Climate changes - is good or evil for the water sector?

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Since the origin of life, different climatic changes took place on the planet Earth, with considerable fluctuations from global warming towards cold spells and vice versa. Ice Ages, in certain periods of Earth's history, sea ice or glaciers have covered a significant portion of the planet's surface, were changing into the periods of global warming that were lasting millions of years. Because of climate changes, flora and fauna were subjected to considerable transformations. Some species of animals and plants disappeared and others have appeared; some civilizations vanished completely.

Mankind, living on Earth for many thousands of years has never was able to influence on weather events. While these events exert considerable impacts on the human beings and communities as far as, first of all, they affect food supply, living conditions in cities and rural areas and access to safe water and energy.

More than 400 million people living in arid, semi-arid and subtropical regions, often overpopulated and economically underdeveloped, are subjected to a serious risk of climatic changes and follow-up effects of political, economic and social instability. Climate changes can become the trials and tribulations for some countries. The whole regions where there is resource deficits and capacities necessary for rapid adaptation to more severe conditions, will be subject to grave consequences of climate changes: hurricanes, floods, and droughts.

It is necessary to note that the future weather conditions or specific elements of sudden climate changes cannot be predicted with a high accuracy. However, studying the retrospective of climate changes provides some useful guidelines. At present, the task of limiting dangerous anthropogenic interference with the climate system is quite topical for policy-makers.

Scientists from all over the world recognize that global warming is already a reality. The UN Intergovernmental Panel on Climate Change (IPCC) concluded that human economic activities (an anthropogenic factor) changes our climate system and will continue to impact on it in the future.

The Earth's surface temperature has risen over the past millennium and it would naturally affect physical and biological systems. Scientists from all over the world recognize that global warming causes gradual changes such as raising global mean sea level, shift in the climatic zones due to rising temperature, and the precipitation patterns. The climate change can also result in increasing the frequency and scale of extreme weather events such as hurricanes, floods, and droughts.

Tracking the history of century-long climatic conditions allows to note that the periods of global warming changes into the periods of global cooling. Since 14th century, the North-Atlantic region had gone through a cold spell that lasted until the mid of 19th century. This cold spell could be caused by a substantial slowdown of the ocean conveyance system, although the opinion that reduced amount of solar radiation reached the earth's surface and/or global tectonic events could cause changes in the ocean system is more widespread. This period that is often called as the Little Ice Age, lasted since 1300 until 1850, resulting in severe winters and sudden climatic shifts and strongly affected the agricultural, economic and political situations in Europe. After that, the global warming has started, which has lasted over 20th century and continues at the beginning of 21st century. As a result, strong positive climate feedback[1] (Figure 6.4) speeds up the rates of annual warming from 0.2 Fahrenheit degree (0.11 ^{o}C) up to 0.4 Fahrenheit degree (0.22 ^{o}C), and finally up to 0.5 Fahrenheit degree (0.28 ^{o}C) in some areas.

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[1] An interaction mechanism between processes in the *climate system* is called a climate feedback, when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it

With heating up the earth's surface, the hydrological cycle (evaporation, precipitation, and surface runoff) speeds up the rise of temperature. By far the most abundant greenhouse gas is water vapor, which reaches the atmosphere through evaporation from oceans, lakes, and rivers, and intercepts additional heat flows and increases the mean temperature near the Earth's surface. With increasing evaporation, a rise of the Earth's near surface temperature also takes place resulting in drying up of forests and grasslands. Due to perishing and cutting trees, forests absorb carbon dioxide to lesser extent leading to higher rates of rise surface temperature as well as due to strong and uncontrollable forest fires. Furthermore, higher temperatures cause melting of snow cover in mountains, on open fields, high-latitude tundra areas and permafrost soils in north zones. When soil adsorbs solar radiation and its reflection power is decreasing the surface temperatures are rising much faster.

Since the processes of climate change is going on all over, one can say with certainty that these changes are of the global scale and according to the forecasts of scientists will last up to 2010.

The rates and duration of global warming that are observed during the 20th century are unprecedented over the last millennium. An increase in maximum temperatures, number of hot days and heat indicators is observed almost over all continents in second half of the 20th century. It is expected that trends of mean surface temperature rise will be kept, and the forecasted rise will vary from 1.4 to 5.8 °C.

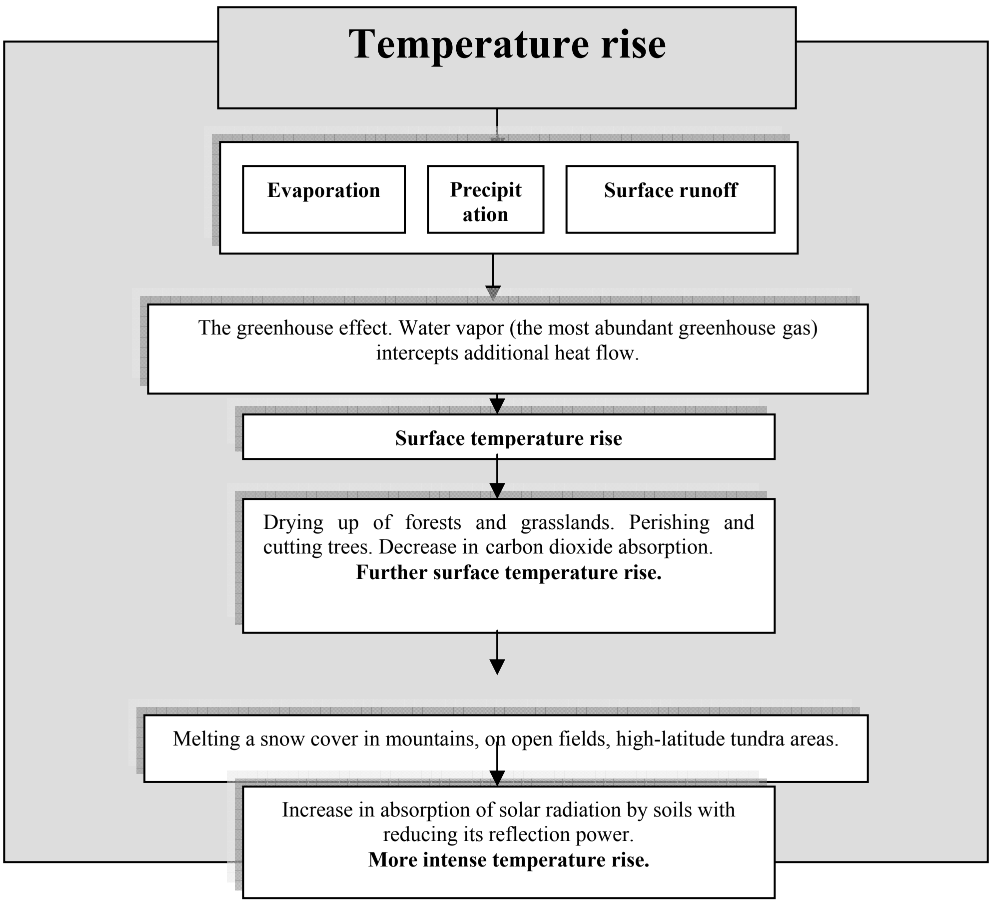


Figure 6.4 A Framework of Climatic Feedback: UN Intergovernmental Expert Panel on Climate Changes

More and more evidences that regional climate changes resulted in various transformations of physical and biological systems in most of regions in the world. They include reducing of glacial areas, thawing of permafrost soils, changes in frequency and intensity of precipitation, shifts in the dates of the beginning and end of the growing season, earlier plant flowering and emergence of insects, as well as shifts in plant and animals ranges in response to climate changes.

Central Asian countries, as members of the world community, have also experienced difficulties caused by climate changes [57]. Effects of joint influence of anthropogenic factor and climate changes that resulted in the Aral Sea disaster are especially visible in the Central Asian region.

The first meteorological observations over the territory of Uzbekistan were started more than 100 years ago. At present, there are 87 meteorological stations, 94 gauging posts, and 120 river flow measurement stations. 18 of them were included into the Global Hydrological Observation System, and 3 into the Global Climate Observation System. Purposeful research on climate changes in Central Asia were initiated in the 1980s.

Studying of climate trends using the series of instrumental measurements has shown that, at present, changes of different components of the climate system are being observed. Positive trends prevail in the temperature series, and the tendency of warming is found both during the cold six-month period and the warm six-month period.

For obtaining an objective assessment of climate changes over the territory, the SANIGMI specialists have selected 50 weather stations having series of observations since 1931 that are located in various conditions from the point of view of anthropogenic impacts on the climate and in different physical and geographical conditions. Thus, there was the opportunity to analyze variability of the mean values that were computed for two basic 30-year series of observations (1931 to 1960 and 1961 to 1990).

Air temperature. Analysis of mean values denotes a significant changes in the directions of warming up. The most significant warming over the territory was observed in April, June, November, and December. In these months, a significant rise of mean monthly air temperature was observed at most weather stations (from 50.2% to 92.3%). At the same time, a significant decrease in mean values was observed less frequently (from 7.7% to 19.8%), mainly in autumn months. Thus, even based on the analysis of the historical series of mean monthly temperatures, it is possible to conclude that statistically significant warming is being observed over the considered territory. The standard deviations of mean monthly temperatures vary to a little degree due to a high natural variability of air temperatures.

Assessment of changes in maximum air temperatures has revealed tendencies of their increase over most of months. It is of interest to note that in summer and autumn, the tendency of minimum air temperatures rise is more visible than maximum ones; at the same time, lowering of maximum air temperatures was observed at rather considerable number of weather stations in summer. Influence of the Aral Sea on the pattern of changes in minimum air temperatures (in November) is observed. This becomes apparent in lower rates of minimum air temperature rise over the area in the vicinity of the Aral Sea due to the effect of aridization (reducing of humidity in the zone of exposed sea bed) that causes widening the range of daily air temperature fluctuations. This case shows that impacts of lowering the sea level and drying up of an exposed seabed on the microclimate of this region during certain months are already visible through changes of the climatic norms.

The areas with decreasing maximum air temperatures that are localized by the irrigation districts (Golodnaya Steppe, Karshi Steppe, Fergana Valley, Surkhandarya Valley). The maximum air temperature in these areas has decreased by more than 1°C compared to the natural variability of maximum air temperatures and these regions distinctly stand out. Observed data over the period of 1991 to 2000 shows that the annual air temperature over this region continues to rise. During the last decade, already winter months have contributed, to a greater extent, to the general picture of warming. For example, the mean 10-year air temperature over the winter period was higher than the base value over the whole area, and in some districts, excess amounted to 1.2-1.5 °C. Observations in the mountain river basins confirms the sustained trends of decreasing transient snow reserves. Degrading glaciers and reduction of their area also takes place; and rise of air temperature by 1-2 °C will intensify this degradation process. Over the period of 1957 to 1980, glaciers in the Aral Sea basin have lost about 115.5 km3 of ice (about 104 km3 of water) or almost 20% of ice reserves as of 1957 (a base level). By the beginning of 2000, the ice losses made up additional 14% of ice reserves as of 1957. According to forecasts, by 2020-2025, the glaciers will lose additionally not less than 10% of the initial volume (of the year 1957) [58].

None of climatic scenarios developed according to the methodology suggested by the UN Intergovernmental Panel Climate Change show an increase in water reserves in the region in the future. In contrast, the decrease in water reserves by 3% to 40% was predicted based on simulations using different models. Water deficit continues to grow while reducing available water resources, and increasing water consumption for crops cultivation. Table 6.2 shows the water resources changes found in Chirchik-Akhangaran basin using assessments (two climatic models **"ECHAM4" and "HadCM2"** were used).

Table 6. 2 Comparison of Two Scenarios for Developing Water Resources in the Chirchik-Akhangaran Basin

Year	Total available resources		Water demand	
	BAU/ECHAM4	OPT/ HadCM2	BAU/ECHAM	OPT/ HadCM2
2006	7,908	8,019	4,778	4,968
2011	8,841	9,404	4,714	5,404
2016	7,263	7,540	4,714	5,188
2021	6,662	6,944	5,299	5,958
2024	5,154	5,871	5,362	6,270

Total available water resources in the basin will decrease during next 10 years by 8% and 6% respectively according to the two scenarios of economic development ("BAU – business as usual" and "OPT – optimistic"). By 2024, the decrease in available water resources will reach 35% and 28% respectively according to "BAU" and "OPT", at the same time, water demands will increase by 12% and 26%. Different approaches and scenarios can be used to assess impacts of expected global warming on water resources.

The mountainous river flow model developed by the SANIGMI allows take into account the basic natural laws of runoff formation and evaluating impacts of climate changes on river flows, snow cover, and glaciers in the scale of separate river basins. In the region, rivers react to the warming process in different ways, due to different drainage patterns of their watersheds. Discharge of rivers fed by snowmelt is faster decreasing with a temperature rise. Rivers fed mainly by glaciers are more "inertial" relative to a temperature rise, since the increase in air temperature that intensifies melting of high-altitude snow covers and glaciers is partly compensated at the expense of specific characteristics of watersheds. Nevertheless, due to glaciers' degradation, which is in progress and will be enhanced owing to an air temperature rise, in the second case, decrease in river flows will intensify. This is likely to happen even more actively in the future.

Adaptation of the water sector to climate change

The modern civilization may either adapt to current and future weather conditions and climate changes or mitigate their negative impacts in any feasible way. At present, the task of limiting dangerous anthropogenic interference with the climate system is quite topical for policy-makers.

Studies of climate trends in the Aral Sea basin testifies the changes in different components of the climate system, positive trends in the temperature series over the cold and the warm six-month periods, increase in the atmospheric concentration of CO_2 and the greenhouse effect. All these factors affect the sustainable development of the region, and, first of all, the agricultural sector where, at present, 70 to 90% of population are engaged. Impacts of above factors on crop productivity are given in Table 6.3.

Studies of the present situation, correct assessment of "bottlenecks" in social and economic development and inter-state policy in the region, as well as developing appropriate measures for desertification control and mitigating of consequences of drought events, allows to withstand adverse effects of the climate change.

Table 6. 3. Impacts of Climate Factors on Agricultural Production in Central Asia

Indicator	Affects	
Air temperature	Increased duration of the growing season;	+
	Earlier date of sowing	+
	Conditions suitable for germination, advancing phenological phases and growth	±
	Extremely high temperatures impede physiological processes in plants	-
Air humidity	Evaporation intensity	-
	Creating conditions for moisture and heat exchange necessary for each specific crop	+
Precipitation	Soil moisture and air humidity create natural wet conditions necessary for crop germination	+
	Storms can be a hinder for germination and agricultural works	-
Temperature, humidity and precipitation	Forming crop evapotranspiration as a whole	+
	Affect salinization	-
Atmospheric concentration of CO_2	Affecting the photosynthesis intensity and gas exchange	-
	Forming biomass and crop productivity	+

Most of irrigated lands in the Aral Sea basin belong to subtropical, semi-desert, desert and piedmont zones. The agro-climatic potential allows cultivating many subtropical plants including cotton and plants belonging to the temperate zone. However, the Aral Sea basin being the most northern zone where cotton is cultivated, it does not have sufficiently sustainable conditions for harvesting guaranteed cotton yields everywhere within the basin. Deteriorating soil conditions and socio-economic factors are a key cause of the loss of land productivity, especially over the recent period of time. Only 52% of irrigated lands can be referred to lands with satisfactory soil and hydro-geological conditions. Irrigated areas with medium and heavy saline soils are increasing. In the region, agricultural land consists of irrigated land, rain-fed land and natural grazing areas. A total area under irrigation amounts to 7.95 million ha. The crop pattern is given in Figure 6.5.

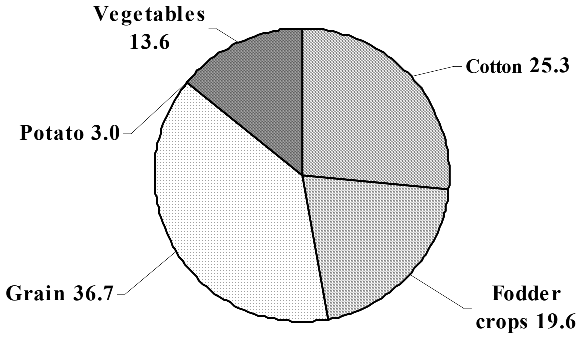


Figure 6. 5 The Sown Area Pattern in the Aral Sea 2005)

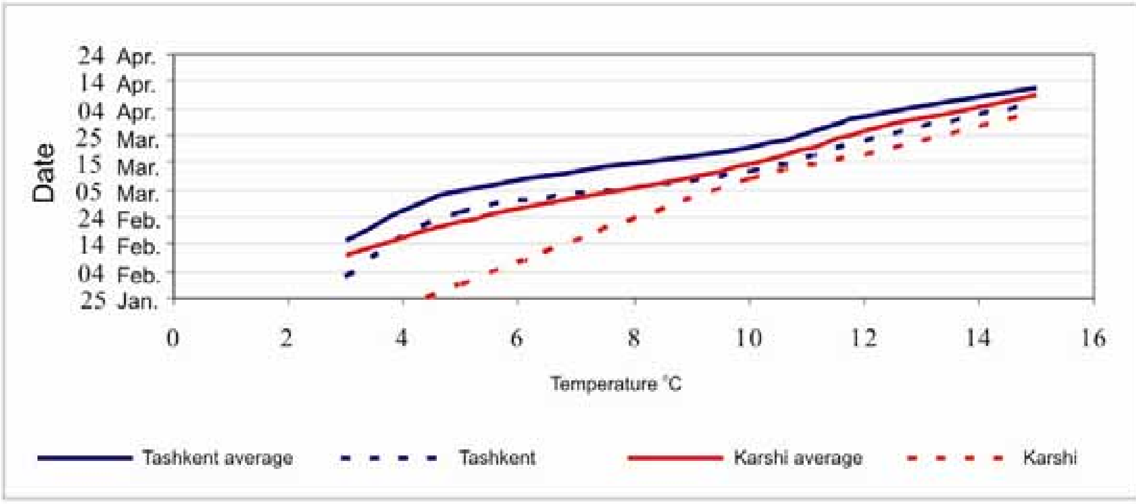


Figure 6. 6 Crossing over the Limits Established for Air Temperatures

(Cp – present conditions, 1 – under climate changes: using data of weather stations in Tashkent and Kashkadarya provinces)

Because of warming and increase in an amount of precipitation, a shift is observed in the altitudinal and latitudinal climatic zones. A border between subtropical and temperate climatic zones has shifted by 150 to 200 km northward and by 50 to 100 km between the actual rain-fed zone and the quasi-rain-fed zone. This means that the northern areas are being transformed into the territories with climatic characteristics more typical for southern areas. Figure 6.6 shows that with air temperature rise due to global warming, the limits established for air temperatures (3, 5, 10, 12, and 15 ^{o}C) in Tashkent Province are lowering up to the mean annual values in Kashkadarya Province. It means that dates of sowing various crops become earlier and, in turn, the growing season starts earlier. Thus, one can say with certainty that under changing climatic conditions, the more northern Tashkent Province gains the climatic characteristics of more southern Kashkadarya Province.

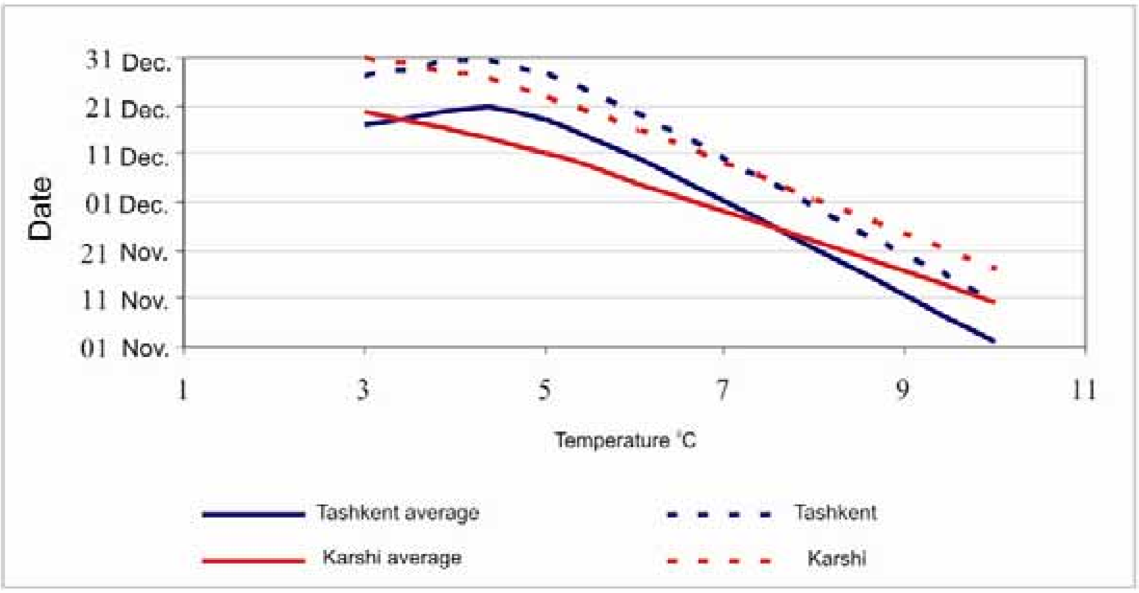
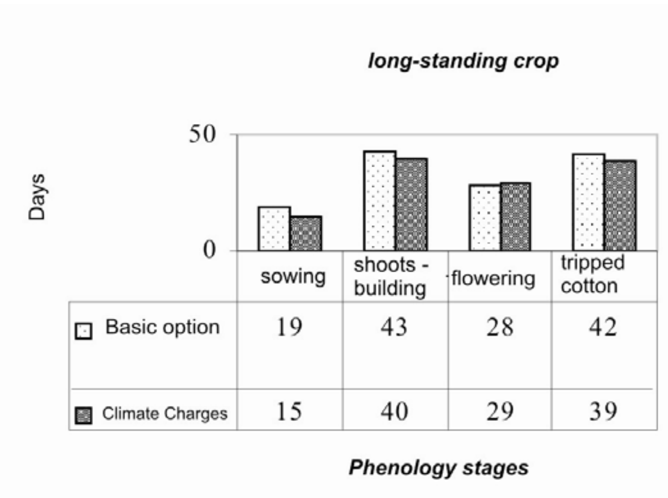


Figure 6. 7 Crossing over the Limits Established for Air Temperatures

(Cp – present conditions, 1 – under climate changes: using data of weather stations in Tashkent and Kashkadarya provinces)

Figure 6.7 shows that the autumn temperatures under crossing over the limits established for Tashkent Province due to the climate change are higher than mean annual temperatures in Kashkadarya Province. They are shifted on 7 to 17 days. This means that the growing season comes to an end later on. A difference in the dates of crossing over the temperature points of 10, 15, and 20 ^{o}C in spring and autumn amounts to 15-30 days, on average, over the whole irrigated area.



Changes in climate forced agricultural managers to revise the principles of crop cultivation practice. All the sequence of farming operations should be modified under these conditions of rising temperature, changes in air humidity and river flow pattern.

Key factor that affects the crop development rates is the thermal conditions over the growing season, which can be characterized by an average daily air temperature. Shift in the phenological phases occurs when a necessary sum of effective temperatures is provided.

Figure 6. 8 Changes in the Growing Season

As was mentioned above, a temperature rise provides more prolonged growing season, and at the same time, shifts in dates of phenological phases take place due to changed weather conditions (a duration of specific phenological phases). The length of phenological phases under usual and changed climate conditions is given in Figures 6.8 and 6.9.

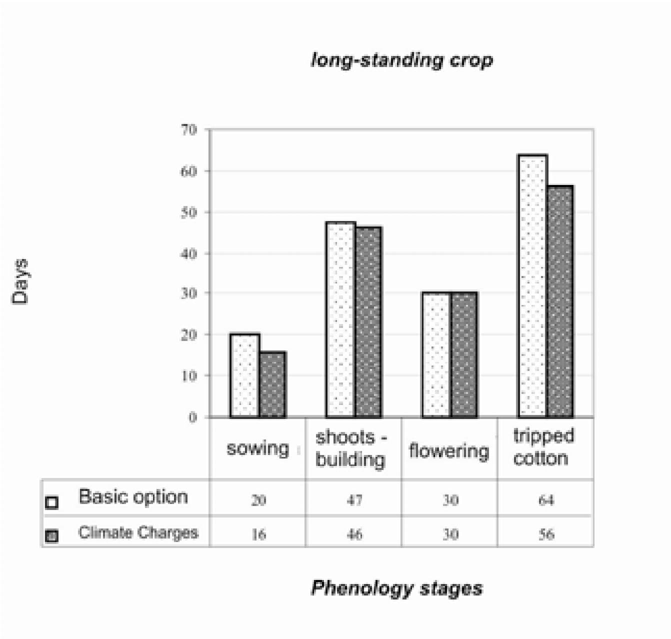


Figure 6. 9 Changes in the Growing Season

Dates of sowing are also shifted. Due to air temperature rise in spring and the increase in soil moisture, sowing operations are started earlier. Therefore, the dates of sowing that were established based on mean annual data are not acceptable under new conditions of climate change. Ignoring the current changes results in reducing of crop yields by 10 to 20% on average, since the most important period for forming yields will be affected by increased temperatures in comparison to optimal mean annual ones.

An extension of the potential growing season will allow growing 2 to 3 yields a year, with the assumption that irrigation water will be available. The rise in air temperature will cause a rise in crop water consumption by 5 to 8% according to our estimate. However, water consumption per unit agricultural output can be reduced at the expense of crop yield growth; at the same time, the effect of higher water productivity can be enhanced in the case of planting secondary crops.

Temperature rise and heightened atmospheric concentration of CO_2 can advantageously affect plant growth [13]. Under climate change conditions, the potential productivity of most crops shall increase, if *due supply of key inputs such as fertilizers, irrigation water, pesticides, etc* are done. Only rice that is especially susceptible to temperature rise is an exception to this rule. Under air temperatures higher than 32 ^{o}C and heightened atmospheric concentration of CO_2, productivity of rice is decreasing (Table 6.4).

The adverse affect of climate change is the increase in the number of days with high temperatures that can cause the water stress of plants, especially under low water availability for irrigation. The experience of food crops cultivation (water melons, maize) in the Fergana Valley and Syrdarya Province with application a polyethylene film as a mulch allowed simulating temperature rise expected, in line with some scenarios of climate change (Figure 6.10). A few variants of mulching were used (a transparent film laid over the soil surface; gallery-type film cover, and black polyethylene film cover); and their results were compared with food crop cultivations on open ground.

Table 6. 4 Trends of Crop Yields, centner/ha

Province	Cotton		Rice		Maize	
	Average over the 5-year period	Climate change	Average over the 5-year period	Climate change	Average over the 5-year period	Climate change
Karakalpakstan	14.1	15.5	19.9	17.9	10.7	12.0
Andijan	30.0	33.0	37.1	33.4	54.4	60.9
Bukhara	28.4	31.2	27.1	24.4	35.2	39.4
Kashkadarya	21.5	23.7			17.6	19.7
Namangan	25.0	27.5	20.9	18.8	41.2	46.1
Samarkand	22.7	24.9	21.6	19.5	29.1	32.6
Surkhandarya	27.0	29.7	25.3	22.8	36.9	41.3
Khorezm	26.5	29.1	40.5	36.4	37.6	42.1
Fergana	26.3	28.9	31.4	28.2	35.6	39.8
Tashkent	23.7	26.0	33.4	30.1	29.9	33.4
Syrdarya	14.4	15.9	22.9	20.6	30.8	34.4
Jizakh	15.7	17.3	15.1	13.6	19.9	22.3
Navoi	25.6	28.1	15.4	13.8	19.3	21.6

Soil temperature values at sowing and during the germination period are the most critical. Sowing of water melon was conducted at the minimum permissible temperature of 13 ^{o}C at a depth of seed lying that should be uniform over a whole field. Three days after sowing, a temperature of soil underneath a gallery-type film cover and a transparent film laid over the soil surface was 15 ^{o}C or sufficient for seed germination. A temperature of soil underneath a black polyethylene film cover was ranged from 12 ^{o}C to 10.5 ^{o}C. In the variant of using a transparent film laid over the soil surface, temperature rise resulted in earlier ripening (by 20 days) and the increased productivity (by 30%) in comparing with the “business as usual” variant.

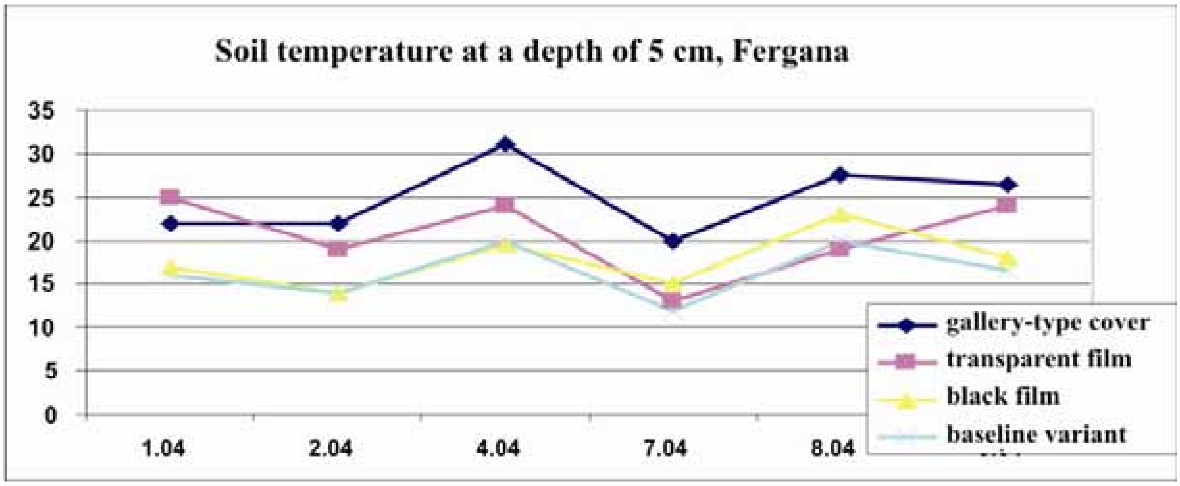


Figure 6. 10 Soil Temperature Pattern on Demonstration Fields

Adverse affects of temperature rise and extreme weather events were simulated using a gallery-type film cover when in daytime, the temperature raised up to 40 ^{o} C, causing considerable slowdown of plant development and, finally, decreasing the productivity (by 8% with compared to "business as usual" variant). It can be noted that mulching and alternate furrow irrigation allows improving the irrigation water productivity almost by 70% (Table 6.5).

Table 6.5 Increase in Irrigation Water Productivity under Maize Cultivation with Mulching by a Film

Field Irrigation system	Water supply in the growing season	% of average value	Crop yield	% of average value	Water productivity	% of average value
	m^3/ha	%	kg/ha	%	kg/m^3	%
Alternate furrow irrigation, mulching with a transparent film	725	-20	5400	35	7.4	69
Traditional furrow irrigation, mulching with a transparent film	915	1	5520	38	6.0	37
Alternate furrow irrigation, "business as usual" variant	730	-20	3400	-15	4.7	6

Traditional furrow irrigation, "business as usual" variant	907	0	4000	0	4.4	0

What conclusions can be made based on the analysis of climate change effects?

1. Climate change is an indisputable fact and it is a factor that considerably affects natural resources in the region;
2. It must be kept in mind that climate change has both advantageous and adverse affects, therefore the adaptation measures need to be developed for mitigating possible adverse affects;
3. Shifting the climatic zones southward is being observed;
4. According to all scenarios of climate changes the increase in crop water consumption in the future is predicted; and
5. Conditions for crop development and growth are changing resulting in the potentially possible extension of growing season and creating an opportunity for harvesting a few yields.