Development of Cotton Irrigation Based on Computer Technology

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Abstract. This study examines the critical intersection of global climate change and increasing water scarcity, with a particular focus on developing optimized irrigation practices for cotton production in the Andijan region. Using the CropWat software, guided by the Food and Agriculture Organization (FAO) methodology, we conducted a comprehensive analysis of local soil and hydrogeological conditions to formulate evidence-based irrigation strategies. The results show that seasonal irrigation requirements for cotton vary significantly across hydromodular regions, ranging from 3000 m³/ha in the dry season (IX) to 5900 m³/ha in the rainy season (I). Moreover, our findings highlight the importance of adapting irrigation practices to regional climate and soil characteristics to improve water use efficiency. By implementing these evidence-based irrigation regimes, we aim to not only improve cotton yields but also contribute to sustainable water management practices in the context of a rapidly changing climate. This study highlights the need for adaptive agricultural practices and provides a basis for further research on irrigation optimization, ultimately supporting agricultural sustainability and food security in water-stressed regions. Future research will also examine the integration of alternative irrigation technologies and their potential impact on optimizing water use in cotton production.

Keywords: Andijan, CropWat program, soil, water scarcity, cotton, irrigation norm, evaporation. computer program, computer technology.

1 Introduction

As it is known, natural-climatic conditions on the planet, including Central Asia, change over time, as a result of changes in daily weather indicators, resource management creates its own difficulties. The main driver of climate change is the Earth's radiation balance (the difference

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between incoming solar radiation and the radiation our planet emits into space). The effects of climate change, primarily due to global warming, are vast, complex and uncertain, as cited by the United Nations, as the Intergovernmental Panel on Climate Change (IPCC) report reaffirms that "Global Warming" is occurring [1, 2]. Climate change affects the hydrological cycle, thus changing the characteristics of river flow dynamics [3].

According to the analysis of the Hydrometeorology Center, water resources will remain at the current level until 2030. However, as a result of further increase in air temperature, river flow will decrease. This is significantly observed in large river basins. None of the climate scenarios considered for global warming predict an increase in available water resources. Warming of the air temperature and increase of total evapotranspiration increase the loss of water from the irrigated areas, which requires the use of additional water resources [4, 5]. Climate change will cause 10-15 percent more evaporation from water surfaces and 10-20 percent more water use due to increased plant transpiration and irrigation rates. According to the results of the study, it is proven that the consumption of water without recovery leads to an average increase of 18 percent. It is important to assess the possible increase in water consumption of cotton cultivation due to changes in natural climatic conditions [6].

The Republic of Uzbekistan is located in the Aral Sea basin, and its main water source is the Amudarya and Syrdarya rivers, as well as 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 which 78.34 m^3 is formed in the Amudarya basin and 36.06 m^3 in the Syrdarya basin. The total reserve of underground water is 31.2 billion m^3, 47.2% of it belongs to the Amudarya basin, and 52.8% to the Syrdarya basin. According to the schemes of integrated use of water resources and their protection of the "Amu Darya" and "Syr Darya" basins, the average multi-year water intake limit for the Republic of Uzbekistan is 64 billion m^3, but 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 in agriculture, 4.5 % in the utility 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 [7, 8].

As a consequence of climate change, the water demand for agricultural crops, particularly cotton, is on the rise, making the efficient utilization of water in agriculture a critical priority. In response to this challenge, innovative water-saving technologies and methods have been implemented globally. However, in the Andijan region, timely data analyses indicate that annual precipitation ranges between 120 and 130 mm, which poses significant challenges for sustainable agricultural practices. The uneven distribution and limited volume of precipitation, coupled with the low water-holding capacity of soils, significantly contribute to the stress experienced by cultivated crops. This highlights the urgent need for effective water management strategies. Therefore, it is essential to assess the water requirements of cotton under varying climatic and soil-hydrogeological conditions, employing the CropWat 8.0 program in accordance with the FAO methodology. Such assessments will not only facilitate the optimization of irrigation practices but also contribute to enhancing the resilience of cotton production in the face of changing climatic conditions.

2 Research methodology

The water demand of cotton was determined by the Penman-Monteth method using the CropWat 8.0 program developed by FAO. Methods of systematic analysis and mathematical statistics, as well as cotton breeding, seeds production and agrotechnologies research institute (CBSPARI's) "Methods of conducting field experiments" were used in conducting research.

3 Results and discussion

Hydromodular zoning of irrigated lands, as well as the development of scientifically based irrigation regimes for agricultural crops in each hydromodular region using the CropWat 8.0 program, is of great importance in solving the problem of growing global water shortage. In the Andijan region, an irrigation regime was established based on the CropWat 8.0 program in accordance with the FAO methodology using meteorological indicators to accurately determine the water needs of cotton. The coordinates of the Andijan weather station were recorded as follows: State: Uzbekistan, Station: Andijan, Altitude: 461 m, Latitude: 40.81 °N, Longitude: 72.28 °E (2023). In addition to these coordinates, essential meteorological parameters-including air temperature, relative humidity, precipitation, and wind speed-were collected from the station, alongside data on the duration of solar radiation (Table 1). Using the obtained data, calculations for solar radiation and evapotranspiration rates were conducted. This rigorous approach not only enhances the accuracy of water demand assessments but also informs the development of targeted irrigation strategies, ultimately contributing to sustainable agricultural practices in the region.

Table 1. Andijan meteorological station data (2023).

Months	Air temperature, ^0C		Relative humidity of the air, %	Wind speed, m/s	Duration of sunlight, day.	Radiation, mj/m^2 /day	ET_o mm/ day
	Min	Max					
January	-4.4	5.0	73	1.1	4.4	7.2	0.66
February	1.2	12.8	72	1.2	3.8	8.5	1.22
March	5.2	14.6	70	2.1	3.1	10.4	1.97
April	8.8	23.5	57	1.7	8.4	19.6	3.81
May	16.5	30.5	52	1.9	8.9	22.2	5.37
June	19.2	35.0	41	2.3	11.3	26.3	7.23
July	21.6	35.4	48	2.0	9.7	23.6	6.43
August	20.0	34.4	46	2.0	10.3	22.8	6.08
September	14.3	31.0	53	1.4	9.5	18.8	4.15
October	6.6	19.0	62	1.4	5.3	10.8	1.93
November	-0.7	11.8	74	1.3	5.3	8.3	0.93
December	-2.3	8.6	81	1.2	4.2	6.3	0.62
Average	8.8	21.8	61	1.6	7.0	15.4	3.37

The amount of evapotranspiration in Andijan region in 2023 in mm/day, precipitation and useful precipitation in mm, max and min air temperature in °C, relative humidity in %, wind speed in m/s, duration of sunlight in hours, radiation mdj/ml/months of data graph of change in (figure 1).

Using the "CropWat 8.0" program of the FAO methodology, the seasonal irrigation rate of cotton was developed for the research object. Based on this, Professor N. F. Bespalov and seasonal irrigation standards developed by scientists of NRU "TIIAME" were compared. As a result, a correlation coefficient coordinate system was developed. The correlation coefficient was equal to $R^2 = 0.8281$. The compatibility of seasonal irrigation standards with existing ones is shown in figure 2.

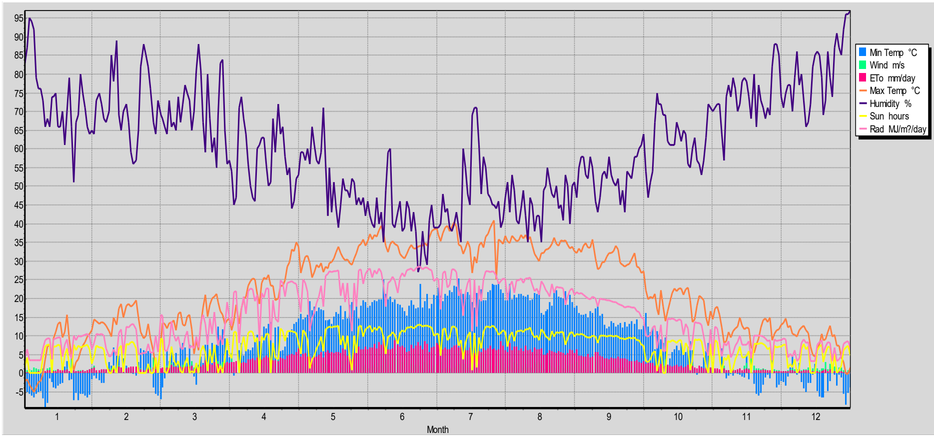

Fig. 1. Change graph of natural climate data in Andijan region.

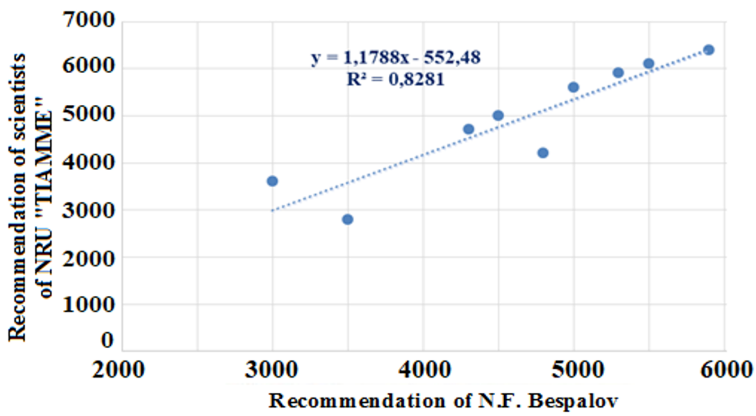

Fig. 2. Compliance with existing seasonal irrigation standards.

The change of the coordinate axis "U" and "X" was determined using the following relationship (1).

$$y = 1.1788X - 552.48 \quad (1)$$

Using the CropWat 8.0 program, it is possible to develop a current and future plan for effective water use, to set criteria for water use in water supply management with the economy of existing water resources, to assess the uniqueness of water resources and management.

CropWat 8.0 software was used to determine standard evapotranspiration developed by Penman-Montent (2) [8].

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma * \left(\frac{900}{T+273}\right) u_2 * (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (2)$$

where: ET_0 - standard evapotranspiration [mm day^{-1}]; R_n is the net radiation reaching the plant level [MDj m^{-2} day^{-1}]; G is the 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 the speed of the wind at a height of 2 m above the ground level [m s^{-1}]; e_s is the saturated vapor pressure [kPa]; e_a is the actual pressure of the actual steam [kPa]; (e_s - e_a) is the saturation pressure deficit of steam [kPa]; D is the gradient of the vapor pressure curve [kPa °C^{-1}]; γ is psychrometric stability (constant) [kPa °S^{-1}] [8].

On the one hand, the evaporation of water from the soil surface and on the other hand, the process of exiting from crop leaves into the atmosphere is called evapotranspiration *(ET_o)*. Based on this, monthly evapotranspiration was calculated for the months of January-December 2023 in the research.

Water requires a certain amount of energy to change from a liquid state to a vapor. This process of energy is solar radiation, which varies depending on changes in air temperature.

Solar energy and air temperature, but also air humidity and wind speed are among the climatic parameters required to estimate evaporation.

Penman-Monteith equation was used to calculate the water requirement of cotton through CropWat 8.0 software. The equation provides for calibration (adaptation) to certain climatic conditions (figure 2).

4 Conclusion

1. In accordance with the recommendations provided by the scientists at NRU "TIIAME" and Professor N.F. Bespalov, a comparative analysis of the seasonal irrigation standards for cotton in the Andijan region was conducted, yielding a correlation coefficient of $R^2 = 0.8281$. This strong correlation underscores the validity of the proposed irrigation standards.
2. Utilizing the FAO's "CropWat 8.0" program, benchmark evapotranspiration and radiation rates for the research sites were determined. The radiation levels in Andijan were measured at 15.4 MDJ/m²/day, while the standard evapotranspiration rate was found to be 3.37 mm/day. These figures provide essential insights for optimizing irrigation practices.
3. A scientifically-based irrigation system for primary agricultural crops, including cotton, was developed in the irrigated lands of the Andijan region using the FAO's "CropWat 8.0" program. This system aims to enhance water-use efficiency and promote sustainable agricultural practices.
4. The study revealed that the seasonal irrigation standards for cotton in the Andijan region vary significantly, ranging from 3,000 to 5,900 m³/ha, depending on the specific hydromodule region. This variability highlights the necessity for tailored irrigation strategies that consider local hydrological conditions.
5. Within the Andijan region, hydromodule irrigation standards for cotton were established to be between 600 and 1,000 m³/ha, with the number of irrigations ranging from 4 to 8. According to Bespalov N.F.'s recommendations, optimal cotton irrigation standards are suggested to be between 700 and 1,000 m³/ha, with a frequency of irrigation between 3 and 7 times. This alignment with established guidelines supports the development of effective irrigation practices that can lead to improved crop yields.

Overall, these findings contribute to the understanding of irrigation dynamics in the Andijan region and emphasize the importance of implementing scientifically informed strategies to enhance water management in agriculture. Future research should focus on the long-term impacts of these irrigation practices on crop productivity and soil health, as well as on adapting to the challenges posed by climate change.

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