



Assessment of Wheat Crop Water Requirement for South Bihar by FAO CROPWAT 8.0

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ABSTRACT

Background: Water is a precious resource that needs increase in its use efficiency for higher productivity of crops. The wheat crop responds more with irrigation and it is cultivated in large area after rice which requires understanding of wheat water requirements in the region for a practical guide for stakeholders involved in agricultural planning and water resource management.

Methods: The present research aims to assess the irrigation water requirement of wheat crop in the specific agro-climatic conditions of South Bihar by using the FAO CROPWAT 8.0 model, a widely recognized tool for calculating crop water requirements.

Result: Meteorological and crop-specific parameters of Patna were used in the model to estimate water requirement of wheat. The total crop water requirement for wheat crop in South Bihar was 267.2 mm with 70% irrigation efficiency. The gross and net irrigation requirement was 299.6 mm and 209.7 mm respectively scheduled in four irrigations. The actual irrigation requirement by the crop was 230.9 mm and the actual water use by the crop was 267.2 mm. The moisture deficit in the soil at the time of harvest was 93.25 mm.

Key words: CROPWAT, Gross water requirement, Irrigation water requirement, Wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) serves as the primary food crop in South Asia, making up over 80% of the total cereal production in the region (Timsina and Connor, 2001). India, ranking second-largest global wheat producer, produces 114 million tons (Gol, 2023). The average productivity of wheat in Bihar is 2.9 tons per ha which is significantly below the average yield of India (3.4 tons per ha) (CIMMYT, 2023).

At present, irrigation accounts for approximately 52% of the overall available water across the country (NITI Aayog, 2023). Anticipated increases in population, urbanization and climate change are expected to intensify competition for water resources, posing significant decrease in availability to agriculture (Banerjee *et al.*, 2016).

The agriculture sector in various regions of India is grappling with a significant challenge of scarcity of fresh water. The unpredictable precipitation, decrease in water table due to over use of ground water and insufficient access to irrigation imposes constraints on the productivity of crops (Shah *et al.*, 2021).

Achieving prudent and optimal allocation and management of water resources necessitates a comprehensive understanding of actual evapotranspiration and irrigation water requirement of crops (Banerjee *et al.*, 2016). Numerous methods are available for estimating Crop Water Requirement (CWR) and determining irrigation schedules such as open pan evaporation rate (Singh *et al.*, 1987, Manjunath *et al.*, 1994), soil moisture depletion (Reddy *et al.*, 1980), aerodynamic method, proportion of irrigation water with respect to the cumulative pan evaporation (Reddy *et al.*, 1999). However, some of these methods are often deemed laborious. The most common method for estimating CWR is based on the climate water balance algorithm (Gaddikeri *et al.*, 2022) where reference

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evapotranspiration (ET_o) is used. In accurate weather data condition, CROPWAT may be used for estimation the ET_o, CWR and irrigation scheduling (Khan *et al.*, 2021, Dang, 2018). For more accurate estimation of CWR, the Food and Agriculture Organization (FAO) suggest utilizing the CROPWAT software (Aiyelaagbe and Ogbonnaya 1994). The use of CROPWAT 8.0 will provide information on CWR, crop evapotranspiration and irrigation schedules (Song *et al.*, 2016, Moeski *et al.*, 2019, Narmilan and Sugirtharan, 2021). Such information of crop water requirement for wheat grown in South Bihar is meagre. Hence, an attempt has been made to estimate CWR of wheat by using CROPWAT 8.0.

MATERIALS AND METHODS

The study was done for Patna, Gaya, Aurangabad, Jamui and Nawada district of South Bihar, India. In the present study, the meteorological data of Patna located at 25°96'N Latitude and 85°27'E was used for the estimation of CWR for wheat crop grown in South Bihar (Table 1).

The parameters used in estimation of CWR for wheat crop using CROPWAT 8.0 software are taken from FAO Manual-56 which are mentioned below:

Data	Meteorological and crop parameters
Climatic	Humidity and wind speed, Sunshine hours, Minimum and Maximum temperature
Meteorological	Rainfall
Soil	Maximum rooting depth, Total available soil moisture, Maximum rain infiltration rate,
Crop	Crop coefficient (Kc) values for different stages of crop

CROPWAT 8.0

CROPWAT 8.0 is a computer-based decision support program designed to utilize climate, crop, rainfall and soil data for the computation of reference evapotranspiration (ET_o), crop water requirement (CWR), irrigation scheduling and irrigation water requirement (IR). It operates a set of equations promoted by the Food and Agriculture Organization.

The CROPWAT 8.0 uses environmental data such as minimum and maximum temperatures, mean relative humidity in percent, wind velocity in km/hr, hours of daylight, rainfall data in mm and also effective rainfall in mm (Rehman *et al.*, 2021).

Crop water requirement

To determine the crop water requirement (ET_c) for wheat, the process involves multiplying the reference crop evapotranspiration (ET_o) values by the crop coefficients (K_c). The specific K_c values corresponding to different growth stages of a wheat crop are acquired from the FAO-56 manual (Table 2). The CWR is equated as;

$$ET_c = K_c \times ET_o$$

Where:

ET_c= Evapotranspiration of crop.

ET_o= Reference crop evapotranspiration.

K_c= Crop factor/Coefficient of crop.

The FAO CROPWAT program (FAO, 2009) includes the method for reference crop evapotranspiration and crop

Table 1: Weather data of Patna, Bihar used in CLIMWAT tool attached to the CROPWAT software.

Month	Temperature (°C)		Humidity (%)	Wind (km/day)	Sunshine (hr)	Rad MJ/m ² /day	Eto mm/day
	Min	Max					
January	4.4	27.9	54	86	8.3	15.3	2.3
February	7.1	33.8	44	104	8.8	18	3.1
March	12.0	40.3	33	121	8.0	19.4	4.7
April	19.8	44.0	27	147	9.0	22.6	5.9
May	24.4	45.9	34	164	9.5	24.3	6.8
June	27.1	44.9	49	147	6.5	19.8	5.2
July	25.5	38.0	76	147	4.5	16.7	3.9
August	25.1	35.0	82	112	5.3	17.4	3.8
September	22.5	34.1	83	104	6.0	17.1	3.8
October	15.8	33.1	75	78	8.0	17.6	3.7
November	10.7	30.2	66	52	8.9	16.4	2.8
December	5.4	27.5	60	61	8.0	14.2	2.1
Average	16.6	36.2	57	110	7.6	18.2	4.0

Table 2: Crop co-efficient (k_c), Etc and irrigation requirement of wheat crop.

Month	Stage	Decade	K _c (Coeff)	ET _c (mm/day)	Etc (mm/dec)	Effective rainfall	Irrigation requirement (mm/dec)
Nov	Initial	2	0.3	0.8	5.2	0.0	5.1
Nov	Initial	3	0.3	0.7	7.9	0.4	7.5
Dec	Initial	1	0.3	0.7	7.2	1.2	6.2
Dec	Development	2	0.3	0.8	7.8	0.5	7.9
Dec	Development	3	0.6	1.4	15.4	2.4	15.1
Jan	Development	1	0.9	2.0	20.9	5.2	19.4
Jan	Mid-season	2	1.1	2.6	26.0	7.2	24.3
Jan	Mid-season	3	1.1	2.9	32.0	5.9	34.2
Feb	Mid-season	1	1.1	3.1	32.0	4.0	37.0
Feb	Late growth	2	1.0	3.1	31.1	3.0	37.8
Feb	Late growth	3	0.7	2.6	20.7	2.9	22.9
Mar	Late growth	1	0.4	1.8	16.2	2.5	16.3

water requirements and permit the calculation of crop water use under several climate, crop and soil conditions.

Crop data

CROPWAT needs specific crop data, including crop coefficient (Kc) values for growth stages, length of crop growth, rooting depth, critical depletion and yield response factor. These parameters are sourced from FAO Irrigation and Drainage Paper 56. Sowing and harvesting dates were taken from the package of practices as suggested by the Bihar state agriculture department (Table 3).

Soil data

The soil characteristics of this area is non-saline, showing neutral to alkaline in reactivity, silty clay in texture.

Irrigation schedule

The CROPWAT model facilitates the process of computing the crop water requirement (ET_o) and irrigation needs. This information is then utilized to formulate irrigation schedules, accommodating several administrative conditions and water supply plans.

RESULTS AND DISCUSSION

For the wheat crop, the model estimated crop water requirements at various growth periods *i.e* initial, development, mid-season and late season. The root depth is 1200 mm and critical depletion factor was 0.50. The ET_o was low in the beginning in December (2.1 mm/day) due to low temperatures in the winter and the higher value was

observed in May (6.8 mm/day) (Table 2). Due to diversity in weather conditions, ET_o value reflected fluctuation in Patna region. Evapotranspiration was high at later growth stage in *rabi* season because of low relative humidity and high temperatures and wind speed.

Crop water requirement vary based on their site, climate, soil type, cultivation method, effective rainfall. The ET_c values were lower at the initial stage and maturity of the crop stage and was higher in the middle. The irrigation requirement is highest at late growth period in february (37.8 mm/dec) month followed by mid-season growth period. The gross irrigation required for wheat crop was observed to be 299.6 mm and net irrigation of 209.7 mm (Table 4) which is to be scheduled in four irrigations (Table 5). According to Kumar *et al.*, (2017), the net irrigation water requirement for wheat crop varied between 173.7 and 240.5 mm for Sabour and Patna location respectively. The four irrigations are to be scheduled at sowing, 27, 53 and 83 days after sowing. During the time of irrigation scheduling, the soil moisture will be 50% which is congenial for wheat crop growth (Tewabe *et al.*, 2022). The actual irrigation requirement for the wheat crop was 230.9 mm and the crop actual water use was 267.2 mm. Total rainfall during crop growing period was 36.3 mm and moisture deficit at the time of harvest was 93.2 mm. The actual irrigation requirement by the crop is 230.9 mm. Further, when the irrigation was scheduled at 50% depletion, the initial readily available moisture (RAM) slowly increased from 20 mm depth to 60 mm by 60 Days after

Table 3: Date of sowing and harvesting of crops critical depletion fraction, rooting depth and days of crop growth stages.

Crop	Scientific name	Sowing and harvesting date of crop	Critical depletion fraction	Rooting depths (mm)	Crop Growth periods (Days)			
					Initial	Development	Mid- season	Late season
Wheat	<i>Triticum Aestivum</i>	15Nov and 9March	0.50	1200	30	30	30	25

Table 4: Gross and net irrigation requirement of wheat crop in South Bihar.

Gross irrigation (mm)	299.6 mm	Total rainfall (mm)	36.3 mm
Net irrigation (mm)	209.7 mm	Effective rainfall (mm)	36.3 mm
Actual water uses by the crop(mm)	267.2 mm	Moisture deficit at harvest (mm)	93.2 mm
Potential water uses by the crop (mm)	267.2 mm	Actual irrigation requirement (mm)	230.9 mm
Efficiency irrigation schedule (%)	70%	Efficiency rain	100%

Table 5: Irrigation schedules for wheat crop for South Bihar CROPWAT 8.0 model.

Date	Day	Stage	Rain (mm)	Ks fraction	Eta %	Depletion %	Net irrigation	Deficit	Loss (mm)	Gross irrigation (mm)
15 Nov	1	Initial	0.0	1.0	100	52	19.8	0.0	28.2	3.27
11 Dec	27	Initial	0.0	1.0	100	50	42.7	0.0	61.0	0.27
11jan	58	Development	0.0	1.0	100	52	72.9	0.0	104.2	0.39
5feb	83	Mid-season	0.0	1.0	100	52	74.3	0.0	106.2	0.49
9march	End	End season	0.0	1.0	0	65		0.0		

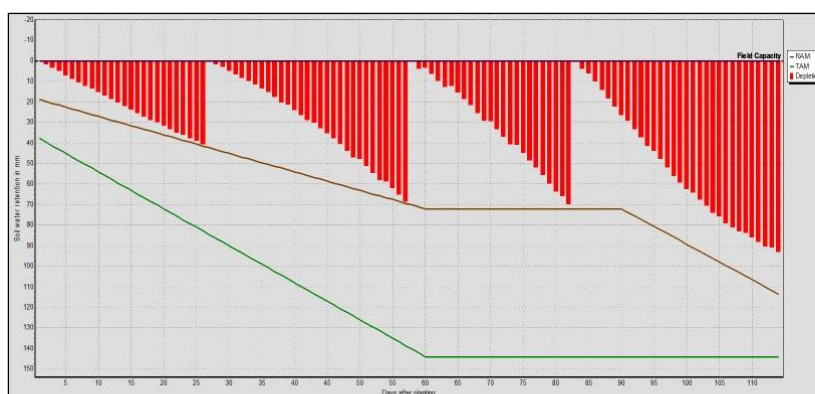


Fig 1: Irrigation scheduling and soil moisture retention during crop growth period in wheat crop.

sowing (DAS) and total available moisture (TAM) from 35 mm to 135 mm by 60 DAS (Fig 1). The crop coefficient is low during initial and late growth stage but high in mid-season and development stage. Total available moisture (TAM) and readily available moisture (RAM) represents the mediums from which the plant can absorb water from the root zone without experiencing stress. Further, as the crop stage advanced and irrigation was given, the RAM further increased to 115 mm by the end of the crop season. However, there was no increase in TAM. The moisture retention and its availability depend on soil type besides the crop growth. As soil under which the crop is cultivated is silty clay which holds more moisture and provides greater RAM. The wheat crop gives higher yield with irrigation schedule at critical growth stage such as tillering, flowering and grain filling (Deo *et al.*, 2017). The estimation made with CROPWAT 8.0 also indicate similar result indicating that the model can be utilized for estimation of crop water requirement and irrigation scheduling in different regions of the country by using metrological data.

CONCLUSION

The study utilizing the FAO CROPWAT 8.0 model has provided valuable information for wheat crop water requirements in South Bihar, India. The precise estimation of consumptive water use at various growth stages of wheat is critical for sustainable agricultural practices and efficient water resource management. The insights gained from this study indicate the application of modelling tools like CROPWAT 8.0 serves as a valuable approach for estimation of crop water requirements by using local climatic data. Such estimation will ensure in allocating water resource to different crops in an irrigation programme for better irrigation efficiencies and water productivity.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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