Second Assessment Report)

5. Investigation of changes of water reserves in major rivers

In order to investigate the possible vulnerability of water resources of the Central Asian region due to anthropogenic climate change, the methodological basis of existing mathematical models of runoff formation was used.

The main input data to model the discharge record of flow would be the sum of daily precipitation and average daily air temperature at meteorological stations located within the basin or near it.

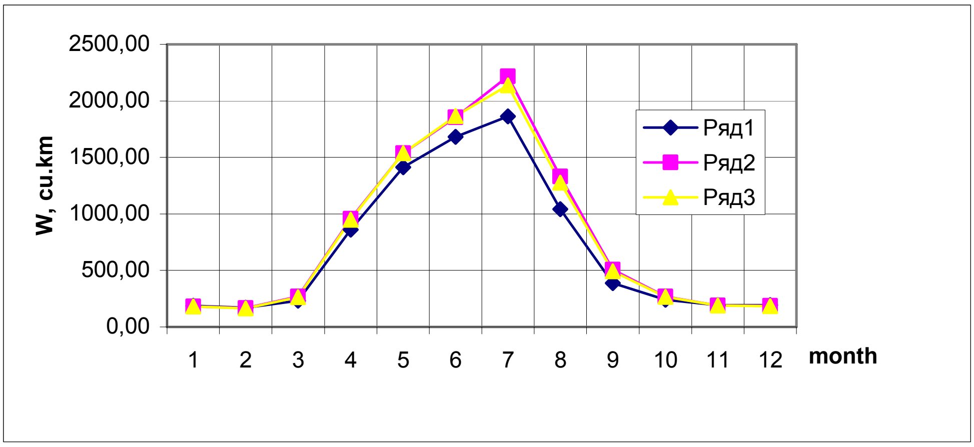
In addition, in order to assess the changes in water reserves, the water balance equation was applied to some countries, involving the air temperature and precipitation amounts, as defined by simulations of global and regional climate and the evaporation values, calculated taking into account the increase in air temperature.

The project included pre-adaptation of simulations to assess the vulnerability of water resources using scenarios of potential human-induced climate change.

The anthropogenic climate changes have been adopted in accordance with the scenarios A2 and B2, for development of which version 2.4 (Turkmenistan) and 4.1 (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan) of MAGICC/SCENGEN (Model of the Assessment of Greenhouse-gas Induced Climate Change / Scenario Generator) software system developed by the order of the IPCC were used, also to carry out the work on vulnerability assessment.

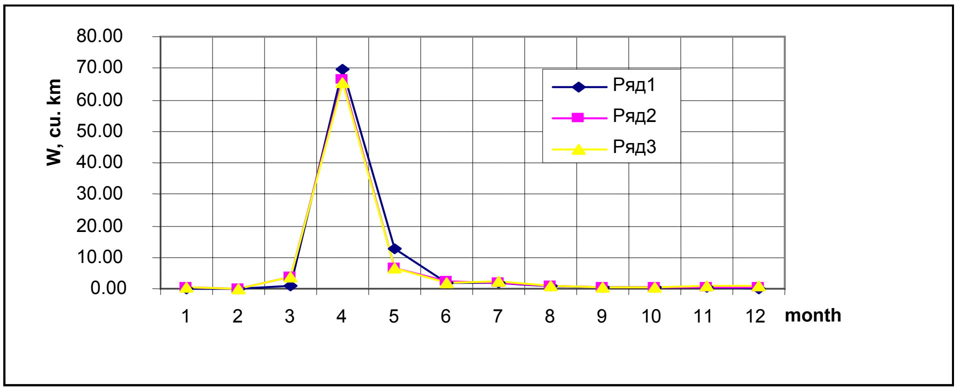
As mentioned above, to some extent we shall be guided by the two scenarios of greenhouse gas emissions, since these should be considered equally possible, and in accordance with those, we shall also review the assessment of the impact of climate change on water resources.

The runoff simulation for the territory of Kazakhstan was conducted for all major rivers of the area. As an example, Figures 5.1 and 5.2 show the comparison of mean values of measured and simulated runoff for mountainous (Balkash-Alakol water-economic basin) and plain (Esilsky water economic basin) areas, respectively.



1 - measured runoff, 2 – simulated runoff based on scenario A2;
3 - simulated runoff based on scenario B2.

Figure 5.1 – Comparison of mean intra-annual dynamic of measured and simulated average long-term runoff values of Ile river (period of 30 years)



1 - measured runoff, 2 – simulated runoff based on scenario A2;
3 - simulated runoff based on scenario B2.

Figure 5.2 – Comparison of mean intra-annual dynamic of measured and simulated average long-term runoff values of Esil river (period of 30 years)

Simulation results showed that:

1. if human-induced climate change as a result of emission of greenhouse gases to the terrestrial atmosphere in future 30 years will occur in accordance with the A2 scenario, the water resources in mountain basins of Kazakhstan will increase in average by 0.8 – 4.5% to 14.0 – 22.5%. In valley river basins the same would be reduced by 7.0 – 10.3%;

2. under the B2 scenario, in up to 30 years prospective, the increase in runoff in mountainous areas will be less and will vary from 2.5% to 9.3 – 12.3%. In the basin of Arys river it will also decline, but by a small volume – 2.0%. The B2 scenario is more “hard” for mountain areas, and for the lowland basins it is more “soft”, therefore in the lowland river basins the decrease will comprise 6.0 – 6.8%;
3. if climate change in the future 50 years will occur in accordance with the A2 scenario, the water resources in mountain basins of Kazakhstan will increase on average by 1.3 - 12.7%. For the lowland rivers basins it will decrease by 4.4 – 7.8%;
4. in an up to 50 years perspective, B2 scenario is more “hard”. Under this scenario, there will be no increase in runoff in mountainous areas, rather it will decrease in the range from 7.2 up to 19.5% and only in the West Altai river basins the runoff will be slightly increased by 3.2%. Scenario B2 is also more “hard” for the lowland basins, since in these basins the decrease reserves will vary from 8.0 to 8.5%;
5. for the years different in terms of water-content, the results of vulnerability assessments of water resources indicate that, regardless of water-content in that year, the change in water reserves will have the same trend as the average for the entire multi-year period;

6. all options and scenarios show the amount of precipitation and temperature increasing. In mountainous areas due to increase of winter precipitation (especially in key watershed areas of the basins) the snow reserves increase, resulting, in circumstances of air temperature rise, in an increase of runoff in spring. The increase of air temperature is not significant enough to lead to a much earlier thawing of soil and, consequently, to increased losses in runoff during the spring flood. The picture is different for the lowland basins. Increased precipitation will to a smaller extend influence the volume of runoff, because of its larger losses at the watershed. In the lowland basins, there is a clear dependence on air temperature. In circumstances of its increase, the depth of autumn frost will decrease, and, consequently, runoff losses due to infiltration will increase as well;

For the territory of Kyrgyzstan during the evaluation and simulation, the surface runoff was calculated as difference between the amount of annual precipitation and annual evaporation layer. Figure 5.3 presents graphs of changes in time for the major simulated characteristics of entire Kyrgyzstan for several options of climate change.

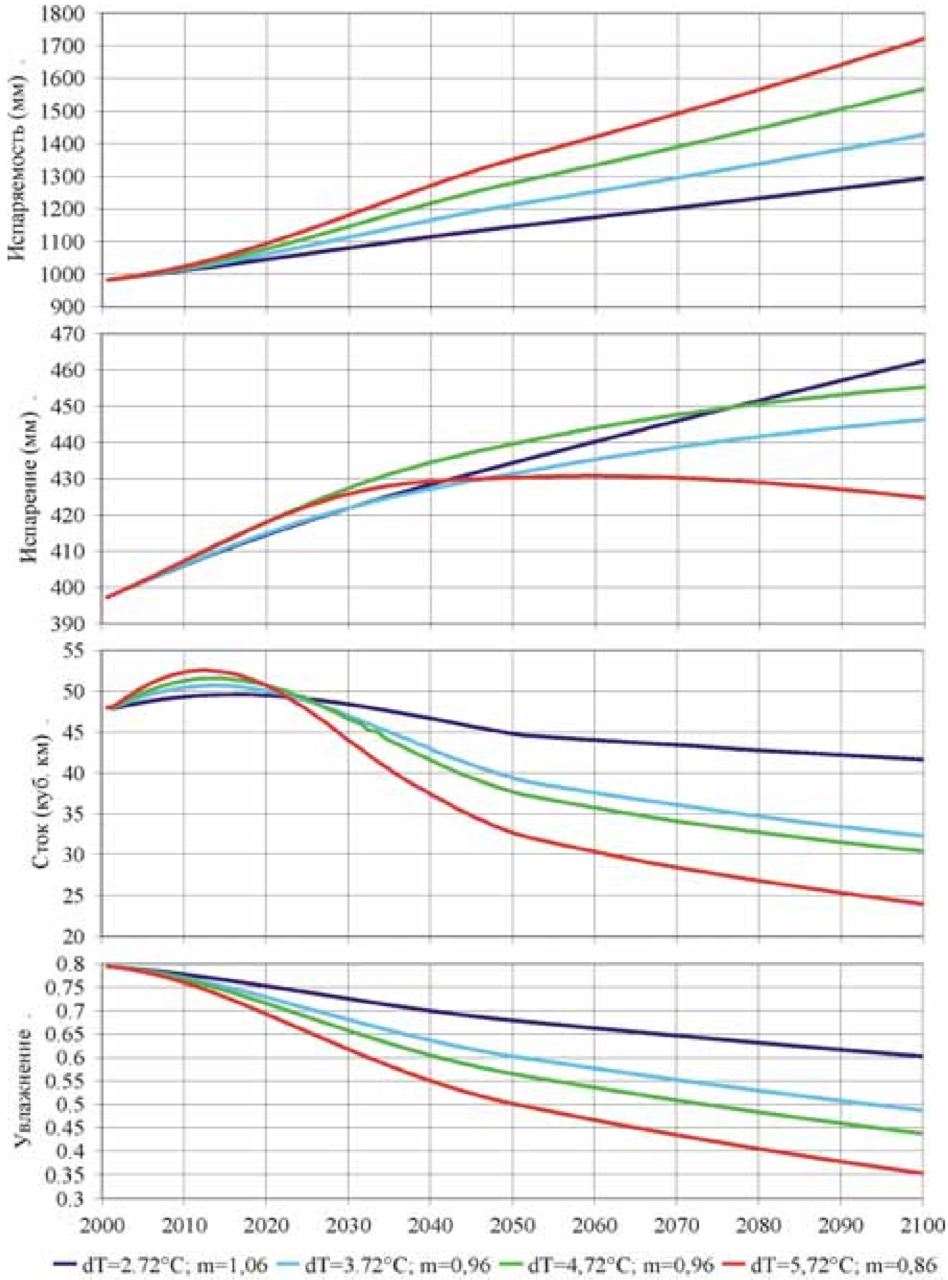


Figure 5.3 - changes in time for the major simulated characteristics of entire Kyrgyzstan for several options of climate change; dT - change in mean annual temperature in ^{o}C, m - the annual amount of precipitation in relation to the reference period.

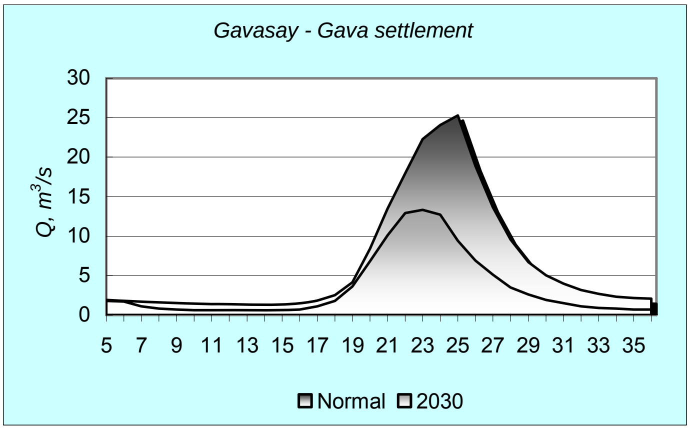
Results of the calculations have shown that significant reduction in runoff is expected for all the most plausible climate scenarios. Increase in runoff is expected in the period before 2020-2025, due to the increase of the glacier component; later on, further reduction of run-off is expected to about 42.4-20.4 km^3, which makes up 43.6 – 88.4% of the runoff volume in 2000. Reduction of runoff, after its slight increase at the beginning of XXI century, shall be caused by, primarily, increase in evaporation.

For the territory of Uzbekistan, the forecasted climate change shall be determined by given scenarios of greenhouse gases emissions, the situation of the global climate system and simulations, according to which the results of prospective evaluation of runoff were calculated. The impact of climate change on runoff varies depending on the scenario and to a large extent due to the differences in expected scenario of precipitation. Given the high natural variability of observed precipitation in stations of the region, and the lack of clear trends in their changes, as well as some uncertainty of scenarios, estimated calculations of the runoff were performed for two options:

- in circumstances of scenery changes in precipitation and temperatures;
- in circumstances of scenery changes in temperatures and modern basic norms of precipitation.

In terms of methodological approach for assessment of the impact of climate change on runoff, the mathematical model of mountain rivers' flow formation was used, being practically implemented in form of an automated information system of hydrological forecasts and estimates.

Figure 5.4 gives an example of comparison of discharge record of Gavasay river runoff – Gava settlement, calculated on the basis of the scenario to the 2030 and 2050, average multiple-year values.



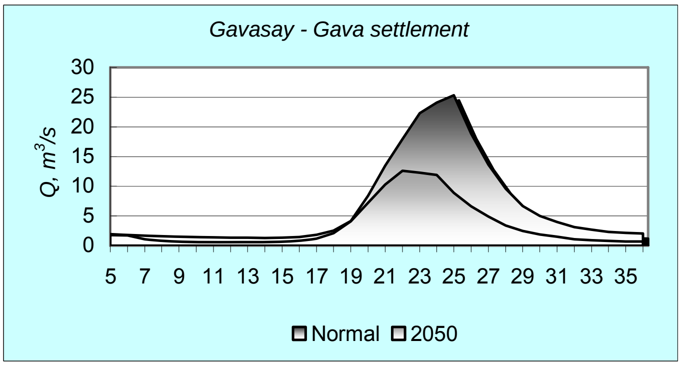


Figure 5.4 - Comparison of discharge record of Gavasay river runoff – Gava settlement, calculated on the basis of the scenario to the 2030 and 2050, average multiple-year values

Obtained estimates of runoff for the Aral Sea Basin rivers within the Republic of Uzbekistan, based in new scenarios of climate change showed that:

- In case of actualization of climate scenarios, describing the changes in precipitation and temperature in Syr-Darya river basin to 2030, there will be no significant changes in reserves. In actualization of B2 scenario, there will probably be a slight increase in runoff upstream, but in general, all deviations will be kept within the limits of natural variability in runoff. In the Amu-Darya river basin, there is some tendency to reduced runoff;

- In case of actualization of climate scenario, which forecasts rising air temperatures with unchanged level of precipitation in Amu-Darya river basin, by 2030 there already may be a reduction of water reserved by 5-8% of the basic norms for the modern period, and in Syr-Darya river basin, there will be no significant changes in resources, and all deviations will be kept within the limits of natural variability in runoff;
- without a scenario calculation of precipitation, changing only the air temperature in the long term perspective (2050) would probably lead to reduction in the flow of the Amu-Darya and Syr-Darya rivers. Possible reduction in runoff of this period for the Syr-Darya river shall lie within the 6-10% of the norm, and for Amu-Darya river - within 10-15%;
- A similar pattern would be observed by 2050 in Amu-Darya river basin under circumstances of A2 scenario, and in Syr-Darya river basin, there are possible reductions in runoff by 2-5% of the basic norm of the modern period.

For the territory of Tajikistan, based on the scenario of change in temperature and moisture, we can assume the following trends in the volume of flow for major rivers, depending on the proportion of the glacier feeding.

Performed calculations showed that, in comparison with runoff values in the second half of XXth century, the volume of runoff in Amu-Darya river basin to 2020 will decline by 3%, to 2035 – by 5% and to 2050 – by 6%.

Increased runoff due to increase in annual precipitation by 14% (HadCM2 scenario) would be insignificant. Reduction of the total annual runoff in Amu-Darya river basin to 2050 at 6% is not significant either.

Based on the scenarios of temperature regime and moisture content, you can suggest the following trends in the volume of major rivers' runoff, depending on the proportion of glacial feeding, as shown in Table 5.1.

Table 5.1 - Reduction of glacial and total runoff (in %) with warming by +2°C and, depending on the proportion of glacial rivers' feeding (%)

Rivers - cross section	Mean annual runoff by years, km^3			
	1990 (normal)	2020	2035	205
Kafirnigan – Tartki	5.11	5.01	4.98	4.94
Vakhsh – Darband	19.1	18.3	17.9	17.6
Pianj – Nizhniy Pianj	31.9	30.7	30.2	29.7
Total	56.1	54.0	53.1	52.2
Reduction in 1990-2050	-	2.1	3.0	3.9
% of normal values	-	3	5	6

Forecasted warming will cause shifts of normal flood dates in intra-annual regime of the rivers: its, peak and duration.

As calculations have shown, the greatest shifts over time will be associated with a change in dates of the beginning and duration of floods. The duration of floods will increase through raising of temperature before the beginning and recession of the flood:

- for the rivers with glacier-snow feeding – by 30-50 days;
- for the rivers with snow-glacier feeding – by 15-20 days;
- for the rivers with snow-rain feeding – by 8-10 days.

Shifting the flood peaks to earlier dates would also be different:

- for the rivers with glacier-snow feeding – by 15-25 days;
- for the rivers with snow-glacier feeding – by 7-10 days;
- for the rivers with snow-rain feeding – by 25-30 days.

Thus, as a result of the forthcoming human-induced climate change, the water resources of northern plains of the Central Asian region in the first half of the XXI century will decrease to 2030 by 6% to 10%. And, to the year of 2050 – by 4-8%.

This is due to the fact that in lowland basins, the increasing temperature will decrease the depth of frost, resulting in increased losses in runoff due to infiltration, and the period of snow accumulation before the spring flood will be reduced.

In mountain areas, the runoff to 2030 will vary within the natural variability, and by 2050 there may be a decrease in runoff by 7-17%.

Significant influence to the changing runoff in the first half of the XXI century will be caused by the degradation of mountain glaciers. Degradation of mountain glaciers, formed before the beginning of XVIII century - the end of the so-called Lesser glacial period characterized by lower temperatures, and increased precipitation in the second half of XX - first half of the XXI century has led to an increase in river runoff in the southern mountainous areas by 4-6%, and in the north - in Naryn river basin and Balkash lake basin by 10 - 15%.

In future, along with the reduction of water reserves in glaciers and the increased losses in river basin surfaces freed from the ice, flow of water to rivers due to degradation of mountain glaciers will reduce.

As a result of almost complete degradation of mountain glaciers, expected by glaciologists in the last decades of the XXI century, water reserves in mountain areas will decrease by 10-12%. Depletion of mountain glaciers will lead to an increase in inter-annual variability of runoff and change in its intra-annual distribution. Along with the reduction of water reserves in glaciers, the summer period runoff – July-September – will decrease, and the spring-summer runoff will increase.

Present-day and future climate change will be accompanied by an increase in inter-annual variability and will lead to an increase in the frequency and depth of hydrological drought.

6. Analysis of most suitable for the region modern simulation models of climate change

In order to summarize the information on climate change in Central Asian countries, the data of Tyndall Center (University of East England) had been used. Calculations of changes in temperature and precipitation by the end of the XXI century (2071-2100) were performed with two scenarios of greenhouse gases concentration – the A2 and B2 – with 4 global climate simulation models (CSIRO2 model - Australia; CGCM2 model - Canada; HAD3 model – UK, PCM model - USA). The models used were approved by the Intergovernmental Panel on Climate Change.

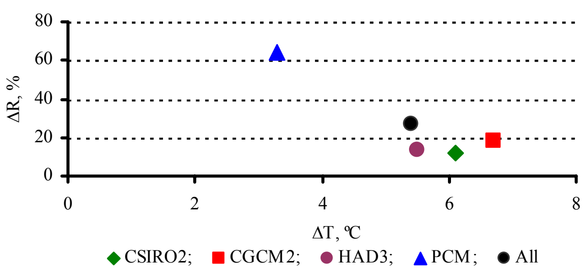
In all models and both scenarios of greenhouse gases concentration - A2 and B2, by the end of the XXI century it is expected to observe the increase in average annual and seasonal temperatures in the Central Asian countries (Figures 6.1-6.5). With respect to precipitation, it is expected for those to decrease in summer, and to increase in winter. During the transitional seasons, the simulation models show mixed trends.

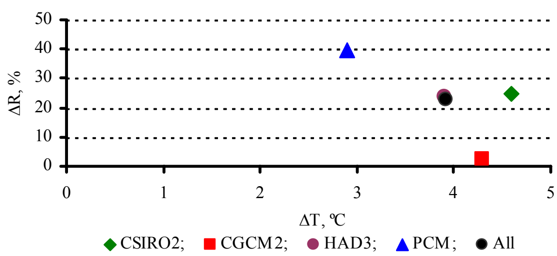
Under A2 scenario, the average annual increase in air temperature relative to the basic period (1960-1990) to the end of the XXI century will comprise on average for all models 4.7ºC (Turkmenistan) to 5.6ºC (Kyrgyzstan). In Kazakhstan, the cutoff mean annual air temperature changes in various models for the territory of Kazakhstan in average would range between 3.3÷6.7ºC, in Kyrgyzstan – 3.3÷7.1ºC, in Tajikistan – 3.4÷7.0ºC, Turkmenistan – 2,8÷5.9ºC, in Uzbekistan – 3.0÷6.7ºC. Mean annual precipitation amount will increase in all countries, except Turkmenistan. In Kyrgyzstan, the average increase for the area will comprise 46%, in Kazakhstan - 27%, in Tajikistan - 18%, and in Uzbekistan - 7% (Figure 6.1).

Based on B2 scenario, which is more "soft", changes in mean annual air temperatures are expected to be lower by 1-1.5ºC than in A2 scenario. Yet, the change of precipitation amount shall remain in the same limits as in A2 scenario.

A2 B2

Kazakhstan





Kyrgyzstan

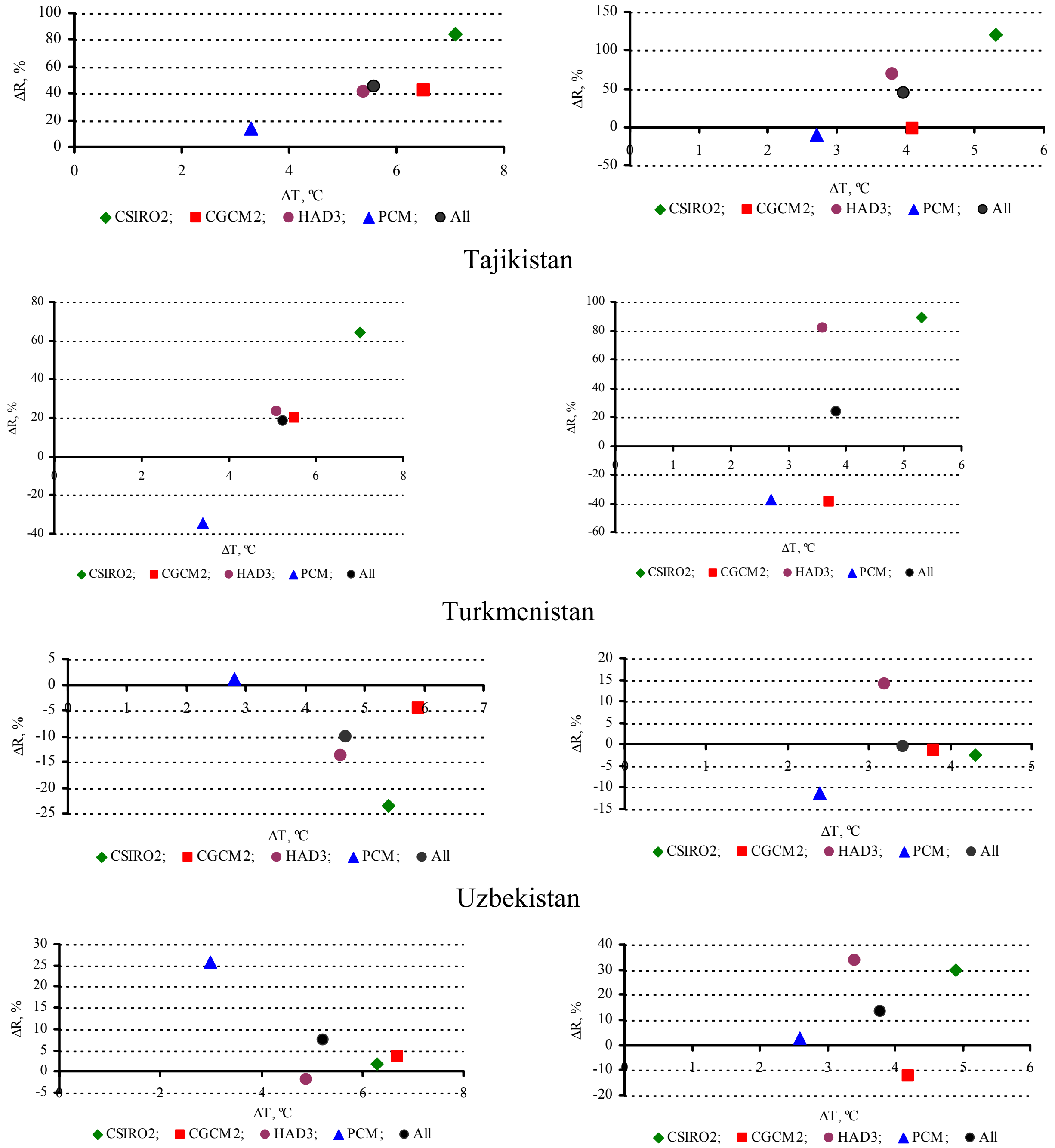
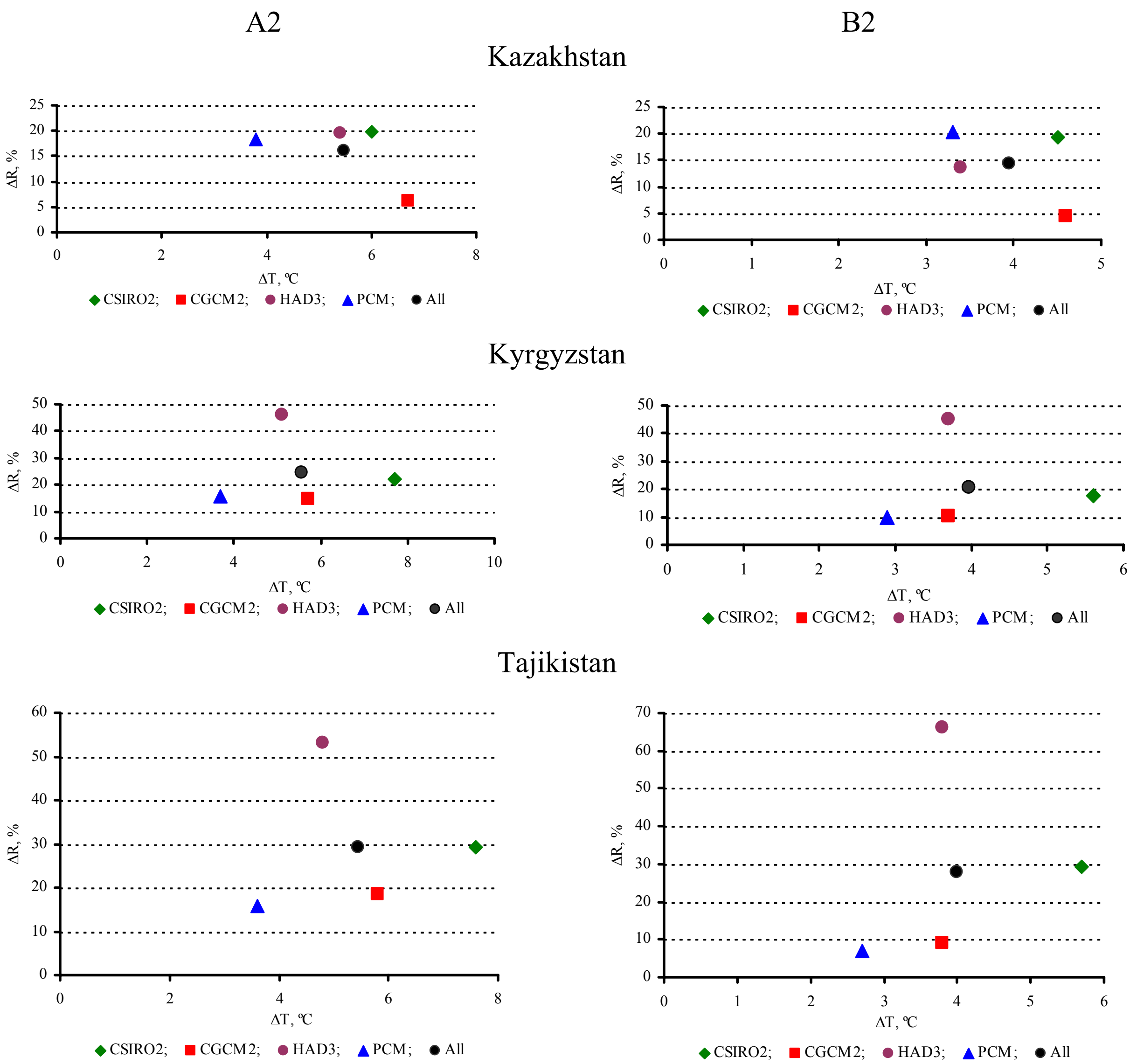


Figure 6.1 - Change in mean surface air temperature (ΔT) and amount of atmospheric precipitation (ΔR) in Central Asian countries, along with changes of CO_2 concentrations under A2 and B2 scenarios, and based on various models of general atmospheric and ocean circulation to the end of the twenty-first century

Below is the change in air temperature and precipitation by seasons of the year.

The winter period. Under A2 scenario, the change of air temperature for the winter season in Central Asia, on average across all models, by the end of the twenty-first century shall range from 4.1ºC (Turkmenistan) to 5.6ºC (Kyrgyzstan). According to various models, the expected maximum raise of mean-seasonal air temperature in winter in Kazakhstan will be 3.3÷6.7ºC, in Kyrgyzstan – 3.3÷7.1ºC, in Tajikistan – 3.4÷7.0ºC, Turkmenistan – 2,8÷5.9ºC, in Uzbekistan – 3.0÷6.7ºC. Changes in the amount of precipitation in winter throughout the Central Asia will have a "plus" sign. The greatest increase in precipitation is expected in Tajikistan - 29%, while the lowest - in Turkmenistan – only 6%. Models provide the ranges of precipitation change:, 6 to 20% in Kazakhstan, 15 to 46% in Kyrgyzstan, 16 to 53% in Tajikistan, 3 to 10% in Turkmenistan, 3 to 14% in Uzbekistan (Figure 6.2).

Under B2 scenario, the mean changes in air temperature for the winter season for the territory of Kazakhstan, Kyrgyzstan and Tajikistan will reach 4.0ºC, in Turkmenistan – 3.0ºC, in Uzbekistan – 3.7ºC. At the same time, the amount of precipitation, on average, will increase by 14%, 21%, 28%, 5%, 12%, respectively.



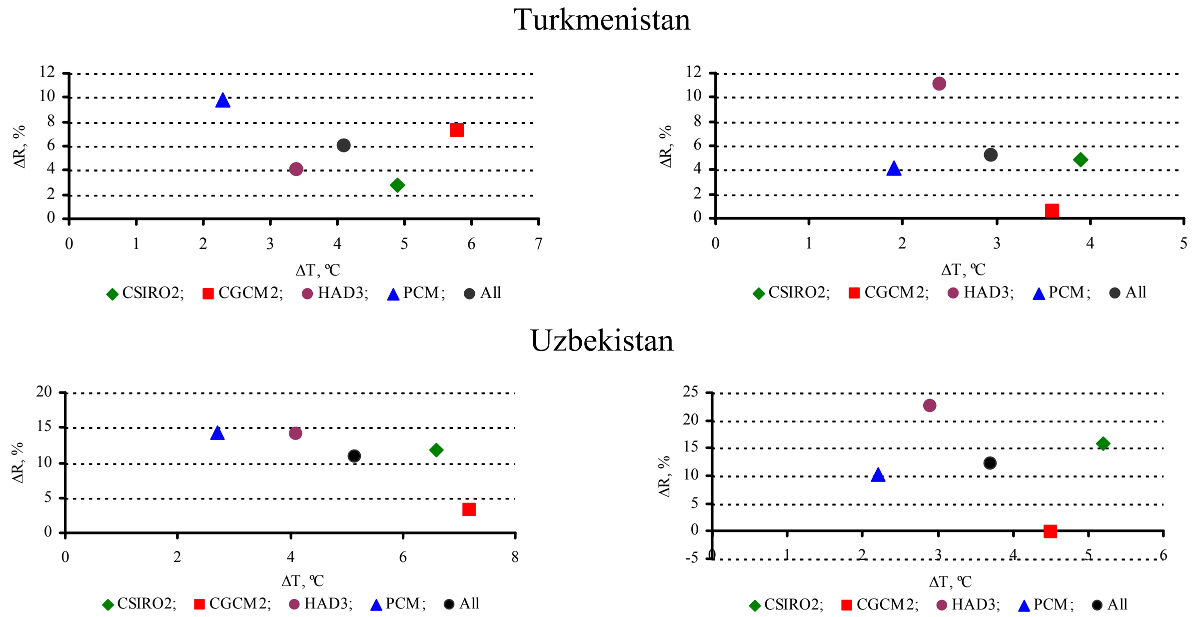
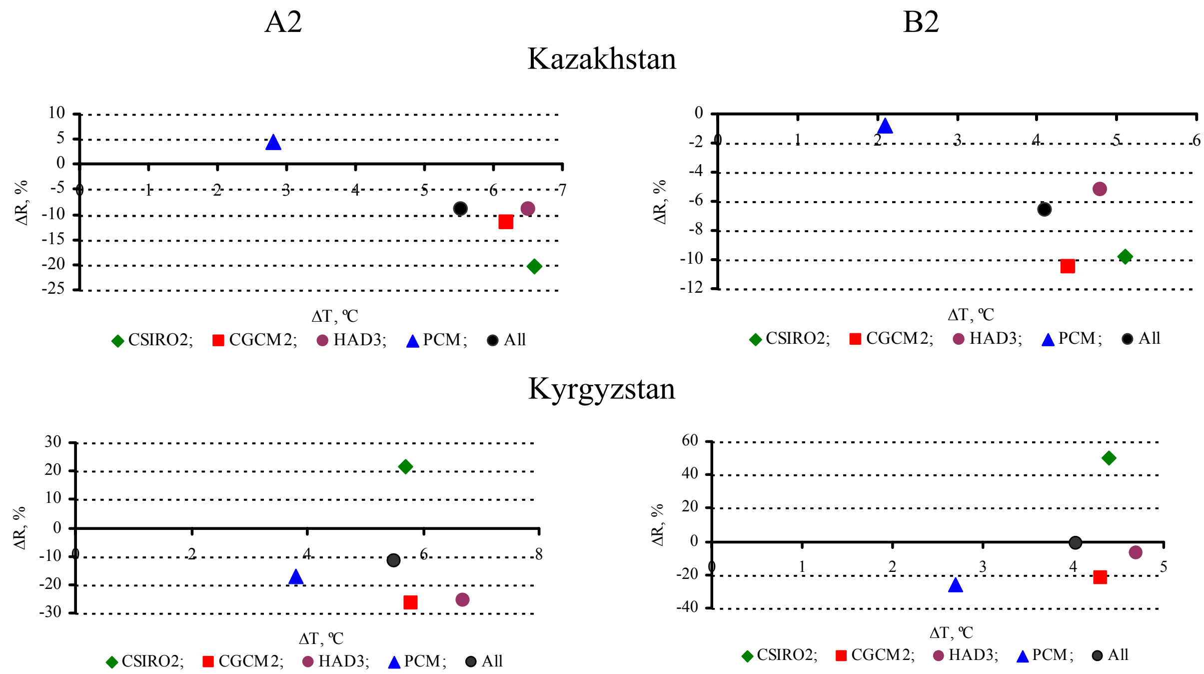


Figure 6.2 - Change in surface air temperature (ΔT) and amount of atmospheric precipitation (ΔR) in winter season in Central Asian countries, along with changes of CO_2 concentrations under A2 and B2 scenarios, and based on various models of general atmospheric and ocean circulation to the end of the twenty-first century

Summer period. Under A2 scenario, positive change in air temperature in summer is expected in all countries of Central Asia, and will average in 5.1-5.5ºC. Amount of precipitation will decrease on average by 4-21%. The largest decrease in amount of precipitation in summer is forecasted for Tajikistan (Figure 6.3).

Under B2 scenario, summer temperatures will increase by an average of 3.8-4.0ºC, and the amount of precipitation will decrease by about 10% or remain unchanged.



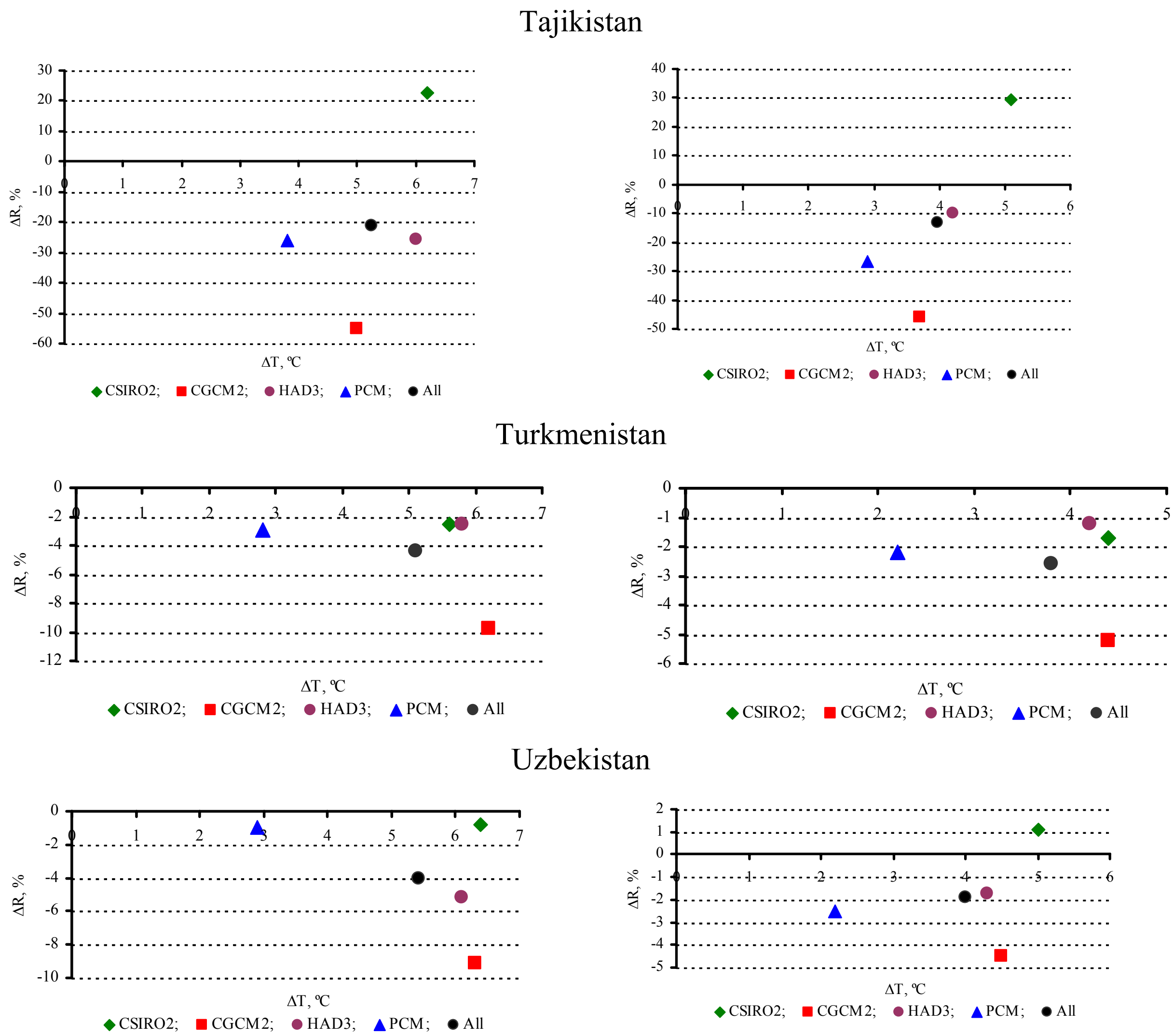


Figure 6.3 - Change in surface air temperature (ΔT) and amount of atmospheric precipitation (ΔR) in summer season in Central Asian countries, along with changes of CO_2 concentrations under A2 and B2 scenarios, and based on various models of general atmospheric and ocean circulation to the end of the twenty-first century

Spring period. Under A2 scenario, the spring temperatures will rise in Kazakhstan by an average of 6.2ºC, in Kyrgyzstan - by 6.3ºC, in Tajikistan - by 5.6ºC, in Turkmenistan - by 5.2ºC, in Uzbekistan - by 5.8ºC. In Kazakhstan and Kyrgyzstan, based on all models, it is expected to have an increase of precipitation by 19 and 33% respectively, while in Turkmenistan it will decrease by 11%. In Tajikistan and Uzbekistan the trend is mixed (Figure 6.4).

Under B2 scenario, the springtime temperatures will rise in Kazakhstan by an average of 4.2ºC, in Kyrgyzstan – by 4.1ºC, in Tajikistan – by 3.8ºC, in Turkmenistan – by 3.6ºC, in Uzbekistan - by 3.9ºC. Precipitation will change to the same extent as in A2 scenario.

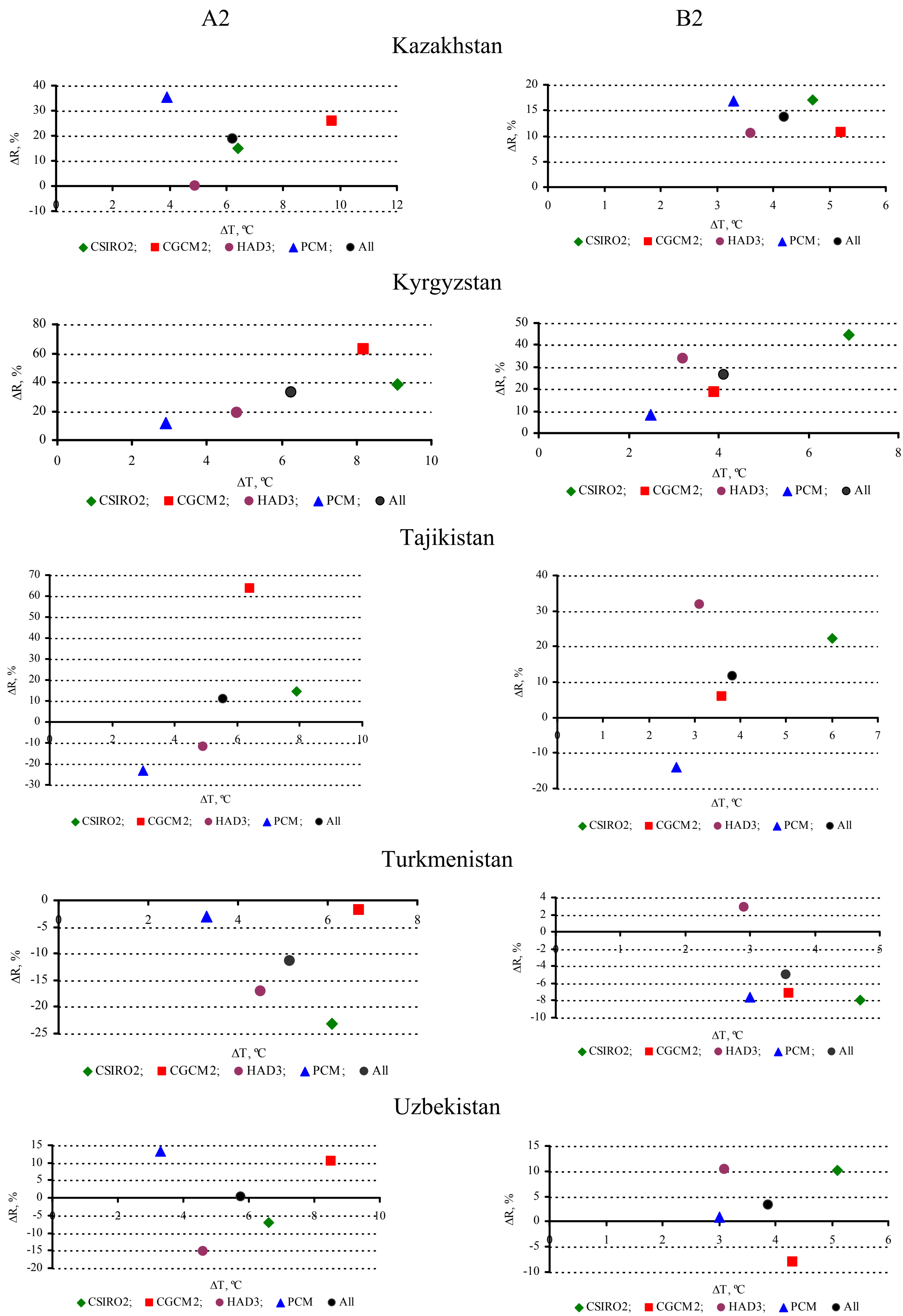


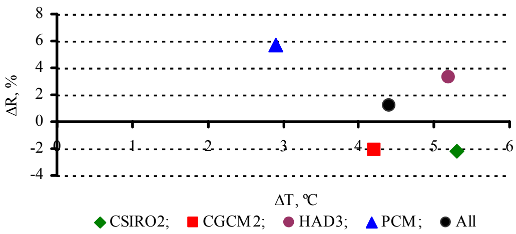
Figure 6.4 - Change in surface air temperature (ΔT) and amount of atmospheric precipitation (ΔR) in spring season in Central Asian countries, along with changes of CO_2 concentrations under A2 and B2 scenarios, and based on various models of general atmospheric and ocean circulation to the end of the twenty-first century

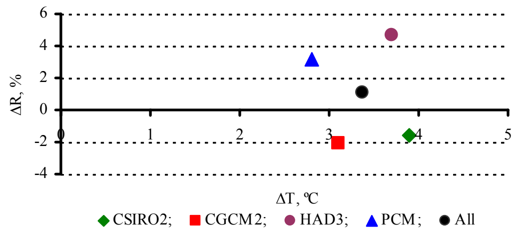
Autumn period. Under A2 scenario, the average autumn temperature will rise in Kazakhstan by 4.4ºC (+2.9÷+5.3ºC), in Kyrgyzstan – by 5.0ºC (+2.8÷+6.3 º C), in Tajikistan – by 4.7ºC (+3.0÷+6.1ºC), in Turkmenistan – by 4.4ºC (+2,8÷+5,1 º C), in Uzbekistan - by 4.5ºC (+2.9÷+5.4ºC). The trend of precipitation changes by simulation patterns is ambiguous, in Kazakhstan, the limits of changes range from minus 2 to 6%, in Kyrgyzstan – from -9 to 4%, in Tajikistan - from -7 to 7%, in Turkmenistan - from -3 to 3%, in Uzbekistan - from -2 to 5% (Figure 6.5).

Under B2 scenario, the autumn temperatures will rise on average for Kazakhstan by 3.4ºC (+2.8÷+3.9 º C), in Kyrgyzstan – by 3.7ºC (+2.6÷+4.5 º C), in Tajikistan – by 3.6ºC (+2.7÷+4.6ºC), in Turkmenistan – by 3.4ºC (+2.7÷+4.1 º C), in Uzbekistan - by 3.5ºC (+2.8÷+4.2 º C). Changes in precipitation are expected to stay within the same limits as in A2 scenario.

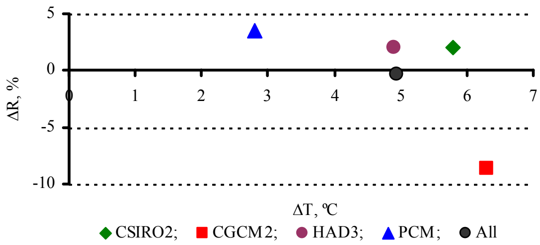
A2 B2

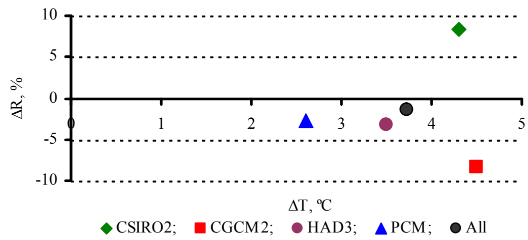
Kazakhstan



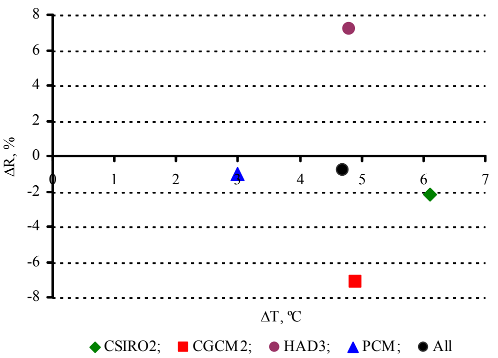


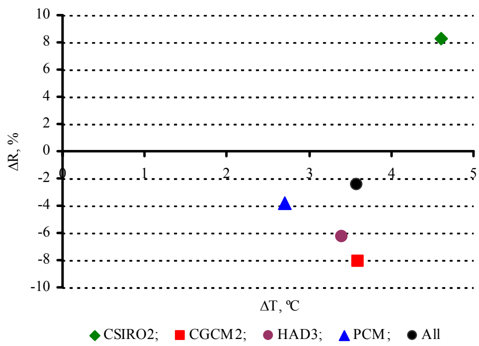
Kyrgyzstan





Tajikistan





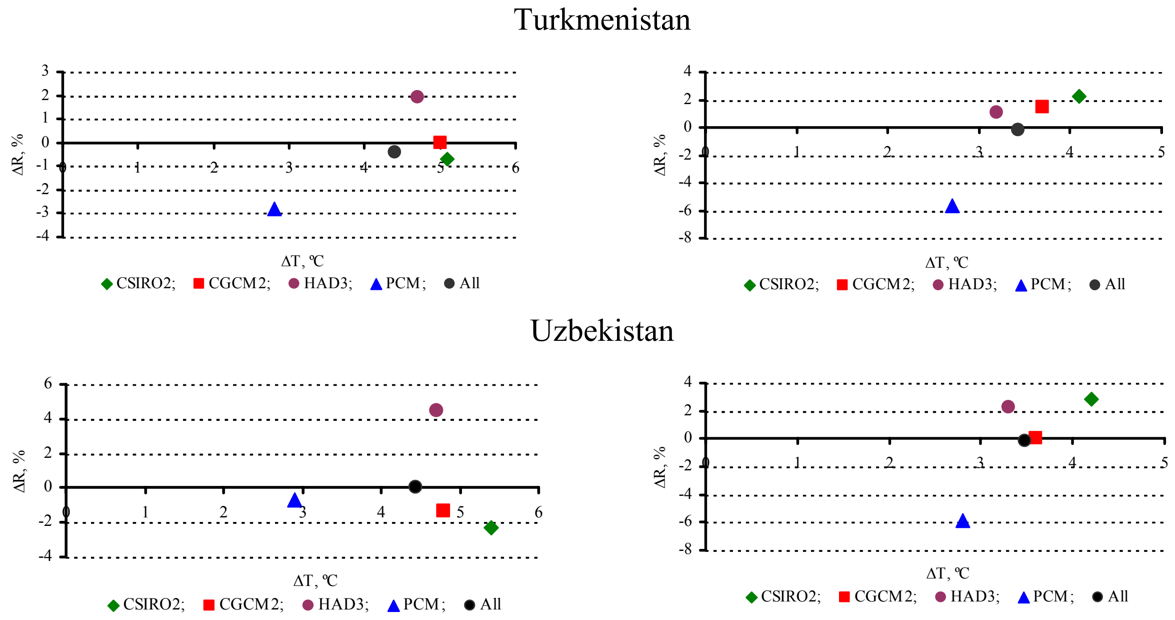


Figure 6.5 - Change in surface air temperature (ΔT) and amount of atmospheric precipitation (ΔR) in spring season in Central Asian countries, along with changes of CO_2 concentrations under A2 and B2 scenarios, and based on various models of general atmospheric and ocean circulation to the end of the twenty-first century

7. Proposals for the efficient use of water reserves in the region, including the challenges of hydropower potential development

Based on vulnerability assessment of water reserves caused by possible human-induced climate change, it is a critical issue to adapt to the changes in the new environment. Water reserves adaptation actions shall be mainly determined by the specificity of water use. For all the Republics of the southern region, the primary sector consuming water resources is agriculture, using up to 90% river water reserves. When selecting the adaptation actions, we should also bear in mind that besides of the expected reduction of surface runoff, there will be an additional problem, increasing the negative effect of reduced runoff, and that is the extreme climatic events, long-term forecast of which is currently impossible. However, there are substantial grounds for believing that floods will be more powerful and prolonged, and the droughts will be more frequent and lengthy.

In fact, adaptation actions are the mandatory accounting of expected changes in climate in development of various types of long-term plans, programs, etc., at both national and regional levels. With regard to Kyrgyzstan and Tajikistan, this is also relevant for the hydropower development plans.

The best approach would be to develop a number of regional pilot adaptation projects with further propagation of the actions to the entire region.

Adaptation to the expected changes in water resources shall have the following priorities:

At the regional level:

1. The most radical adaptation actions could be projects for transfer of part of runoff within the region and adjacent territories;

2. Priority should be given to the activities related to water-saving and environmental protection;

3. A simulation system must be created to enable the detailed assessment and management of water resources;

At the national level:

4. Introduction of water-saving technologies in agriculture, industrial and domestic sectors.

5. In order to compensate for the increase of inter-annual variability of river flow and its intra-annual changes resulting from the degradation of mountain glaciers, it is necessary to design and construct reservoirs on the rivers, mainly with seasonal regulation, and the flood and mudflow prevention hydraulic structures.

Based on selected priorities, as well as on multi-ethnic people living in the basins of major rivers of Syr-Darya and Amu-Darya, it is necessary to take the following steps for the management of vital water resources in Central Asia in future. The actions listed below are **common throughout the region** and are aimed at establishment and development of cooperation mechanism between the nations on the basis of an integrated approach.

Actions to support the development of water-consuming economic sectors:

- strategic development of the economy based on the waterless and low-water-consuming technology;
- switching to water-saving technologies in irrigated agriculture;
- increasing the proportion of groundwater use;
- regulation of runoff and creation of water reserves in reservoirs;
- encouragement of water users to more efficiently use the available reserves through the introduction of paid water use;
- shift to more drought-resistant cultivars and crops, better adapted to climate change;
- construction of flood and mudflow prevention hydraulic structures, in order to mitigate water-related natural disasters;
- partial diversion of river flow within a region to the outside of the region.

Actions to mitigate the negative effects of the impact of the vulnerability of water resources to the economy sectors:

- Minimizing water losses through the effective management and rehabilitation of irrigation systems and water-supply systems;
- Replacement of hygrophilous crops in irrigated lands with less hygrophilous crops;
- Introduction of advanced technologies to irrigated agriculture;
- Use of modern, more efficient systems and regimes of water distribution to reduce the losses;
- Introduction of low-water-consumption technologies and systems of revolving water use in the existing industrial enterprises and utilities;
- Reuse of wastewater;
- Development of water and energy exchange patterns, through which the winter accumulation of water in reservoirs would become, at least, not detrimental for the upstream countries, while allowing not to consume the water in winter periods, but to use it in summer for irrigation;
- Dredging operations, reconstruction of jetties and berths on navigable river;
- Replacement of the existing river transport ships and fishing fleet with smaller draft vessels.

Activities to optimize the situation of aquatic ecosystems and to protect the environment:

- creation of favorable water-heat regime for habitation and reproduction of fish and other living organisms, regulating their number;
- chemical and biological wastewater treatment;
- implementation of additional reclamation, agroforestry and agricultural activities to ensure environmental safety;
- establishment of sanitary protective zones near surface water sources and in areas of groundwater abstraction;
- severe limitation of economic activity in water-poorest areas and its transfer to other territories;
- scientifically based natural-ecological zoning of the territory for the development of the main branches of agricultural production;
- mandatory environmental assessment of new projects, involving water reserves.

Activities to reduce the social losses:

- granting compensations to the people when relocating them from the areas of desertification when there is decrease in surface water resources;

- allocation of funds for infrastructure development in new settlement areas;
- importing the lacking food and industrial goods in connection with the unfavorable conditions of their production in circumstances of possible reduction of water reserves.

Activities to improve the timeliness of decision making:

- Improvement of legislation and conclusion of international treaties for regulation of economic water relations in the light of forthcoming changes in water reserves;
- Strengthening material and technical and legal foundation of interstate organizations;
- Improvement of earliness and justifiableness of hydrological forecasts;
- Development of models and science-based recommendations for proper and quick assessment of the situations, resulting from the formation and use of water resources;
- Preparation of necessary services for immediate implementation of possible solutions;
- Identification, under changed circumstances, of surface water resources and statistical characteristics of river flow for the development of integrated water resources management patterns and for designing the hydraulic engineering structures;
- Improving the runoff accounting system and development of water resources monitoring (national and trans-boundary), strengthening the hydro-meteorological monitoring in order to account for and to forecast water resources, as well as changes in water resources in future in view of global warming;
- Raising knowledge and skills for the sustainable management of water resources;
- Development of hydrological forecasting system;
- Development of hydrological drought early warning systems;
- Development of concerted mechanisms for integrated water resources management in the Aral Sea Basin.

The activities proposed above will solve several problems of water resources sharing in the Aral Sea Basin at the regional level, when one Republic is located in the zone of runoff formation, while others are located downstream of it and experience an acute shortage of water.

In addition to the mentioned activities of regional significance, **national level** activities are proposed for Kazakhstan, Kyrgyzstan and Tajikistan, subject to intensifying mudflow activity due to the climate change.

In a changing climate, when the mudflow activity may increase by tens of times, the prevention of mudflows becomes a national concern. Depending on the importance of a facility, located in mudflow-risk zone, solutions to ensure the security could be both political and economic. An example of a political solution to the problem of Almaty protection against mudflows could be transfer of the city to the north, right up to the Kapshagayskoye reservoir.

In circumstances, where the basis for mudflow prevention is an economic factor, mudflow prevention activities should be performed: preventive, organizational, economic and protective. Activities of preventive nature, designed to prevent or reduce damage caused by mudflows, include: preventing of formation and development of lakes, breakthrough of which could lead to mudslides; emptying mudflow-risk-raising lakes in the moraine-glacial complexes; reclamation of rain-genesis mudflow origin zones; revegetation of medium and low-altitude zones, terracing of slopes in low-altitude zones, creation of reservoirs for detention of mudflows and floods that could emerging as a result of glacial-moraine complexes' surface and groundwater reservoirs breakthroughs, or heavy precipitation in liquid form on the main mudflow origin pockets; active influence to the intensity, duration and phase composition precipitations, etc.

Organizational and economic activities aim at relieving the risk of mudflows in order to reduce possible harm: restriction of economic activity in mudflow risk zones, conservation of vegetative cover in watersheds, landscape reclamation, safe placement of recreational objects and organization of mudflow hazard warning system; promoting the appropriate behavior of population in mudflow-risk zones, etc.

Protective activities, particularly those specifically related to water, ensure the safety of objects, threatened by mudflows, through: detention of mudflows, safe passage of mudflows through the protected areas; diversion of mudflows from the protected sites, etc. To date, generally accepted methods of combating mudflow phenomena that would have passed the test of time, do not exist. It has only been proven that the activities of preventive nature do not guarantee full protection, therefore construction of mud reservoirs (mud storages) in the mountain valleys is an essential element of security. If the urbanization level of the mudflow evacuation cone is low, and the cost of preventive measures is much higher than the value of the protected sites and lands, seized in order to ensure safety, organization of safe passage of mudflows through the protected area, or use of mudflow evacuation cone to carry mud deposits, shall be recommended.

Catastrophic mudflows originating in high-altitude zone cause damage to objects located in the valleys and on the mountain rivers' evacuation cones, and for every mudflow basin there should be an individual protection strategy designed.

Preliminary assessment of hydropower potential. The problem of Kyrgyzstan and Tajikistan energy sector development requires urgent further studies to obtain reasonably justified assessments of the hydropower potential of the Republics in future without jeopardizing the countries located in the middle and lower reaches of the Amu-Darya and Syr-Darya rivers.

Fundamental activities and guidelines with respect to the issued of efficient use of water resources are reflected in some of the following international instruments and treaties (Annex 1).

Water relations of Central Asian countries are governed by several major agreements, the legality of which is recognized by the heads of the Central Asian states.

Treaty between the Republic of Kazakhstan, Kyrgyz Republic, the Republic of Uzbekistan, the Republic of Tajikistan and the Republic of Turkmenistan on Cooperation in Joint Management and Protection of Water Resources from Interstate Sources was signed on February 18, 1992 (Alma-Ata).

Treaty between the Government of the Republic of Kazakhstan, Government of Kyrgyz Republic, and the Government of the Republic of Uzbekistan concerning the use of hydropower resources of Syr-Darya River Basin was singed on 17 March 1998 (Bishkek).

In accordance with the Treaty of 1992, the Interstate Commission for Water Coordination of Central Asia (ICWC) and its executive bodies – "Syr-Darya" and "Amu-Darya" Basin Water Associations (BWAs) operate in the region.

On 26 March 1993, the Heads of States, at their meeting in the town of Kyzylorda, once again brought attention to the interstate water relations and signed an instrument to establish the International Fund for Saving the Aral Sea (IFAS), as well as Treaty "On Joint Action to Address the Problem of the Aral Sea and Aral Sea Neighborhood, Environmental Health and Socio-Economic Development of the Aral Sea Region". These instruments consolidated the vision of the overall objectives of the region and identified the structure of intergovernmental bodies with a mandate to perform the tasks laid out in this Treaty.

On 11 January 1994, in Nukus, the Heads of Central Asian states resolved to approve the "action-oriented programs to improve the environmental situation in the Aral Sea Basin for the next 3-5 years, taking into account socio-economic development of the region" and "Basic provisions of Aral Sea, Aral Sea Neighborhood and Aral Sea Basin problem-solving concept".

Within the framework of the International Conference on the Sustainable Development of the Aral Sea, held on 20 September 1995 in Nukus, the Heads of Central Asian States have signed "Nukus Declaration of Central Asian States and International Organizations on Sustainable Development of the Aral Sea Basin". In it, the heads of Central Asian States have confirmed that they recognize the previously signed and acting agreements, treaties and other regulatory acts governing the relationships between them with respect to water resources in the basin of Aral Sea, and take them to undeviating performance. The declaration also contains an appeal to the international community, to the Governments and peoples around the world to help solve the problems of sustainable development and improvement of ecological situation in the region.

Conclusions

1. Intense warming of the climate is observed in the whole of Central Asia. The long-term assessment of water resources in rivers with respect to the climate change showed that none of the climate scenarios considered, which reflect the warming, will increase the available water resources. These calculations have shown that by 2050 the volume of river runoff in Amu-Darya basin will reduce by 10-15%, and in Syr-Darya basin by 6-10% (Figure B1)

Figure B1 - Impact of climate change to runoff of rivers in Central Asia

Significant reduction of water resources will be reached in 2050. However, water demand is already growing faster and comes to a mismatch with the available resources. The expected increase in water demand for the vital needs of growing population and economic activity will be increasing the pressure on river flows, global climate and water turnover, and the problems of water scarcity in arid and semi-arid regions of Uzbekistan will become increasingly critical.

2. Water resources of rivers are increasingly becoming the key limiting factor in food production, equivalent, if not more important, to the shortage of land resources. Irrigated agriculture already consumes more than 93% of the total water available, and water demand will increase, in order to insure food security for the rapidly growing population. Therefore, in the medium term, serious conflicts of interests will arise in terms of distribution of water between irrigated agriculture and other sectors of the economy, as well as at the local level, particularly with regard to global warming.

3. Today, Central Asian countries have faced the need to find ways to address, minimize and, if possible, to prevent water problems associated with the

lack of water, changing water regime of rivers, pollution and depletion of water sources. In modern circumstances and in future, the shortage of water resources is one of the main factors limiting the development of countries. Improving efficiency of water use, water-saving and management of water demand, based on equitable distribution, achieving compromises between the interests of the representatives of the upper and lower reaches of rivers, water-users and ecosystem needs, are the vital issue for the Aral Sea Basin.

4. Introduction of integrated water resources management (IWRM) at the national and regional levels will contribute to water-saving, strengthening of international cooperation in the field of water and energy resources, based on the principles of unity of water resources. The development and implementation of basic IWRM tools, such as:

- mechanisms to manage the distribution of water resources;
- mechanisms to manage the water usage and water demand;
- mechanisms to manage the environment, including water quality management;
- mechanisms to manage critical situations;

would ensure safe and viable national and regional water resources management in the context of current and future climate change.

5. An important task is to resolve conflicts between environmental demands for water and irrigated agriculture, which is possible by setting the requirements to the regulation of environmental discharges, protection of the environment in the region by national and inter-state legislation.

6. Natural uneven distribution of water resources in the region leads to the contradicting approaches to the usage regime of hydraulic structures, erected upstream of Syr-Darya and Amu-Darya rivers. Conflict of interests of countries located in the upper and lower reaches of transboundary rivers must be eliminated on the basis of mutually beneficial cooperation and balanced approach to projects that change the existing balance of water usage from transboundary rivers, taking into account the international norms and rules.

7. Assessment of vulnerability of water resources that was for the first time developed by this consolidated report, caused by the expected climate change, is the basic material for the next phase of research aimed at developing strategies and adaptation activities at the regional level.

8. This report will be used by IFAS in the preparation of the third edition of the World Water Development Report in accordance with the World Water Assessment Program (WWAP).

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Annex 1

Version number 12, April 2008, Tashkent
ADB RETA 6163 Project

AGREEMENT
between the Government of the Republic of Kazakhstan, Government Kyrgyz Republic, Government of the Republic of Tajikistan and Government of the Republic of Uzbekistan
ON THE USE OF WATER AND ENERGY RESOURCES OF SYR-DARYA RIVER BASIN

Preamble

The Government of the Republic of Kazakhstan, Government of Kyrgyz Republic, Government of the Republic of Tajikistan and Government of the Republic of Uzbekistan, hereinafter referred to as the Parties,

guided by sincere spirits of good-neighborliness and cooperation;

developing the provisions of the Agreement between the Government of the Republic of Kazakhstan, Government of Kyrgyz Republic, Government of the Republic of Tajikistan and Government of the Republic of Uzbekistan "Use of hydropower resources of Syr-Darya River Basin", signed on 17 March 1998;

recognizing the fact that the Parties aim to follow the agreed procedure of Syr-Darya River Basin Water and Energy Use, ensuring social and economic development of their countries and people's welfare;

noting that Syr-Darya River Basin contains the water and energy resources capable of facilitation of the economic growth of countries of the region;

having a common desire to find the most fair and mutually acceptable solution in the use of the water and energy resources of the Syr-Darya River Basin, bearing in mind the problems of the Aral Sea;

acknowledging that joint operation of the reservoirs of the Naryn-Syr Darya Cascade, through a multi-year flow regulation and the flood control measures, allows ensuring a secure water supply and the mutual benefits of irrigated agriculture and power generation;

taking into account that the joint and integrated usage of water and energy resources of the Syr-Darya River Basin must be based on the Correction Note to the "Elaborated scheme of complex use and protection of water resources of the Syr-Darya River Basin", approved with protocol number 413 of the Scientific and Technical Council under the Ministry of Land Reclamation and Water Resources of the USSR of 29 February 1984;

have agreed on the following:

Article 1 Definitions

1. "Syrdarya" BWA - "Syrdarya" Basin Water Association, for the purposes of this Agreement, is the executive body of ICWC in Central Asia.

2. "Lateral inflow" - the inflow into the river from a part of the watershed, enclosed

between two cross-sections, it is the sum of the values: estuarine discharge of lateral feeders, collector drainage water entering the stem stream at the considered area, underground component, wedging in to the river.

3. “Growing season” - the period from 1 April to 30 September of the calendar year.

4. “Water economy and other facilities of interstate significance” - objects that are included to the Register as agreed upon by the Parties.

5. “Development of large areas of irrigated land” - development of new lands beyond the areas and limits of water division, provided in the updated Scheme of Syr-Darya (1984).

6. “Inter-growing season” - the period from 1 October of current year to 31 March of next year.

7. “Naryn-Syr-Darya cascade reservoirs” - a set of reservoirs with multiple-year and seasonal regulation in the basin of Syr-Darya River - Toktogulskoye, Andizhanskoye, Kairakkumskoye, Charvakskoe and Shardarinskoe.

8. “Regulating release” - the minimum flow of water in a water object, capable of preservation of aquatic ecosystems, without causing it any significant harm.

9. “Energy” Coordinating Control Center - the organization for coordination and control of technological activities of Central Asian and southern Kazakhstan power systems.

Article 2. Subject of Agreement

The subject of this Agreement is to govern the interstate relations in usage of water and energy resources of the Syr-Darya River Basin.

Article 3. Purpose of the Agreement

3.1. To ensure effective management and use of water and energy resources of Syr-Darya river.
3.2. To ensure agreed regimes of Naryn-Syr-Darya cascade reservoirs operation through long-term planning and multiple-year flow regulation, and annual coordination of water releases regimes, production and transmission of electricity as compensation on a contractual basis.

PART 1. GENERAL PROVISIONS

Article 4. Principles of shared water and energy resources usage

4.1. In process of use of water and energy resources of the basin, the Parties will be guided by the following principles:

a) Equitable and reasonable utilization of water and energy resources of the Basin by each Party.

b) Ensuring prevention, limitation and reduction of negative impacts of interstate water sources through required coordinated actions (technical, legal, administrative and economic).

c) Compliance with the agreed regimes of water and power facilities operation, water-withdrawal limits, observance of national regulatory requirements for water quality and other environmental requirements in order to preserve Syr-Darya River in its entirety as a natural object.

d) Prompt notification about emergencies and adaptation of comprehensive measures to prevent, mitigate and eliminate harmful effects.

Article 5. Volume and accounting of water resources of the Basin

5.1. The Parties acknowledge that the volume of annual allocated water resources of Syr-Darya River Basin within a water-economic year should be consistent with the Correction Note to the "Elaborated scheme of complex use and protection of water resources of the Syr-Darya River Basin" (1984).

5.2. Accounting for runoff shall be performed at the river hydroposts, measurements at which shall be performed by authorized bodies of the Parties.

Article 6. Distribution of water resources

6.1. Prior to approval of any new water distribution strategy in the basin, distribution of water withdrawal limits of the Parties for a water-economic year from the stem Syr-Darya river (Appendix 1) and its major feeders, including the River of Chirchik, shall be performed on the basis of Correction Note to the "Elaborated scheme of complex use and protection of water resources of the Syr-Darya River Basin", approved with protocol number 413 of the Scientific and Technical Council under the Ministry of Land Reclamation and Water Resources of the USSR of 29 February 1984, for a period of 5 years and shall be automatically renewed for the next five years, if none of the Parties, not later than 6 months in advance, have submitted a written notice of its cancellation.

6.2. Approval of water withdrawal limits separately for inter-growing season and for the growing season, taking into account the protection of the environment of Lower Syr-Darya, regulating releases and discharges of water into Aral Sea shall be performed by the Interstate Commission for Water Coordination of Central Asia (ICWC), and execution – by "Syr-Darya" BWA.

Article 7. Releases from Toktogulskoye reservoir

7.1. Parties acknowledge the following hydrological indicators of water content for Naryn River in the cross-section of Toktogulskoye Reservoir:

- Mean annual flow (normal flow) - 11.9 billion m^3 per year
- Shallow year - 8.9 billion m^3 per year
- Abounding year - 14.9 billion m^3 per year.

7.2. The parties acknowledge that releases from Toktogulskoye water reservoir in the multiple-year regime shall be performed, depending on hydrological conditions of a year, based on long-term planning of runoff regime regulation.

Article 8. Maintenance mechanism for water and energy regimes of the Naryn-Syrdarya cascade reservoirs

8.1. The Parties shall annually coordinate and decide on the volume of water releases, production and transmission of electricity and compensation supplies of energy resources.

8.2. Electricity additionally produced by Naryn HPPs cascade, in excess of the needs of the Kyrgyz Republic, as a result of agreed water releases from Toktogulskoye water reservoir, during the vegetation period, shall be transferred to the Republic of Kazakhstan and the Republic of Uzbekistan on a contractual basis. Kyrgyz Republic may supply of electricity produced to third countries, if agreed by the Parties hereto.

8.3. In order to ensure consistent regimes of Kairakkumskoye water reservoir, the supply of electricity from the Republic of Tajikistan to the Republic of Uzbekistan shall be carried out on a contractual basis.

8.4. Electricity produced under paragraph 8.2, shall be supplied on a contractual basis to the Republic of Kazakhstan and to the Republic of Uzbekistan in equal shares, with possible adjustments as may be agreed upon by the Parties.

8.5. During the inter-growing season, in order to ensure consistent water releases from the Toktogulskoye water reservoir, which will reduce the energy efficiency of Naryn HPPs cascade, the Republic of Kazakhstan and the Republic of Uzbekistan shall cover the corresponding deficit of energy resources to the Kyrgyz Republic on a contractual basis.

8.6. During the growing season, the Republic of Tajikistan and the Republic of Uzbekistan shall ensure the agreed timely passage of the volumes of water required to the corresponding downstream users.

8.7. In order to prepare to the start the inter-growing season, the Parties shall ensure the emptying of Kairakkumskoye and Shardarinskoye reservoirs to agreed levels.

8.8. Any changes to the approved regimes shall be approved by all Parties.

8.9. During the years of average and above average water content and under a threat of an emergency Shardarinskoye reservoir and downstream Syr-Darya River, due to high inflows, water discharges shall be made to Aidar-Arnasaiskoye lowland. Volumes and rates of discharges shall be agreed between the Republic of Kazakhstan and the Republic of Uzbekistan.

8.10.The Parties shall ensure, through multilateral and bilateral agreements:

- Multiple-year regulation of Naryn river runoff by Toktogulskoye reservoir on the basis of long-term planning of the regime and its enforcement;
- Seasonal regulation of the runoff by Kairakkumskoye reservoir.

8.11.Regimes and volumes of releases from the reservoirs and corresponding supply of electricity, material and technical and fuel resources required, shall be agreed by the national and regional water and energy organizations and shall be formalized by the protocols of the Parties.

8.12. The Republic of Uzbekistan shall provide a flow of electricity to the Republic of Tajikistan during the inter-growing season on a contractual basis.

8.13. The Parties shall develop mutually acceptable methods of compensation for costs and damages associated with the use of water and energy resources of the Basin.

8.14. Supplies of fuel and energy resources to the Kyrgyz Republic and to the Republic of Tajikistan may be performed from countries outside the Agreement.

Article 9. Joint review and long-term development

The Parties shall jointly consider the following issues:

- *- Construction of new hydropower facilities and reservoirs of multiple-year and seasonal regulation in the region, as well as* (Tajikistan and Kyrgyzstan Parties propose deletion of this item) the development of large areas of irrigated lands;
- economic mechanisms in the field of water relations between the Parties;
- ensuring the safe operation of hydraulic structures;
- efficient use of water resources and energy on the basis of water and energy conservation technologies;
- reducing the dumping of polluted water to the water objects of the basin;
- runoff formation zone protection and development;
- improving the water resources management system for the basin
- information exchange.

Article 10. Operation

The Parties agree that operation, maintenance and reconstruction of water and hydroelectric facilities of interstate significance shall be carried out in accordance with the balance belonging of the object, bearing in mind the provisions of the article.

Article 11. Funding

11.1. Costs incurred by each Party hereto for maintenance of water facilities of interstate water distribution shall be distributed among Parties in proportion to the volume of water supplied.

11.2. Costs of operation of reservoirs, taking into account the accumulation of water and hydropower facilities of interstate significance, shall be born by the owning Party, under conditions of compensation by the participants, according to items 8.2., 8.3., 8.4., 8.5 and 8.10 of this Agreement.

11.3. Each Party shall take measures to fulfill their obligations before each of the other Party through budgetary allocations, provision of government guarantees, credit lines, depositing money, and in other forms.

Article 12. Benefits

12.1. The Parties agree not to apply custom duties and charges to the supplies of energy, material and technical resources, tools and equipment for maintenance needs and for modernization of water and hydropower facilities and associated works and services, carried out under this Agreement.

12.2. The Parties have agreed to provide the necessary conditions for the supply and the passage across the territory of the Syrdarya River Basin States, of machinery, equipment, devices, spare parts, material and technical resources and other goods required for the implementation of the provisions of this Agreement

Article 13. Liability of Parties

13.1.Parties shall be liable for any failure or improper implementation of the provisions of this Agreement, except for force-majeure cases.

PART II. PROCEDURAL OBLIGATIONS

Article 14. Information exchange

14.1. The Parties shall exchange data and information authorized by national legislation, of hydrological, meteorological and ecological nature, including the situation of the watercourse, as well as related forecasts.

14.2. The Parties shall exchange information concerning implementation of the provisions of this Agreement not less than twice a year, at meetings of ICWC and the Energy Coordinating Council for the Joint Power System of Central Asia and southern Kazakhstan.

Article 15. Notifications and consultations

15.1.The Parties hereto shall notify each other in writing on all planned long-term measures that may affect the regime, quantity and quality of water.

15.2.

15.3.

15.4.

15.5.In the event of natural disasters and emergencies, based on public health and public safety care or other equally important interests, any Party may proceed immediately to implement urgent measures.

15.6.The Parties shall promptly notify all potentially concerned Parties and regional organizations of any emergency water situation, which may present a threat to the Parties.

A detailed procedure for notification, consultation and concerted actions on all items of Article 9 and Article 15 shall be developed by the Parties.

Article 16. Enforcement Mechanisms

16.3. Management of Syr Darya River and its feeders' water resources: the Naryn above Uchkurganskaya GES, Karadarya above the cross-section of Andijankoye reservoir and Chirchik above the cross-section of Charvakskiy hydrosystem, shall be performed by national water agencies.

16.4. Annual limits for the distribution of water resources shall be developed by the BWAs in accordance with the hydrometeorological services' forecasts and proposals of the Parties, and shall be submitted to the ICWC separately for the Growing and the Inter-Growing Seasons. Approved limits shall be the basis of the annual regimes for release of water from reservoirs, as developed by the BWAs and "Energy" CCC, and shall be approved by the national water and energy agencies in order to link the interests of the Parties to Articles 5, 6 and 7 of this Agreement and to ensure their execution.

16.5.The annual release regimes, developed by the ICWC and agreed with the energy agencies of the Parties for the Growing and the Inter-Growing periods, shall enter into force after the signing of multilateral protocols.

16.6.In order to maintain and operate the water and hydroelectric facilities of interstate significance, the Parties shall prepare and provide a list of border crossings and movement of regional and national water and energy agencies' workers within the territory of the basin, as well as to create conditions for the smooth performance of the functions in accordance with this Agreement.

Article 17. Disputes settlement

17.1. Disputes and disagreements between the Parties shall be resolved by negotiation and mutual consultation.

17.2. Should the Parties fail to reach an agreement through negotiations and consultations concerning the subject of their dispute, involving non-performance or improper performance of the provisions of this Agreement, such disputes shall be brought up at meetings of ICWC and IES ECO for Central Asia and southern Kazakhstan.

17.3. Should the Parties fail to reach an agreement through negotiations and consultations concerning the subject of their dispute, involving non-performance or improper performance of the provisions of this Agreement, the Parties shall establish an Investigation Commission.

17.4. Procedure for handling disputes, establishment and functioning of an Investigation Commission, as well as establishing procedures for liability for failure or improper performance of this Agreement, shall be developed by the ICWC and IES ECO for Central Asia and southern Kazakhstan.

Article 18. Changes and amendments

With the approval of the Parties hereto, this Agreement may be changed and amended, and such modifications shall be formalized with separate protocols and shall become an integral part of this Agreement.

Article 19. Final provisions

19.1.This Agreement shall enter into force on the date of receipt by the Depositary of the last notification on the implementation of the signatory Parties of necessary domestic procedures, and shall be valid for 5 years and automatically extended for subsequent five-year period, unless any one of the parties would no later than 6 months in advance submit a written notice of its dissolution.

19.2.By entering of this Agreement into force, the Agreement between the Government of the Republic of Kazakhstan, Government of Kyrgyz Republic, and the Government of the Republic of Uzbekistan concerning "the Use of Hydropower Resources of Syr-Darya River Basin", singed on 17 March 1998 (Bishkek), shall be terminated

19.3.Depositary of this Agreement shall be the Executive Committee of IFAS.

19.4.This Agreement is executed in the City of "______________" on "___" ___________ 200__, in one original in Russian language.

19.5.The original Agreement shall be kept with the Depositary, who shall transmit to each signatory State a notarized copy of this Agreement.