Water scarcity under global climate change: Ways of addressing them in the lower reaches of the Amu Darya River in Uzbekistan

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Abstract. The article provides an analysis of global climate change and its impact on the further development of agriculture in Uzbekistan and the problems associated with the growing shortage of irrigation water in the country. Based on the example of irrigated lands in the lower reaches of the Amu Darya, a region where there is the greatest water shortage and is highly susceptible to the negative impact of often repeated dry years, recommendations have been developed for the efficient use of water resources. Additionally, the recommendations for the effective use of water resources have been developed. In the conditions of meadow alluvial soils subject to salinization and shallow salinized groundwater level, it is proposed to use subsurface irrigation – subirrigation and drip irrigation for irrigation of the main crop grown in the Republic-cotton, while maintaining the pre-irrigation soil moisture at the level of 70-80-60% LSMC (lowest soil moisture capacity). The introduction of a science-based regime on cotton with subirrigation and drip irrigation methods provides conservation of water up to 1.596–1.757 (subirrigation) and 1.596–1.757 (drip irrigation) cbm/ha, as well as an increase in cotton yield with these methods of irrigation up to 6.3 centner/ha.

1 Introduction

In Uzbekistan, due to global climate change, the growth of the population and economic sectors, the annual increase in their need for water, the shortage of water resources increases from year to year.

The Republic of Uzbekistan is located in the Aral Sea basin, its main sources of water are the Amu Darya and Syr Darya rivers, as well as inland rivers, sai and groundwater. The average long-term annual flow of water from all sources of the Aral Sea basin is 116.2 billion cubic meters, of which 67.4 percent is formed in the Amu Darya basin, 32.6 percent – in the Syr Darya basin. The total groundwater reserve is 31.2 billion cubic meters, 47.2 percent of which is in the Amu Darya basin, 52.8 percent in the Syr Darya basin. According to the schemes for the integrated use and protection of water resources in the Amu Darya and Syr Darya basins, the average annual water withdrawal limit for the Republic of Uzbekistan is 64 billion cubic meters. At the same time, in the 1980s, the annual water consumption of the republic was within the multi-year limits, in recent years, due to global climate change and problems of transboundary water use, the average annual volume of water used is 51–53 billion cubic meters. The irrigated land area of the republic is 4.3 million hectares, on average 90–91 percent of all water resources are used in agriculture,

As a result of insufficient natural drainage and a high level of groundwater mineralization, a number of territories are prone to primary salinization. At the same time, as a result of the irrational use of water resources and the negative impact of other anthropogenic factors, secondary salinization of lands is observed in some territories (45.7 percent of the irrigated land area has a different degree of salinity).

As a result of global climate change over the past 50-60 years, the area of glaciers in Central Asia has decreased by about 30 percent.

According to forecasts, with an increase in temperature by 20C, the volume of glaciers will decrease by 50 percent, by 40C – by 78 percent. According to calculations, by 2050, a decrease in water resources in the Syr Darya basin is expected – up to 5 percent, in the Amu Darya basin – up to 15 percent. If in the period up to 2015 the total water shortage in Uzbekistan was more than 3 billion cubic meters, then by 2030 it could reach 7 billion cubic meters, and by 2050 – 15 billion cubic meters. Analyzes have shown that climate change will further exacerbate the water shortage in Uzbekistan, may lead to an increase in the duration and frequency of drought, and the formation of serious problems in meeting the needs of the economy in water resources. Over the past 15 years, per capita water availability has decreased from 3,048 cubic meters to 1,589 cubic meters [1].

The assessment and forecast of the impact of climate change on the ameliorative state of irrigated lands and water consumption of agricultural crops showed that by 2030, due to an increase in evaporation from the water

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surface by 10–15 percent, transpiration, respectively, irrigation norms, water consumption in agriculture will increase up to 20 percent [2].

Under the influence of natural factors, the yield of cotton will be 19.45–22.3 c/ha in 2050, and by 2100 it will decrease to 17.2–19.65 c/ha. In addition, an increase in the area of saline lands is predicted. Thus, under the influence of natural factors, slightly saline territories in 2050 will amount to 52.3–55.9%, and by 2100 they will decrease to 49.4–54.5%. moderately saline territories will amount to 31.2–33.4% in 2050, and by 2100 will increase to 32.4–34.6%, and highly saline territories will amount to 12.9–14.3% in 2050, and by 2100 will increase to 13.1–16% [3].

A. Rachinsky [5] recommends irrigation of cotton with a norm of 900–1200 cbm/ha, which exceeds the deficit of the root layer by 20–30%, in saline soils and ground water depth of 1–2 m in southern Khorezm. In the conditions of meadow-alluvial soils slightly saline irrigated soils of the Khorezm region for obtaining high and qualitative yields of cotton varieties "Mekhnat" it is necessary to conduct irrigation scheme 0-3-1 (the first irrigation norm of 900 cbm/ha, the subsequent 1000 cbm/ha) [6].

The best regime of pre-irrigation soil moisture for the growth, development and yield of cotton on irrigated lands of the Khorezm region is 70-80-60 % LSMC. In this mode, cotton is watered: on light mechanical soils according to the scheme 1-4-1, irrigation norms 437–825 cbm/ha, irrigation norms 3641-3676 cbm/ha; on medium loamy soils according to the scheme 1-4-0, irrigation norms 494–664 cbm/ha and irrigation norms 3090–3133 cbm/ha and on heavy mechanical soils according to the 1-3-0 scheme, with irrigation standards of 541–753 cbm/ha and irrigation standards of 2766–2786 cbm/ha a [2]. To achieve high yield of cotton of the Bukhara-6 variety on meadow soils of the Bukhara region, it is necessary to conduct 5 vegetation irrigation according to the 0-4-1 scheme, with irrigation norms of 650-1050 cbm/ha and irrigation norm of 4600 cbm/ha [7].

Their studies have shown that irrigation water losses differ with different irrigation methods and technologies: plants do not reach 10–20% of water with drip irrigation, 30–50% with sprinkling, and 50-60% with furrow irrigation [8]. Many scientists have written about the effectiveness of drip irrigation to save water, mineral fertilizers, and other resources [9, 10].

Studies have shown that the loss of irrigation water with different irrigation methods and technologies is different: 10–20% of water does not reach the plants with drip irrigation, 30–50% with sprinkling and 50–60% with furrow irrigation [11]. Many scientists wrote about the effectiveness of drip irrigation for saving water, mineral fertilizers and other resources [12, 13].

As a result of many years of research, it has been established that the drip irrigation method is a water-saving, anti-erosion method and increases the efficiency of mineral fertilizers. They recommend the use of drip irrigation primarily on lands with water deficit and with a groundwater depth of 2–3 meters [14].

The use of drip irrigation on large slopes of the terrain prevents irrigation erosion. In experiments with the use of drip irrigation of cotton on land with large slopes, they saved 45–50% of irrigation water and, due to the lack of water flow along the slope, prevented soil erosion [12]. Drip irrigation of cotton on typical gray soils of the Tashkent region provides water savings of 35.6–41.5% compared to surface irrigation. At the same time, it is necessary to maintain the pre-irrigation soil moisture at the level of 70-70-60% LSMC. The irrigation rate in these studies was 2400 cbm/ha [13].

Many scientists have dealt with the issues of subsurface irrigation – subirrigation. With this method of irrigation, the root layer of the irrigated area is moistened due to nearby fresh or slightly mineralized (in conditions of severe water scarcity) ground water. Comprehensively studied the use of plants, groundwater and concluded that the share of groundwater in total water consumption of lucerne the first year standing at a level of 1 meter is 73–80%, with a level 2 meter is 30% and at level 3 m – 11 to 22% [14].

Subirrigation is recommended for obtaining high cotton yields on meadow layered soils of the Ferghana valley. To do this, drains are closed for 1–1.5 months and artificially raise the ground water level to 1–1.5 m. At the same time, the amount of irrigation will be reduced by 1–1.5 times and the saving of river water from each hectare will be 800–1400 cbm [15]. In terms of the Zerafshan valley for irrigation of cotton way subirrigate the number of irrigations will be less than 1–1.5 times, economy of water resources will be 987–1880 cbm/ha, reduced the number of row cultivation of cotton, respectively, the consumption of fuels and lubricants, will increase, the cotton yields by creating favorable meliorative modes of soils of 1.5–7.0 t/ha will be provided with prevention of environmental pollution by agro chemicals [16]. The optimal irrigation regime and favorable reclamation conditions for the growth and development of cotton in the Bukhara region were created furthermore, when cotton is irrigated using the subirrigation method and when the pre-irrigation soil moisture is maintained at the level of 70-80-60 % LSMC. At the same time, irrigation was carried out according to the 1-2-1 scheme, with irrigation norms of 607-889 cbm/ha and irrigation norms of 2774–2839 cbm/ha [17].

2 Materials and methods

The study took place in the meadow alluvial heavy loamy soils. During the research, "methods for studying the agrophysical, agrochemical and microbiological properties of soil in cotton fields, "methods for conducting field experiments of cotton" were used, and the dispersion method of V. P. Peregudov was used for mathematical and statistical processing of the obtained data.

Field experiments on the study of the cotton irrigation regime during subirrigation and drip irrigation were conducted in the Shavat district of the Khorezm region in the Toji-Islom farm.

Field experiments on the mode of cotton irrigation with the method of irrigation subirrigation were carried out according to the scheme: 1-option: production control (furrow irrigation), 2-option: pre-irrigation soil moisture 70-80-60 % LSMC (subirrigation) and 3-option: pre-irrigation soil moisture 80-80-60 LSMC (subirrigation). The irrigation rate in the control version was determined by actual measurements, in other versions by the moisture deficit in the layer of 0–100 centimeters.

Field experiments on the mode of cotton irrigation with drip irrigation were carried out according to the scheme: 1-option: production control (furrow irrigation), 2-option: pre-irrigation soil moisture 70-80-60% LSMC (drip irrigation) and 3-option: pre-irrigation soil moisture 80-80-60 % LSMC (drip irrigation). The irrigation rate in the control version was determined by actual measurements, in other versions by the moisture deficit in the layer of 50-70-50 cm.

3 Results and Discussion

The mechanical composition of the soils of the experimental plots was determined according to the classification of N.A. Kachinsky. The mechanical composition of soils refers to heavy loam that is lightened downwards.

In the experiment on studying the mode of irrigation of cotton during subirrigation at the beginning of the growing season, the bulk density of soil in the arable layer of 0–30 cm was 1.34–1.36 g/ccbm, in the layer of 0–100 cm 1.40–1.41 g/ccbm. By the end of the growing season, due to agrotechnical work and irrigation with different methods, in the 1st control variant, an increase in bulk density by 0.03–0.04 g/ccbm was noted, in the 2nd variant by 0.01–0.03 g/ccbm and in the 3rd variant by 0.02–0.03 g/ccbm.

At the beginning of the growing season, the water permeability of soils in the experimental cotton plot for 6 hours was 853–900 cbm/ha or 0.236–0.250 mm/min. By the end of the growing season, in all variants of the experiment, soil water permeability decreased. In the 2nd variant, with the irrigation method subirrigation with a pre-irrigation soil humidity of 70-80-60% LSMC, the soil water permeability for 6 hours was 697–720 cbm/ha or 0.194–0.200 mm/min, which turned out to be 72–128 cbm/ha or 0.02–0.036 mm/min more than in the 1st control variant.

Table 1 shows the scheme, terms and norms of cotton irrigation for different irrigation methods. In the control version of the experiment, a constant high level of humidity in the active soil layer was provided due to large irrigation norms (1165–1364 cbm/ha) according to the 0-3-0 scheme, the irrigation rate of cotton was 3614–3879 cbm/ha. In the 2nd variant, cotton was watered three times, with an irrigation rate of 664–715 cbm/ha according to the 0-3-0 scheme. The irrigation rate of cotton was 2018–2122 cbm/ha, which is 1596–1757 cbm/ha less than in the control version.

The results of studies of the dynamics of groundwater showed that their level during the growing season in the control version was 137–135 cm. During subirrigation due to artificial elevation of their level and maintenance at this level in the pre-flood period due to the blocking structure on the drain was 98–156 cm (Fig. 1).

Table 1. Irrigation regime of cotton in the method of subirrigation (average years of research)

Options	Irrigation, cbm/ha				Inter- Irrigation period, day	Irrigation scheme	Irrigation rate, cbm/ha
	1	2	3	4			
1	1241–1265	1208–1297	1165–1364		25–27	0-3-0	3614–3879
2	681–709	664–715	673–705		19–22	0-3-0	2018–2122
3	585–682	636–693	650–682	634–690	16–21	1-3-0	2536–2707

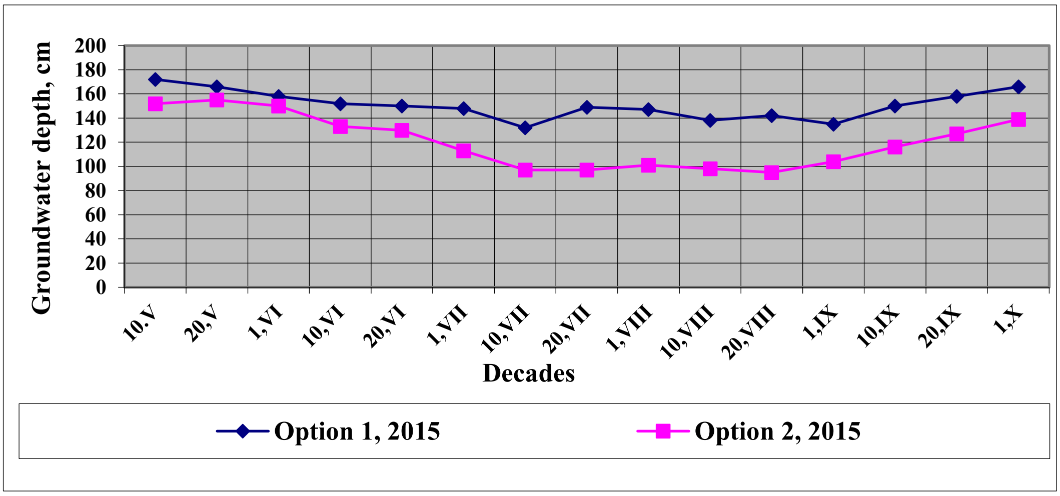

Figure 1. Dynamics of the groundwater level at the experimental site

The experiments studied the effect of the method and mode of irrigation on the salt regime of the soil of the experimental site. In the active soil layer (0–100 cm) of the control variant at the beginning of the growing season, the content of chlorine ions was 0.009–0.011%, and by the end of the growing season 0.015–0.020%, the amount of dry residue was 0.172–0.190%, by the end of the growing season 0.296–0.352%, the coefficient of seasonal salt accumulation for chlorine ions was 1.67–1.82, and for dry residue 1.72–1.85.

In the 3-variant, when subirrigation in a layer of 0–100 cm at the beginning of vegetation the amount of chlorine ions relatively to the soil mass was 0.009–0.011%, by the end of vegetation 0.014–0.018%, the amount of dry residue was 0.172–0.190% and 0.231–0.272%, respectively. The coefficient of seasonal salt accumulation for chlorine ions was 1.56–1.64, and for dry residue 1.34–1.43, which shows the effectiveness of this irrigation method.

The study of the influence of the irrigation method and regime on cotton yield showed that when maintaining pre-irrigation humidity at the level of 70-80-60% LSMC and irrigation by subirrigation, the best reclamation conditions for the development of cotton are provided and the yield is 38.0–42.8 C/ha, which is 4.2–6.3 C/ha more than in the control version (Fig. 2). In this option, the water consumption coefficient was 49.6–53.1 cbm/c.

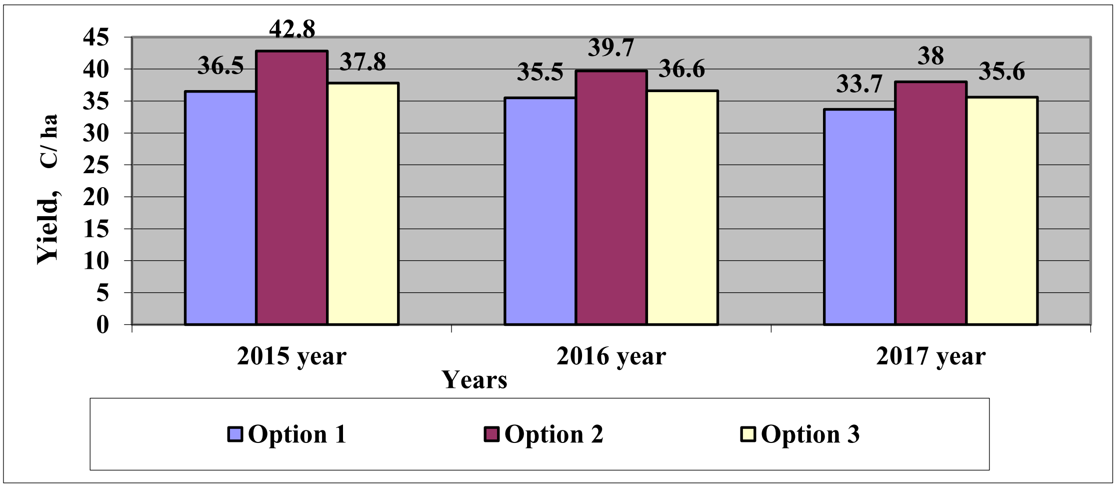

Figure 2. Cotton yield depending on the mode and method of irrigation

Based on the experience of developing a science-based cotton irrigation regime with a drip irrigation method, the volume mass of the soil of the experimental plot at the beginning of the growing season in the 0–100 cm layer was 1.39–1.40 g/ccbm. By the end of the growing season, due to agricultural work and various modes and methods of irrigation in the control version, the volume mass of the soil in the 0–100 cm layer increased by 0.04–0.05 g/ccbm. With drip irrigation (option 2), the smallest soil compaction was observed at 0.01 g/ccbm.

The water permeability of the soil of the experimental site for 6 hours was 970–984 cbm/ha or 0.269–0.273 mm/min. By the end of the growing season, in all variants of the experiment, soil water permeability decreased. In the 2nd option, with a drip irrigation method with a pre-irrigation humidity of 70-80-60% LSMC, the soil water permeability for 6 hours was 816–826 cbm/ha or 0.227–0.229 mm/min, which is 106–132 cbm/ha or 0.029–0.037 mm/min more than in the control [18].

The study of the irrigation regime of cotton under drip method of irrigation showed that in the 2nd option with drip method of irrigation pre-irrigation soil moisture of 70-80-60 % LSMC, cotton was irrigated 6 times according to the scheme 0-6-0, 436-468 irrigation norms cbm/ha and irrigation norm 2678–2698 cbm/ha, thus saving 1437–1472 cbm/ha river water in comparison with the control option (Table 2).

Table 2. Irrigation regime of cotton under drip method of irrigation (average research time)

Options	Irrigation, cbm/ha							Inter-Irrigation period, day	Irrigation scheme	Irrigation rate, cbm/ha
	1	2	3	4	5	6	7			
1	1360–1458	1370–1445	1310–1360					22–28	0-3-0	4115–4170
2	436–447	436–456	447–460	436–450	436–460	439–468		7–11	0-6-0	2678–2698
3	318–337	456–468	439–478	436–471	447–457	436–460	439–456	7–11	1-6-0	3015–3057

Table 2 represents the scheme, terms and norms of cotton irrigation with furrow and drip irrigation methods. In the control version of the experiment, a constant high level of humidity in the active soil layer was provided due to large irrigation norms (1310–1458 cbm/ha) according to the 0-3-0 scheme, the irrigation rate of cotton was 4115–4170 cbm/ha. In the 2nd option, cotton was watered six times, with an irrigation rate of 436–468 cbm/ha according to the 0-6-0 scheme. The irrigation rate of cotton was 2678–2698 cbm/ha, which is 1437–1472 cbm/ha less than in the control version [19–21].

To study the effect of irrigation regime under drip method of irrigation on the growth and development of cotton showed that in 2-variant with drip irrigation, with pre-irrigation soil moisture of 70-80-60 % LSMC, in 1st September to the growth of cotton amounted to 92.5–96,2 cm, number of sympodial branches 11,8–12,3; the number of bolls 10,6–11,0 PCs of which revealed a 3.6 to 4.2 units, which is 0.4–0.7 sympodial branches, 0.7–0.8 by 0.7 bolls and pieces of split bolls was greater than in controls [22–23].

Experiments on the effect of drip irrigation on cotton yield in the Khorezm region showed that in the first control version of the experiment, 121.6–129.1 cbm of river water was used to produce one hundredweight of cotton of the Bukhara-102 variety and 32.3–34.2 C/ha of raw cotton was obtained. In the second variant, with the drip irrigation method, with a pre-irrigation soil humidity of 70-80-60% LSMC, a smaller amount of water (66.5–70.1 cbm) was used to produce 1 centner of raw cotton and a 38.5–40.3 C/ha yield of raw cotton was obtained. This is 6.1–6.3 C/ha more than the control variant (table 3).

Table 3. Influence of the irrigation regime for drip irrigation on cotton yield (average over the years of research)

Options	Average yield, C/ha	Additional yield, relative to control, ± C/ha,	Water consumption per 1 C of raw cotton, cbm/C
1	32.3–34.2	0.0	121.6–129.1
2	38.5–40.3	+(6.1–6.3)	66.5–70.1
3	36.3–38.3	+(4.0–4.6)	78.7–83.7
E=1.10 C/ha; P=2.92%			

4 Conclusion

In connection with global climate change, the growth of the population and economic sectors, the annual increase in their demand for water, the shortage of water resources increases from year to year in Uzbekistan. Analyzes show that climate change will further exacerbate water scarcity in Uzbekistan, may lead to an increase in the duration and frequency of droughts, as in 2000, 2008, 2011, 2014 and 2018, as well as the formation of serious problems in meeting the needs of the economy in water resources.

Subirrigation – subsurface irrigation is a water-saving method of irrigation. The use of subirrigation in the irrigation of cotton on meadow alluvial soils of the Khorezm region at a depth of medium mineralized groundwater of 1–2 meters and maintaining pre-irrigation soil moisture at the level of 70-80-60% HB will provide a favorable reclamation regime of soils, increase the yield of the main crop – cotton by 4,2–6.3 c/ha and save river water by 1596–1757 cbm/ha compared to traditional furrow irrigation [24, 25].

The introduction of the drip method of irrigation of cotton on meadow alluvial soils of the Khorezm region and the maintenance of pre-irrigation soil moisture at the level of 70-80-60% HB will create the best conditions for the growth, development and productivity of cotton. Drip irrigation of cotton will ensure the yield of raw cotton at the level of 40.3 c/ha, with an irrigation rate of 2678–2698 cbm/ha, which is 6.1–6.3 c/ha more and 1437–1472 cbm/ha less compared to traditional furrow irrigation.

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