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Estimation of water requirements of pearl millet under different climate change scenarios (Under Different RCP Scenarios) for semi-arid region of Hisar, Haryana

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Abstract

Pearl millet (*Pennisetum glaucum*) is an important drought-tolerant cereal crop widely cultivated in dryland areas of India and other parts of Asia and Africa. Although the crop is well adapted to harsh climatic conditions, changes in temperature and precipitation patterns due to climate change may significantly influence its water requirement. Therefore, assessing crop water demand under future climate scenarios is crucial for effective irrigation planning and sustainable water resource management. Efficient water management is essential for sustainable agricultural production, particularly in arid and semi-arid regions where water resources are limited.

The present study aims to estimate the crop water requirement and irrigation requirement of pearl millet under future climate conditions using the CROPWAT model. Climatic data including temperature, rainfall, relative humidity, wind speed, and sunshine hours were used to calculate reference evapotranspiration through the FAO Penman–Monteith equation. Crop evapotranspiration was estimated by applying appropriate crop coefficients for different growth stages. Future climate projections were analyzed using *Representative Concentration Pathways* (RCP) scenarios to evaluate potential changes in water requirement under varying greenhouse gas emission pathways.

The findings highlight the importance of climate-responsive irrigation management strategies to enhance water use efficiency and sustain pearl millet production under changing climatic conditions.

It also demonstrates the applicability of the CROPWAT model in estimating crop water requirements under projected climate scenarios, providing useful insights for irrigation planning, agricultural water management, and climate adaptation strategies in semi-arid regions.

Keywords: Evapotranspiration, Pearlmillet, CROPWAT, Irrigation water requirement

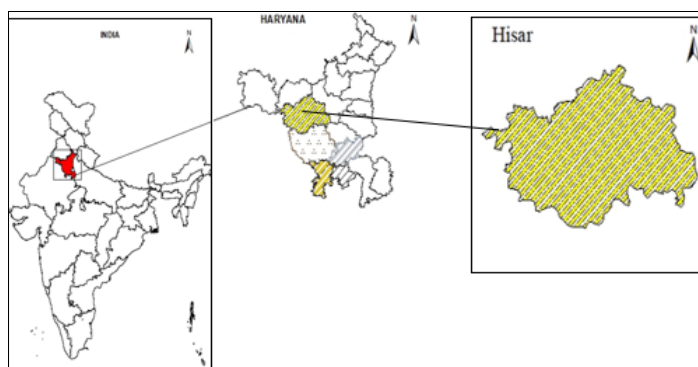
Introduction

Pearl millet (*Pennisetum glaucum*) is an important cereal crop widely cultivated in arid and semi-arid regions of Asia and Africa. It is well known for its exceptional tolerance to drought, high temperature, and low soil fertility, making it a suitable crop for marginal environments where other cereals often fail. Because of its adaptability to harsh climatic conditions, pearl millet plays a crucial role in ensuring food and nutritional security in many developing countries (Yadav *et al.*, 2012) ^[6].

In India, pearl millet (commonly known as bajra) is a major staple food and fodder crop, particularly in the semi-arid regions of Rajasthan, Haryana, Gujarat, and Maharashtra. The crop is primarily grown during the kharif season, relying mainly on monsoon rainfall. Apart from being a staple food, pearl millet grains are rich in proteins, minerals, and dietary fiber, while the crop residues serve as valuable fodder for livestock, making it an integral component of crop–livestock farming systems (ICAR, 2017) ^[2].

Water is one of the most critical inputs influencing crop growth, productivity, and sustainability in agriculture. Efficient irrigation management requires accurate estimation of crop water requirement and evapotranspiration. According to the guidelines provided by the Food and Agriculture Organization (FAO), crop water requirement is generally determined using reference evapotranspiration and crop coefficients under specific climatic conditions (Allen *et al.*, 1998) ^[1].

Climate change is expected to significantly affect agricultural production systems through changes in temperature, precipitation patterns, and evapotranspiration rates. Future climate projections are commonly represented using *Representative Concentration Pathways* (RCPs), which describe different greenhouse gas concentration trajectories. These scenarios are widely used in climate impact studies to assess potential changes in crop water demand and irrigation requirements (IPCC, 2014) [3]. Therefore, estimating the water requirement of pearl millet under different RCP scenarios is essential for developing climate-resilient irrigation strategies and sustainable water resource management. CROPWAT model is an effective tool in recent time to estimate the water requirement of a crop under projected scenarios of future (Thimme *et al*, 2013) [5] and (Thanoon *et al*, 2019) [4].



Materials and Methods

The study was conducted in the field of CCS HAU Hisar during kharif season 2023. The study area is located with an elevation of 215.2 meters above the mean sea level and located between of 29° 10'N latitude and 75° 46' E longitude. District Hisar of Haryana is located in India's semi-arid, subtropical climate zone. Climate of this place is primarily characterized by temperature extremes, little rainfall and dryness. The soils of this region are

derived from Indo-Gangetic alluvium, which are very deep and sandy loam in texture and have some amount of calcium carbonate (CaCO₃) in the soil profile. The soil of experimental field station was sandy loam in texture and belongs to Entisols soil order. Soil has mechanical composition of Sand (56.7%), Silt (25.8%) and Clay (17.8%).

Experimental details

The experiment uses FRBD (Factorial Randomized Block Design) design with four replications. Three dates of sowing were selected for the crop *i.e.*, 30th June, 13th July and 27th July and three varieties were taken GHB 558, HHB 67 Improved and HHB 299 with four replications. Crop was examined at each phenophase from emergence to harvesting.

The details of experiment are given below

Factor A: Three (Sowing dates)

D₁: 30th June, 2023

D₂: 13th July, 2023

D₃: 27th July, 2023

Factor B: Three (Varieties)

V₁: GHB 558

V₂: HHB 67 Improved

V₃: HHB 299

Experimental design: Factorial RBD

Number of replications: 4

Gross plot size: 4.0 m x 3.6 m

Net plot size: 3.0 m x 2.6 m

Spacing: 45 cm X 12 cm

Harvesting: D₁: 13th September, 2023

D₂: 22nd September, 2023

D₃: 4th October, 2023

Results and Discussion

Table 1: Projected weather conditions for Hisar district, Haryana

Scenarios	Year	T _{max} (°C)	Change in T _{max} (°C) over baseline	T _{min} (°C)	Change in T _{min} (°C) over baseline	T _{avg} (°C)	Change in T _{avg} (°C) over baseline	Rain fall (mm)	Change in rainfall over baseline (mm)	Change in rainfall over baseline (%)
Baseline	2001-2020	31.2		16.7		23.9		514.7		
RCP 2.6	2040s	33.32	2.12	18.93	2.23	26.12	2.22	571.9	57.2	11
	2060s	33.92	2.72	19.24	2.54	26.58	2.68	592.3	77.6	15
	2080s	34.21	3.01	19.26	2.56	26.74	2.84	571.2	56.5	11
RCP 4.5	2040s	33.46	2.26	18.57	1.87	26.02	2.12	660.0	145.3	28
	2060s	34.65	3.45	19.88	3.18	27.27	3.37	641.0	126.3	25
	2080s	35.18	3.98	20.45	3.75	27.81	3.91	787.6	272.9	53
RCP 6.0	2040s	30.05	-1.15	17.35	0.65	23.70	-0.19	574.1	59.4	12
	2060s	29.57	-1.63	17.71	1.01	23.64	-0.26	638.4	123.7	24
	2080s	30.74	-0.46	18.70	2.0	24.72	0.82	627.0	112.3	22
RCP 8.5	2040s	33.64	2.44	19.04	2.34	26.34	2.44	590.8	76.1	15
	2060s	34.87	3.67	20.32	3.62	27.60	3.7	636.4	121.7	24
	2080s	36.14	4.94	21.80	5.1	28.97	5.07	830.4	315.7	61

Projection of irrigation water requirement using CROPWAT 8.0 model for Hisar, Haryana

Crop evapotranspiration, effective rainfall and Irrigation water requirement for pearl millet crop was projected using CROPWAT 8.0 for Hisar district of Haryana and projected values shows that there would be increase in the effective

rainfall for the periods *viz.*, 2040s, 2060s and 2080s over baseline period. By RCP 2.6, the irrigation requirement for the pearl millet crop was higher during the period 2020-2040 (26.2 mm, 12.3 mm, 26.1 mm) for all sowing dates than other two periods *i.e.*, 2060s and 2080s for the three different growing environments (30th June, 13th July, 27th July) shown in table 2.

Table 2: Irrigation water requirement projecting under RCP 2.6 in CROPWAT 8.0

	Decades	ET _c (mm)	Eff. Rainfall (mm)	Irrigation req. (mm)
D1 (30 th June)	2020-2040	196.1	230.7	26.2
	2040-2060	196.8	289.6	15.8
	2060-2080	199.3	304.9	7.0
D2 (13 th July)	2020-2040	179.5	220.5	12.3
	2040-2060	180.0	275.5	4.6
	2060-2080	182.5	286.3	2.9
D3 (27 th July)	2020-2040	179.5	227.5	26.1
	2040-2060	189.7	273.8	15.7
	2060-2080	192.0	280.3	3.9

Table 3: Irrigation water requirement projecting under RCP 8.5 in CROPWAT 8.0

	Decades	ET _c (mm)	Eff. Rainfall (mm)	Irrigation req. (mm)
D1 (30 th June)	2020-2040	197.1	253.0	21.7
	2040-2060	199.1	301.5	8.6
	2060-2080	203.1	272.0	27.8
D2 (13 th July)	2020-2040	180.6	238.0	8.0
	2040-2060	182.5	282.5	3.0
	2060-2080	186.1	264.6	13.9
D3 (27 th July)	2020-2040	190.0	247.1	21.7
	2040-2060	192.2	294.3	8.7
	2060-2080	196.2	269.4	28.1

RCP 8.5 projected irrigation requirement during the three periods 2040s, 2060s and 2080s and noted that there would be minimum amount of irrigation water requirement during the period of 2040-2060 than other two periods (2020-2040 and 2060-2080). For the first date of sowing, maximum irrigation requirement would be during the period 2060-2080 (27.8 mm) and minimum during 2040-2060 (8.6 mm). similarly, for the second date of sowing, maximum irrigation requirement would be during the period 2060-2080 (13.9 mm) and minimum during 2040-2060 (3.0 mm) and for third date of sowing, maximum irrigation requirement would be during the period 2060-2080 (28.1 mm) and minimum during 2040-2060 (8.7 mm) as shown in table 3.

Conclusion

Crop water irrigation requirement was projected using CROPWAT 8.0 model for the major pearl millet growing districts of Haryana (Hisar). It was projected that there would be more water requirement during the period of 2020-2040 under RCP 2.6 and higher water requirement during the period of 2060-2080 under RCP 8.5 for all the three dates of sowing for the district Hisar. The requirement would be less in such periods because of more amount of effective rainfall during this time compared to the baseline period of the district individually. CROPWAT model projected, that there would be more irrigation water requirement during the period of 2020-2040, under RCP 2.6 and higher during the period of 2060-2080, under RCP 8.5 for all the three growing environments, for Hisar district.

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