Development of scientific-based irrigation systems on hydromodule districts of ghoza in irrigated areas of bukhara region based on computer technologies

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Abstract. In this article, due to year-by-year global climate change and the increase in water shortage, the water demand for cotton in the Bukhara region was developed based on FAO methodology, i.e., CropWat 8.0 model program, taking into account soil-hydrogeological conditions the results of scientific research are presented. Water-saving, scientifically based irrigation procedures for cotton irrigation were developed according to the generally accepted scale of hydromodular regions N.F. Bespalov. The seasonal irrigation norms of cotton in the Bukhara region by hydromodule regions were 3900 (VIII) - 7200 (I) m^3/ha.

1 Introduction

According to the analysis of the Hydrometeorological Service Center of the Republic of Uzbekistan, water resources will remain at their current level until 2030. With the further increase in air temperature, river flows will decrease, the effect of climate warming on the rivers and small streams of the Amudarya basin will be relatively significant, and the flow variability will increase in all basins. None of the considered climate scenarios for climate warming predict an increase in available water resources, the increase in total evapotranspiration under the conditions of expected climate warming will increase the loss of water from irrigated areas, which will require additional water consumption [1].

Climate change will cause 10-15% more water evaporation from water surfaces and 10-20% more water use due to increased plant transpiration and irrigation rates. This leads to an average 18% increase in non-renewable water consumption. Assessment of the possible increase in water consumption in irrigated lands due to changes in climate conditions (water consumption of various crops, losses, and changes in land reclamation) is an urgent problem today [2].

The Republic of Uzbekistan is located in the Aral Sea basin. Its main water source is the Amudarya and Syrdarya rivers, internal rivers and streams, and underground water. The average long-term water flow of all sources in the Aral Sea basin is 114.4 billion m^3, of

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which 78.34 m^3 is formed in the Amudarya basin and 36.06 m^3 in the Syrdarya basin. The total underground water reserve is 31.2 billion m^3; 47.2% of it belongs to the Amudarya basin and 52.8% to the Syrdarya basin. Following the schemes of integrated use of water resources and their protection of the "Amudarya" and "Syrdarya" basins, the average multi-year water intake limit for the Republic of Uzbekistan is 64 billion m^3. Still, in recent years, due to global climate change, as well as the problems of using water resources of transboundary rivers, the average annual amount of water used is 51-53 billion m^3, on average 90-91% of the total water resources are used in agriculture, 4.5% in the communal household sector, 1.4% in industry, 1.2% in fisheries, 0, 5 percent is used in heat energy, and 1 percent is used in other sectors of the economy [3, 4].

In our Republic, there is a serious shortage of irrigation water for agriculture and water management, and as a result of climate change, the demand for water for agricultural crops is increasing, so efficient use of water in agriculture is a priority. Periodic data on precipitation analysis in the Bukhara region show that the annual amount of precipitation is 140-145 mm. Uneven distribution and, low amount of precipitation, low water holding capacity of soils are the main causes of crop stress [5, 6]. Therefore, it is important to determine the water needs of agricultural crops in our country's different climatic and soil-hydrogeological conditions using the CropWat 8.0 model based on the FAO methodology.

2 Methods

The water demand of crops was determined based on the SropWat 8.0 program developed by FAO. Evapotranspiration (ET_0) of individual agroecological units was determined according to the Penman Monteth method [7]. Methods of systematic analysis and mathematical statistics, as well as "Methods of conducting field experiments" of the Scientific-Research Institute of Cotton Selection, Seeding, and Agrotechnology of Cultivation, were used in research [8].

3 Results and Discussion

Hydromodular zoning of irrigated areas in our region, including our Republic [9], and the development of scientifically based irrigation procedures for agricultural crops in each hydromodular region according to the SropWat 8.0 program are relevant in the conditions of the observed and increasing water shortage in our Republic. Based on the Food and Agriculture Organization (FAO) methodology, the CropWat 8.0 program, the water demand for cotton in the Bukhara region was determined using meteorological parameters, the main meteorological indicators for the development of irrigation procedures taking into account the soil-hydrogeological conditions were carried out according to the data of the Bukhara meteorological stations [13, 15].

The coordinates of the Bukhara weather station in the Bukhara region are determined (State: Uzb 2020 Station: Altitude: 225 m.; Latitude: 39.46 °S; Longitude: 64.26 °W), and the required air temperature, relative humidity, precipitation, wind speed of the meteorological station for the program and solar radiation duration data were obtained (Table 1), based on which the data were developed.

Table 1. Bukhara meteorological station data (2021y).

Months	Air temperature, ^{0}S		Relative humidity of the air %	Precipitation, mm	Wind speed, m/s	Duration of sunlight, day.
	Max	Мин			Average	
January	5.7	-2.5	75	0.4	0.9	3.6
February	11.1	0.3	71	29	1.2	5.6
March	17.4	4.1	50	3	1.3	8.9
April	23.7	10.1	51	4.8	1.3	8.9
May	31.6	17.3	45	6.2	1.4	11.1
June	36.3	21.4	47	7.0	1.1	12.7
July	37.1	22.8	46	0.4	1.0	12.7
August	33.2	19.7	50	0.3	1.1	11.8
September	26.9	12.1	46	0.0	1.1	11.2
October	20.4	4.8	48	0.0	0.9	9.6
November	8.9	-1.9	62	8.6	1.2	6.3
December	-0.6	-8.9	72	1.0	1.3	5.7
Average	**21**	**8.3**	**55**	**60.7**	**1.1**	**9.0**
Source: Information from the Hydrometeorological Service Center.						

The amount of evapotranspiration in the Bukhara region in 2021 in mm/day, precipitation and useful precipitation in mm, max and min air temperature °C, relative air humidity %, wind speed m/s, duration of sunlight in hours, radiation mdj/ml/months of data Fig. of change (Fig. 1).

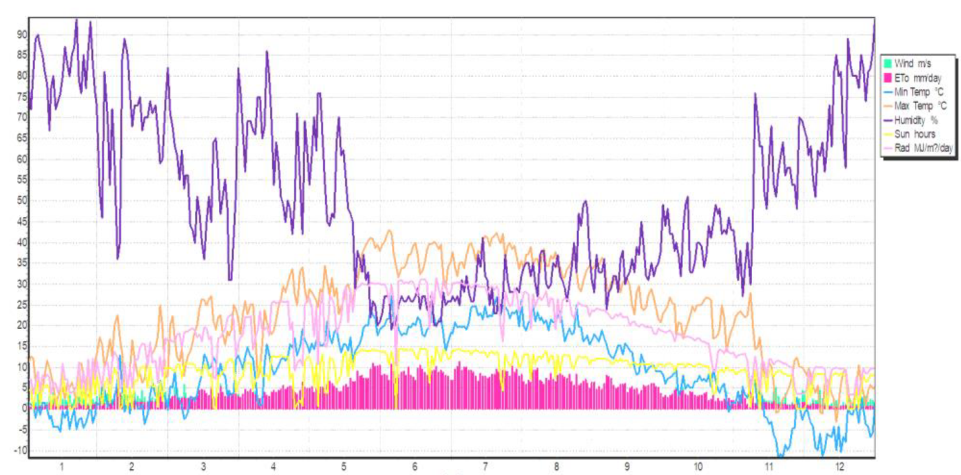

Fig. 1. Change figure of natural climate data in Bukhara region (*Source: «Compiled by the authors»)*

It was determined that the following tasks could be performed within the framework of the existing program. Effective use of water in irrigation is based on the possibility of determining the criteria of water use in the process of reducing water supply with the economy of water at the current and future development levels and the impact on crop productivity, determining the water demand of cotton, as well as the uniqueness of rational management of water resources.

Standard evapotranspiration was calculated using the software using the Penman Monteth formula (Table 2) [12].

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

Here: ETo is standard evapotranspiration [mm day^{-1}]; Rn is net radiation reaching the plant level [MDj m^{-2} day-1]; G is heat flow density in the soil, [MDj m^{-2} day-1]; T is the average daily temperature of the air at a height of 2 m above the ground level [°C]; u^2 is speed of the wind at a height of 2 m above the ground level [m s^{-1}]; es is saturated vapor pressure [kPa]; ea is the actual actual steam pressure [kPa]; (es-ea) vapor saturation pressure deficit [kPa]; D is vapor pressure curve gradient [kPa $°C^{-1}$] is psychrometric stability (constant) [kPa $°C^{-1}$] [12, 14].

Table 2. Calculation of standard evapotranspiration and radiation rate in Bukhara region.

Months	**Air temperature, ^0C**		**Relative humidity of the air %**	**Precipitation, mm**	**Wind speed, m/s**	**Duration of sunlight, day.**	**Radiation rate MJ/ml/day**	**Eto mm/day**
	Max	Min			Average			
January	5.7	-2.5	75	0.4	0.9	3.6	6.9	0.77
February	11.1	0.3	71	29	1.2	5.6	10.7	2.03
March	17.4	4.1	50	3	1.3	8.9	17.4	3.33
April	23.7	10.1	51	4.8	1.3	8.9	20.5	4.13
May	31.6	17.3	45	6.2	1.4	11.1	25.3	6.56
June	36.3	21.4	47	7.0	1.1	12.7	28.3	8.56
July	37.1	22.8	46	0.4	1.0	12.7	27.9	8.69
August	33.2	19.7	50	0.3	1.1	11.8	25.1	7.09
September	26.9	12.1	46	0.0	1.1	11.2	21.2	5.34
October	20.4	4.8	48	0.0	0.9	9.6	15.7	3.09
November	8.9	-1.9	62	8.6	1.2	6.3	9.6	1.58
December	-0.6	-8.9	72	1.0	1.3	5.7	7.9	0.68
Average	**21**	**8.3**	**55**	**60.7**	**1.1**	**9.0**	**18.0**	**4.32**
Source: Developed by the authors based on data from the Hydrometeorological Service Center.								

Etalon evapotranspiration and radiation rates were calculated using SropWat software, using air temperature, relative humidity, precipitation, wind speed, and solar radiation data from the Bukhara weather station in the Bukhara region (Fig. 2).

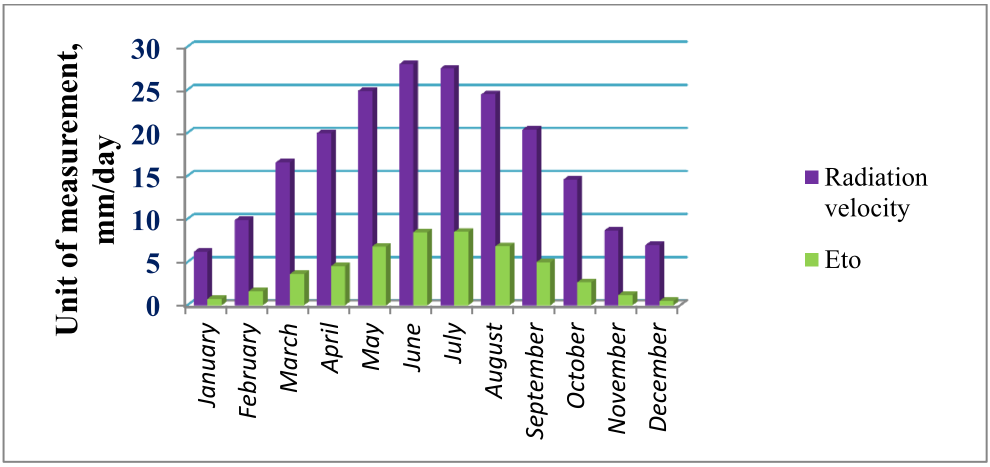

Fig.2. Change of radiation speed and standard evapotranspiration by months in Bukhara region

The total water standards and crop coefficients of cotton for the Bukhara region are presented in Table 3. We developed crop coefficients based on the values recommended by the Scientific Research Institute of Irrigation and Water Problems [10]. The total water demand for cotton in the Bukhara region is recorded from 3900 to 7200 m^3/ha. In short-duration crops, cotton's water demand in dryland areas is particularly high during the growing season, as meteorological parameters are very high and rainfall is very low. We have analyzed the experiences conducted in the conditions of Uzbekistan and the international FAO method adapted to local conditions [11].

Table 3. Seasonal irrigation standards of cotton, m^3/ha.

Hydromodule region	**Seasonal irrigation standards m^3/ha** Recommendation of scientists of TIAME NRU for Bukhara region	**Seasonal irrigation standards m^3/ha** Recommendation of F.N. Bespalov of Bukhara region	**Crop coefficients**
I	7200		0.42-0.89-0.65
II	6800	7900	0.39-0.82-0.60
III	6000	7500	0.38-0.82-0.55
IV	6300	8100	0.40-0.85-0.60
V	6000	5500	0.34-0.74-0.50
VI	5800	6800	0.33-0.74-0.50
VII	5500	6400	0.35-0.72-0.55
VIII	3900	3800	0.31-0.56-0.50
IX	4200	4900	0.30-0.56-0.50
Source: Developed by the authors.			

Seasonal cotton irrigation rates and water consumption were calculated using SropWat software. With the program's help, the water demand of cotton for the growing season was calculated at what times and how much it should be irrigated, as well as the Fig. of changes in the norms and the net water consumption (Fig. 3).

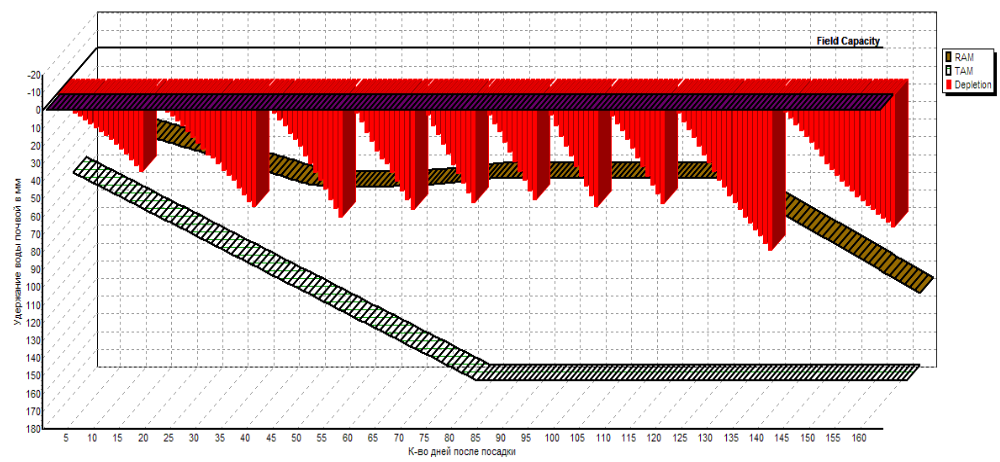

Fig. 3. Indicators of cotton irrigation according to FAO methodology in Bukhara region.

According to the recommendations made by professor N. Bespalov for the Bukhara region, seasonal irrigation norms of cotton were developed, and irrigation works are being carried out according to these recommendations. Using the CropWat 8.0 program, the seasonal irrigation rate of cotton was developed for the research objects, the correlation coefficient coordinate system was developed, and the correlation coefficient was equal to R^2=0.80. Each pair of values is marked with a specific symbol (Fig. 4).

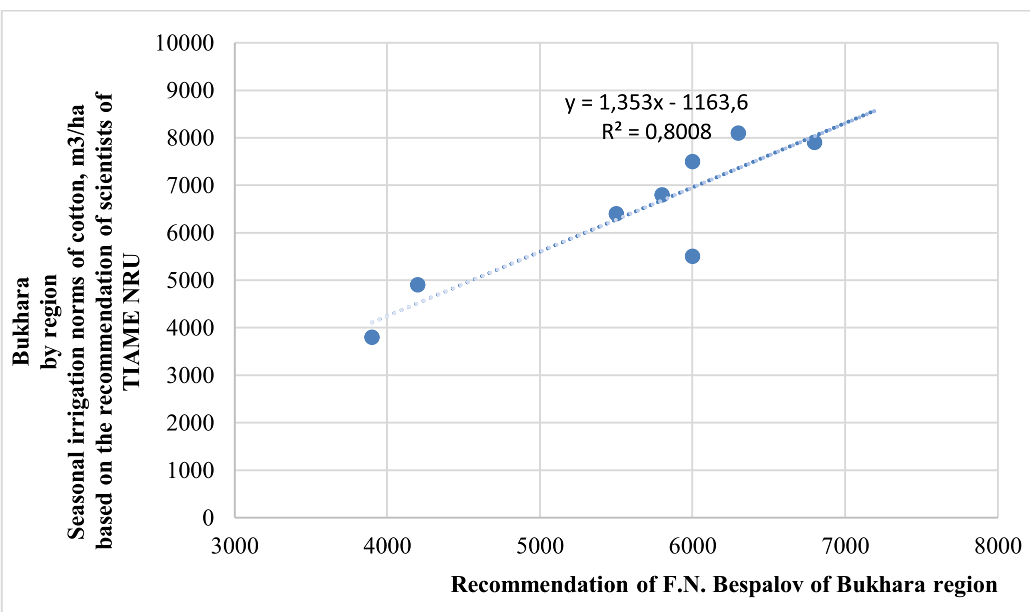

Fig 4. Correlation coefficient comparing seasonal irrigation rates of cotton *(Source: Developed by the authors)*

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4 Conclusions

1. Using the CropWat 8.0 program, reference evapotranspiration and radiation rates were determined for the research objects. These indicators were equal to 18.0 mdj/ml/day and 4.32 mm/day in the Bukhara region.

2. The correlation coefficient of the seasonal irrigation norms of cotton for the Bukhara region by hydromodule regions was equal to R^2=0.80

3. Seasonal irrigation norms of cotton in the Bukhara region were equal to 3900 (VIII - Hydromodul region) - 7200 (I - Hydromodul region) m^3/ha according to hydromodule regions. These indicators were estimated to be 500 - 1800 m^3/ha less than the data of N.F.Bespalov.

4. Irrigation standards (net) of cotton in hydromodule regions of the Bukhara region were 600-1050 m^3/ha, and the number was 6-8. These data were, on average, 700 m^3/ha less than the recommendations used in the Republic (N.F. Bespalov).

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