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Using the Modern Method in Determination of The Irrigation Regime of Cotton in The Republic of Karakalpakstan

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Abstract: The article presents data on cotton irrigation planning, taking into account soil and hydrogeological conditions, natural and climatic factors of the region, and the cultivated variety. The study was conducted in response to the year-on-year increase in water scarcity in the Republic, including the Republic of Karakalpakstan. Existing meteorological indicators and the FAO methodology "CropWat 8.0" program were used to plan cotton irrigation based on water demand. The scientifically based irrigation regime for cotton, developed by N.F.Bespalov based on the standard hydromodular zoning scale, according to the recommendations of scientists who conducted research in the conditions of the Republic of Karakalpakstan, provides for irrigation of cotton during the growing season in the northern zone: 3400 (IX) - 6400 (I) m3/ha and in the southern zone: 3800 (IX) - 7000 (I) m3/ha. Within the framework of FAO's " CropWat 8.0" methodology program, the cotton irrigation regime is planned using meteorological data from the region.

Keywords: Republic of Karakalpakstan, cotton, FAO methodology, "CropWat 8.0" program, soil, hydrogeology, irrigation regime, hydromodular area, irrigation rate.

Introduction: According to the forecasts made as a result of the analytical study of scientific research by scientists, by 2080 it is expected that, despite the efficient use of irrigation water, appropriate experiments will be carried out to meet the water needs of crops. The observation of water scarcity worldwide, changes in the form of precipitation, global warming of air temperature, and ensuring adequate water supply for the growing season of crops are of great importance. Currently, the observation of high temperatures, hail, extreme heat, low precipitation, and extreme weather events during drought periods have limited the possibilities of irrigated areas for growing agricultural crops. With a further increase in air temperature, river runoff decreased, as a result of which the influence on rivers and small streams became relatively significant, and the variability of runoff in all basins increased. None of the considered climate warming scenarios predict an increase in available water resources; under the conditions of the expected climate warming, an increase in total evaporation will cause an increase in water losses in irrigated areas, which will require additional water consumption. [1, 2].

Climate change leads to 10-15% more water evaporation from water surfaces, and 10-20% more water consumption due to evaporation from plants and increased irrigation rates. This leads to an increase in non-renewable water consumption by an average of 18%. Assessment of the possible increase in water consumption on irrigated lands due to climate change (water consumption of various crops, losses, changes in the melioration state of lands) is one of the urgent tasks of today. [3, 4].

The main water source of the Republic of

Karakalpakstan is the Amu Darya River, the lower part of which is located in the Aral Sea. [5, 6].

In the water management sector of the Republic of Karakalpakstan, an extremely serious and high shortage of irrigation water is observed year after year, and due to the growing demand for water for agricultural crops, including cotton, as a result of climate change, the efficient use of water in agriculture remains a priority area. Periodic data on the analysis of precipitation in the Republic of Karakalpakstan show that the amount of precipitation in the northern and southern regions for 2024 is 67-77 mm [7]. Therefore, determining the water requirements of agricultural crops, including cotton, in various climatic and soil-hydrogeological conditions of the Republic of Karakalpakstan based on the FAO methodology using the "CropWat 8.0" program is one of the urgent tasks.

METHODS

The water demand of crops was determined by the Penman-Monteth method of evapotranspiration (ET0) of individual agroecological units based on the "SropWat 8.0" program developed by FAO [8]. The research used methods of system analysis and mathematical statistics, as well as the "Methods of Conducting Field Experiments" of the Research Institute of Irrigation and Agricultural Mechanization [9].

RESULTS AND DISCUSSION

Hydromodular zoning of irrigated lands of the Republic of Karakalpakstan was carried out (Table 1). For each hydromodular region, a scientifically based irrigation regime for cotton was developed according to the "SropWat 8.0" program. Currently, developing cotton irrigation regimes and water distribution planning using modern computer programs is relevant in conditions of increasing water scarcity observed year after year [10, 11].

Table 3

Regime of cotton irrigation by hydro-modular regions in the Republic of Karakalpakstan

Hydromodular region	Number of irrigations, times	Irrigation norms, m3/ha	Seasonal irrigation rates	Irrigation timing	
				beginning	ending
Northern region					
I	8	700-1100	6400	24 V	4 IX
II	8	500-1000	6000	26 V	8 IX
III	8	600-850	5250	24 V	19 VII
IV	7	600-1000	5900	3 V	24 VIII
V	7	500-850	4900	26 IV	14 VIII
VI	7	600-800	4500	18 V	18 VIII
VII	7	600-700	4700	25 V	30 VIII
VIII	6	500-700	3550	28 V	22 VIII
IX	8	400-500	3400	31 V	26 VIII
Southern region					
I	9	700-1000	7000	24V	21VIII
II	8	650-1000	6400	24V	26VIII
III	10	600-800	6200	24V	25VIII
IV	9	700-800	6700	20V	21VIII
V	7	650-1000	5200	1VI	1IX

VI	8	650-750	5800	2VI	21VIII
VII	7	750-850	5400	2VI	23VIII
VIII	5	650-850	3600	4VI	20VIII
IX	6	650-800	3800	6VI	21VIII

In the Republic of Karakalpakstan, when developing the irrigation regime using the "CropWat 8.0" program of the Food and Agriculture Organization (FAO) methodology using meteorological indicators, the soil-hydrogeological and natural-climatic conditions of the region were taken into account.

Data on the natural and climatic conditions of the Republic of Karakalpakstan were obtained from the "Nukus" weather station and used for water use planning. Location coordinates of the "Nukus" weather station (State: Uzb 2024 Height of the station relative to the Baltic Sea: 77 m; Latitude: 42.45 °C; Length: 59.62 °V) and the required air temperature (maximum and minimum temperature), relative humidity, amount of precipitation, wind were formed (Tables 2 and 3) and fully loaded into the program and launched.

Table-2

Water consumption of cotton for the northern territory of the Republic of Karakalpakstan.

Months	Air emperature, 0C		Relative humidity, %	Wind speed, m/s	Precipitation, mm	Sunshine duration, days	ET_o mm/day
	Max	Min					
January	3,9	-3,8	74	2,4	3,2	3,6	0,76
February	9,6	-1,5	66	2,9	7,6	5,6	1,64
March	16,4	1,7	37	3,3	5,2	8,9	3,63
April	21,8	8,9	43	2,9	33,3	8,9	4,55
May	30,9	17,3	37	2,8	18,2	11,0	6,83
June	35,6	20,3	22	2,7	0,0	12,7	8,49
July	37,0	22,7	29	2,7	3,2	12,7	8,53
August	32,6	19,0	34	2,6	0,7	11,8	6,85
September	25,8	11,3	33	2,6	0,0	11,2	5,01
October	19,5	3,1	38	1,9	0,0	9,6	2,69
November	7,3	-4,7	55	2,1	3,6	6,3	1,21
December	-2,0	-12,0	72	2,2	2,0	5,7	0,50
Average	**19,9**	**6,8**	**45**	**2,6**	**77,0**	**9,0**	**4,22**

Source: Annual report of the Hydrometeorological Center.

Table-3

Water consumption of cotton for the southern territory of the Republic of Karakalpakstan.

Months	Air temperature, 0C		Relative humidity, %	Wind speed, m/s	Precipitation, mm	Sunshine duration, days	ET_o mm/day
	Max	Min					

January	4,5	-3,1	66	1,4	0,9	3,6	0,76
February	10,0	-0,6	64	1,6	7,3	5,6	1,35
March	17,0	3,3	48	1,8	5,4	8,9	2,81
April	23,2	10,2	46	1,7	7,9	8,9	4,12
May	31,3	18,2	41	2,0	29	11,0	6,11
June	36,4	21,3	30	1,7	0,0	12,7	7,31
July	37,5	24,5	30	1,8	4,2	12,7	7,45
August	33,2	19,6	36	1,7	2,0	11,8	6,05
September	26,6	12,7	41	1,8	0,0	11,2	4,34
October	19,8	4,9	46	1,7	0,0	9,6	2,55
November	7,8	-3,5	57	1,7	9,3	6,3	1,17
December	-1,2	-9,9	66	1,7	1	5,7	0,55
Average	**20,5**	**8,1**	**48**	**1,7**	**67**	**9,0**	**3,71**

Source: Data from the Hydrometeorological Service Center.

Data on the amount of evapotranspiration, precipitation, amount of useful precipitation, maximum and minimum air temperature, relative humidity, wind speed, duration of solar radiation, and radiation in the Republic of Karakalpakstan in 2024 were included in the program. Using the program, the following works were carried out, namely, the current and future level of development of the effective use of irrigation water, determining the criteria for water use in the process of reducing water supply through water conservation, the influence of irrigation water on crop yields, and the rational use of available water resources were determined.

Reference evapotranspiration was calculated using the Penman-Monteth formula (Tables 2 and 3) [8].

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma * \left(\frac{900}{T+273}\right) u_2 * (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}; \quad (1)$$

ET_o - reference evapotranspiration [mm/day-^{1}];

R_n- net radiation reaching the plant surface [MJ m-^{2} day-^{1}];

G - density of heat flow in the soil, [MJ m-^{2} day-1];

T - average daily air temperature at an altitude of 2 m above the ground level [°C];

u^2 - wind speed at an altitude of 2 m above ground level [ms-^{1}];

e_s - saturated vapor pressure [kPa];

e_a - actual pressure of actual steam[kPa];

(e_s-e_a)vapor saturation pressure deficit [kPa];

Δ - steam pressure gradient curve [kPa °C-1];

γ - psychrometric stability (constant) [kPa °C-^{1}] [8].

Solar radiation absorbed by the atmosphere and heat emitted from the earth increase the air temperature. Sensitive heating of the surrounding air provides the crop with energy and affects the evaporation rate. In sunny warm weather, water loss from evaporation is greater than in cloudy and cool weather.

As mentioned above, reference evapotranspiration was calculated using the "SropWat 8" program based on meteorological station data near the research object in the Republic of Karakalpakstan.

The irrigation regime for cotton in the Republic of Karakalpakstan is presented in Table 2. Crop coefficients were developed and adopted based on values recommended by the "Scientific Research Institute of Irrigation and Water Problems" [12]. The water demand of cotton in the Republic of Karakalpakstan, depending on the hydromodular region of the region, for the organization of irrigation during the season, in the northern zone: 3400 (IX) - 6400 (I) m3/ha, and in the southern zone: 3800 (IX) - 7000 (I) m3/ha (Table 1). In short-term crops, especially in the dry regions of the Republic of Karakalpakstan, the cotton's water demand during the growing season was high, since the indicators of the meteorological station in the area where these studies were conducted were very high and precipitation was very low. Experiments conducted in the conditions of the Republic of Karakalpakstan, as well as the "SropWat 8.0" program, presented by the international FAO methodology, were analyzed in adaptation to local conditions.

Using the "CropWat 8.0" program of the FAO methodology, seasonal irrigation norms for cotton were developed for the objects of research. Based on this, the seasonal irrigation norms recommended by Professor N.F. Bespalov for cotton cultivation and developed by scientists of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers National Research Institute were compared, and a correlation coefficient coordinate system was developed.

The correlation coefficient in cotton cultivation was R2=0,922 for the northern region and R2=0,9804 for the southern region. Each pair of values is denoted by a certain symbol, and these indicators are presented in Figures 1 and 2. It was established that the change in the coordinate axes "Y" and "X" has the following relationship (2, 3).

$$y = 0{,}6429\,X + 0{,}7152 \quad (2)$$

$$y = 0{,}6594\,X + 0{,}6452 \quad (3)$$

Using the "SropWat 8" program, an irrigation regime for cotton grown in the Republic of Karakalpakstan was developed. With the help of the program, irrigation timing, timing, and irrigation rates were determined, taking into account the cotton's water requirements for the growing season.

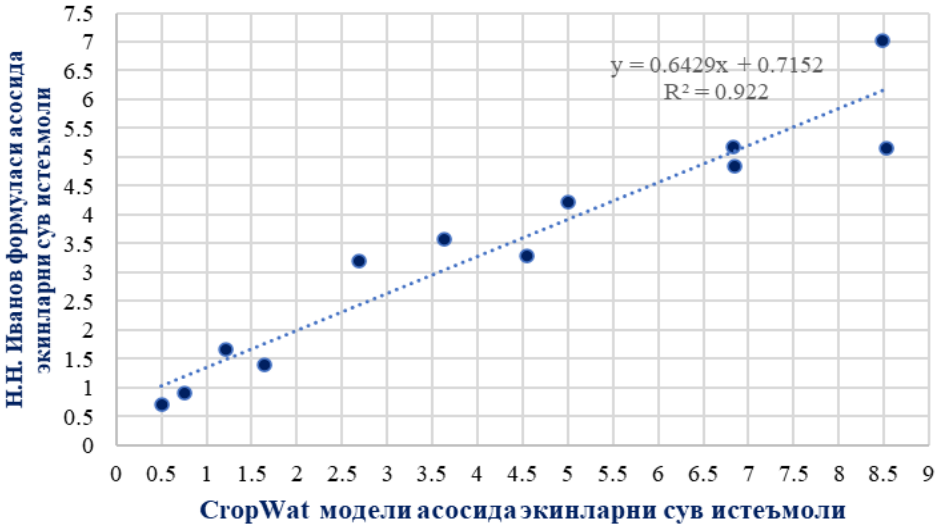

Figure 1. Coefficient of correlation of crop water consumption in the northern region

Figure 2. Correlation coefficient of water consumption of crops for the southern region

CONCLUSION

1. Using the "CropWat 8.0" program, reference evapotranspiration was determined for the research object.

2. Using the FAO CropWat 8.0 program, a scientifically based irrigation regime for cotton grown in the southern and northern regions of the Republic of Karakalpakstan has been developed.

3. It was established that the correlation coefficient of the seasonal irrigation rate of cotton for the hydromodular regions of the Republic of Karakalpakstan is R2=0,922 for the northern zone and R2=0,9804 for the southern zone.

4. Seasonal irrigation norms for cotton in the Republic of Karakalpakstan by hydromodular regions were 3300-5900 m3 per hectare.

5. According to the hydromodular regions, the irrigation rate of cotton in the northern zone was 500-1100 m3 (netto) and the number of irrigations was 6-8, while in the southern zone it was 600-1000 m3 (netto) and the number of irrigations was 6-10.

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