

Original Research Article

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Water Requirement and its Trend for Rice and Wheat Crops in Haryana State, India

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ABSTRACT

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Estimation of crop water requirement is essential for agricultural planning and irrigation scheduling. The aim of this study was to compute the water requirement of wheat and rice crops for all districts of Haryana. Climatic data on maximum and minimum temperature, rainfall, relative humidity, wind speed and solar radiation were used to estimate the reference evapotranspiration (ET_0) at different gridded locations by using Penman Monteith method in MATLAB software. Further, the actual evapotranspiration for rice crop grown in the region was estimated by multiplying the ET_0 with crop coefficient (K_c) values. Subsequently, the effective rainfall and the irrigation water requirement for wheat and rice crops at gridded points pertaining to different districts of Haryana were estimated. Thereafter the trend analysis was performed by using non parametric Mann Kendall test by using MATLAB software. Results indicated that water requirement (ET_C) of wheat was increasing significantly for eleven districts viz. Ambala, Bhiwani, Fatehabad, Hisar, Jind, Kurukshetra, Mahendargarh, Panchkula, Panipat, Sonipat and Yamunagar while in case of rice crop it was increasing significantly only for eight districts viz. Bhiwani, Fatehabad, Hisar, Sirsa, Jind, Kurukshetra, Panipat and Sonipat. This work can help in water management practices for better irrigation management.

Introduction

In India, decreasing water availability is one of the major problems over last few decades that could severely restrict agricultural development. Knowledge of the exact amount of water required by different crops in a given set of climatic conditions of a region is important for planning of irrigation schemes that requires accurate estimation of crop water requirement. Remote Sensing (RS) and Geographical Information System (GIS) techniques have emerged as powerful tools

for crop water management. Crop water requirement refers to the amount of water needed to compensate for the evapotranspiration loss from the field crop (Allen *et al.*, 1998). Supit *et al.*, (2010) analyzed trends for water demand, consumption, and deficit in field crops throughout Europe. Pakhale *et al.*, (2010) estimated the crop water requirement for wheat crop in Karnal district of Haryana and observed that wheat water requirement was higher in the vegetative and mid-season stage and shows decreasing trend towards the

maturity stage. In the study area it was found that irrigation water requirement highly correlated with crop water requirement due to absence of monsoon in rabi season (November to March). Singh *et al.*, (2010) reported that improper irrigation water management would make the rice-wheat cropping system of Haryana unsustainable with dwindling quantity and deteriorating quality of the ground water resources in the region. Singh *et al.*, (2013) estimated crop evapotranspiration for Cotton crop in Sirsa district of Haryana and reported that the spatial distribution of seasonal ET_c varied between 317 to 534 mm for growing season of cotton depending upon sowing date and other condition. Vibhute *et al.*, (2016) developed Crop Water Demand Based Water Delivery Schedule for a canal command for the Jhajjar distributary of western Yamuna canal command in Haryana, India and observed that the gross irrigation water requirement of wheat was 363.4 mm and that of rice was 1386 mm with effective rainfall depths of 55.8 and 461.8 mm during the wheat (rabi) and rice (kharif) growing seasons, respectively. Khandelwal and Dhiman (2017) estimated Net Irrigation

Requirement of different crops of Limbasi Canal command area, Gujarat and reported that estimated average NIR of 19 years for kharif crops paddy & vegetables was 229.8 & 92.9mm and for rabi crops sorghum, tobacco, wheat & vegetables was 355.5, 391, 427.2 & 407.1mm and hot weather crops paddy, pearl millet & vegetables was 863.9, 600.6 & 754.7 mm respectively. The Penman-Monteith method, which is recommended by FAO, has been widely used to calculate ET_o in recent years (Cai *et al.*, 2007; Yin *et al.*, 2008). Yadav *et al.*, (2019) calculated crop water requirement using Modified Penman Equation and Duty Delta method for present cropping pattern and reported that, approximately 50% of water could be saved

using modified Penman method compared to crop water requirement calculated using Duty Delta method. Tezera *et al.*, (2019) reported that the seasonal ET_c was found to be 52.2mm, 97.1mm, 191.5mm and 73.2mm of water calculated for initial, crop development, mid-season, and late-season stages, respectively. The measured crop coefficient (K_c) values were 0.54, 1.15 and 0.67 for the initial, mid and late stages, respectively. Some of the K_c values found slightly different from the average of FAO estimation.

Data on evapotranspiration is a fundamental requirement for develop in gannual irrigation plans and estimating the amount of water used in agricultural environments (Kuo *et al.*, 2011). Because most of the available water resources are used in agriculture, an accurate estimation of crop evapotranspiration helps in the efficient management of the limited water resources by irrigation associations (Cai *et al.*, 2007; Lovelli *et al.*, 2008). With the above background the aim of this study was to assess crop water requirement for wheat and rice crops in Haryana.

Materials and Methods

Study area

State is situated in the north western part of India, between 27°39' to 30°55.5' N latitude and 74°27.8' to 77°36.5' E longitude. Total area of the state is 44212 km² which constitutes about 1.35% of total geographical area of the country. The height above mean sea level is generally 200 to 300 m in about 90% of the area, which rises to 450 m in southern part with Aravalli hills and more than 1000 m in north eastern parts with Siwalik Hills. Temperature regime over the entire state area is hypothermic as the mean annual, mean summer and mean winter air temperatures are 26.3°C, 33.3°C and 16.2°C, respectively.

Data acquisition

Gridded climatic data (1° x 1°) on maximum and minimum temperature, rainfall, relative humidity, wind speed and solar radiation downloaded for a period from 1st January 1985 to 31st December 2015 from secondary sources of NASA Climatology Resources for Agro-climatology. Available climatic parameters were further used to estimate the reference evapotranspiration (ET₀) at different gridded locations by using Penman Monteith method in MATLAB software.

Further, the actual evapotranspiration for wheat and rice crop grown in the region was estimated by multiplying the ET₀ with crop coefficient (K_c) values. Thereafter the trend analysis was performed by using non parametric Mann Kendall test by using MATLAB software. The Penman-Monteith equation used for estimation of reference evapotranspiration (ET₀) is given by:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where

ET₀ = reference evapotranspiration [mm day⁻¹]
 R_n = net radiation at the crop surface [MJ m⁻² day⁻¹]

G = soil heat flux density [MJ m⁻² day⁻¹]

T = mean daily air temperature at 2 m height [°C]

u₂ = wind speed at 2 m height [m s⁻¹]

e_s = saturation vapour pressure [kPa]

e_a = actual vapour pressure [kPa]

[e_s - e_a] = saturation vapour pressure deficit [kPa]

Δ = slope vapour pressure curve [kPa °C⁻¹]

γ = psychrometric constant [kPa °C⁻¹]

Crop water requirement is estimated from the

product of ET₀ multiplied by the crop coefficient. Crop coefficient values of wheat and rice are shown in Fig.1.

$$CWR = K_c * ET_0$$

Results and Discussion

Crop water requirement of rice and wheat crops were estimated and spatial variability maps were developed for the year 1990, 1995, 2000, 2005, 2010 and 2015 using the GIS software ArcMap10.1. Trend analysis was performed by using non parametric Mann Kendall test by using MATLAB software.

Crop water requirement of wheat and rice

The result indicated that water requirement (ET_C) of wheat was increasing significantly for eleven districts viz. Ambala (Sen's slope 2.77), Bhiwani (Sen's slope 3.08), Fatehabad (Sen's slope 3.26), Hisar (Sen's slope 3.24), Jind (Sen's slope 2.51), Kurukshetra (Sen's slope 2.50), Mahendargarh (Sen's slope 2.16), Panchkula (Sen's slope 3.09), Panipat (Sen's slope 2.14), Sonapat (Sen's slope 2.51) and Yamunagar (Sen's slope 3.35) but for other remaining districts no significant trend was observed (Table 1). The crop water requirement for Ambala, Fatehabad, Panchkula and Yamunagar was found less than 500 mm and only for Faridabad it was observed higher which was found between the range 550-600 mm and for other remaining five districts it was noticed between the ranges 500-550 mm in the year 1990. During the year 2000 Yamunagar was the only district which was observed with the crop water requirement less than 500 mm. Mahendargarh and Faridabad were found between the range 550-600 mm and the other remaining eight districts were observed between the range 500-550 mm.

Table.1 Trend test statistics and interpretation of crop water requirement of wheat

Mann-Kendall test					
Districts Name	Kendall's tau	p-value (Two-tailed)	Sen's slope	Test interpretation	Significance
Ambala	0.25	0.04	2.77	Trend increasing	S
Bhiwani	0.24	0.05	3.08	Trend increasing	S
Fatehabad	0.33	0.00	3.26	Trend increasing	S
Hisar	0.33	0.00	3.24	Trend increasing	S
Kaithal	0.24	0.06	2.18	Trend increasing	NS
Karnal	0.24	0.06	2.18	Trend increasing	NS
Rohtak	0.22	0.08	1.89	Trend increasing	NS
Palwal	0.08	0.54	0.68	Trend increasing	NS
Sirsa	0.27	0.03	3.33	Trend increasing	NS
Faridabad	0.09	0.49	0.73	Trend increasing	NS
Gurgaon	0.23	0.07	1.94	Trend increasing	NS
Jhajjar	0.20	0.16	1.65	Trend increasing	NS
Jind	0.27	0.03	2.51	Trend increasing	S
Kurukshetra	0.27	0.03	2.50	Trend increasing	S
Mahendergarh	0.26	0.04	2.16	Trend increasing	S
Panchkula	0.28	0.03	3.09	Trend increasing	S
Panipat	0.25	0.06	2.14	Trend increasing	S
Rewari	0.14	0.34	1.05	Trend increasing	NS
Sonipat	0.27	0.03	2.51	Trend increasing	S
Yamunanagar	0.33	0.01	3.35	Trend increasing	S

*S-significant NS-not significant

Table.2 Trend test statistics and interpretation of crop water requirement of rice

Mann-Kendall test					
Districts Name	Kendall's tau	p-value (Two-tailed)	Sen's slope	Test interpretation	Significance
Ambala	0.11	0.37	2.34	Trend increasing	NS
Bhiwani	0.32	0.01	7.64	Trend increasing	S
Fatehabad	0.34	0.008	7.05	Trend increasing	S
Hisar	0.34	0.008	7.04	Trend increasing	S
Kaithal	0.23	0.06	4.81	Trend increasing	NS
Karnal	0.23	0.06	4.81	Trend increasing	NS
Rohtak	0.21	0.09	3.84	Trend increasing	NS
Palwal	0.14	0.25	2.91	Trend increasing	NS
Sirsa	0.38	0.003	10.96	Trend increasing	S
Faridabad	0.17	0.19	3.70	Trend increasing	NS
Gurgaon	0.24	0.06	4.55	Trend increasing	NS
Jhajjar	0.24	0.06	4.55	Trend increasing	NS
Jind	0.26	0.04	5.43	Trend increasing	S
Kurukshetra	0.25	0.05	4.63	Trend increasing	S
Mahendergarh	0.24	0.06	4.53	Trend increasing	NS
Panchkula	0.12	0.34	2.94	Trend increasing	NS
Panipat	0.26	0.04	5.43	Trend increasing	S
Rewari	0.24	0.06	4.55	Trend increasing	NS
Sonipat	0.26	0.04	5.43	Trend increasing	S
Yamunanagar	0.11	0.40	1.84	Trend increasing	NS

Fig.1 Crop coefficient values of wheat and rice

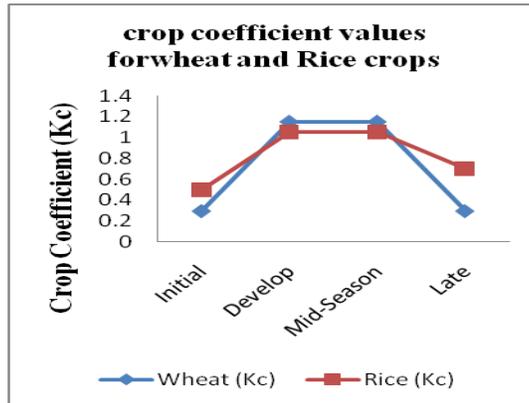


Fig.2 Spatial variation of crop water requirement of wheat

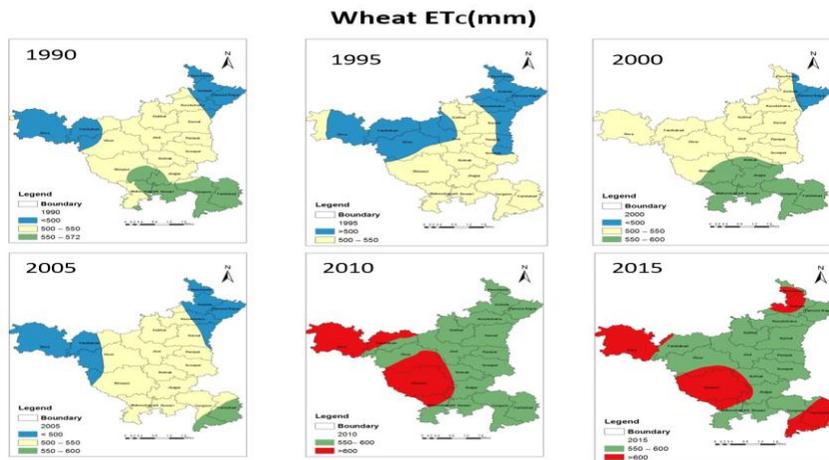
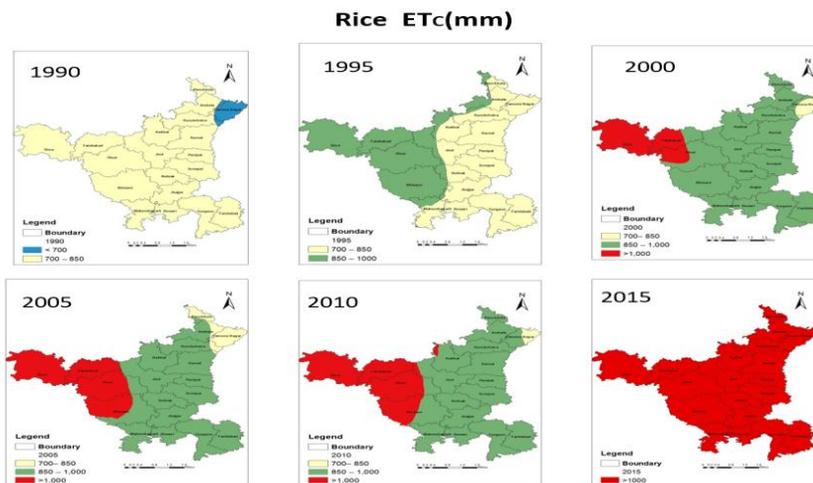


Fig.3 Spatial variation of crop water requirement of rice



In the year 2010 only Bhiwani was the only district which was found more than 600 mm and the other remaining districts were found between the range 550-600 mm. Among all eleven districts crop water requirement for Panchkula, Ambala, Bhiwani and Faridabad were observed more than 600 mm and the remaining districts were found between the range 550-600 mm during 2015 as shown in Fig.2.

Crop water requirement (ET_C) of rice was increasing significantly only for eight districts viz. Bhiwani (Sen's slope 7.6), Fatehabad (Sen's slope 7.05), Hisar (Sen's slope 7.04), Sirsa (Sen's slope 10.9), Jind (Sen's slope 5.4), Kurukshetra (Sen's slope 4.6), Panipat (Sen's slope 5.4) and Sonipat (Sen's slope 5.4) but for other remaining districts no significant trend was observed (Table.2). The crop water requirement for all eight districts was found between the ranges 700-850 mm during the year 1990. Among all eight districts crop water requirement for Sirsa and Fatehabad was observed more than 1000 mm and the remaining six districts were found between the ranges 850-1000 mm in the year 2000. During the year 2010 ET_C was found more than 1000 mm for Sirsa, Fatehabad, Hisar and Bhiwani districts but in the year 2015 more than 1000 mm crop water demand was noticed for all districts (Fig.3)

The study shows that the crop water requirement for rice and wheat crops is increasing with the passage of time. The results obtained from the study can be used as a guide by farmers for selecting the amount and frequency of irrigation water for wheat and rice crops. Irrigation requirement will vary based on the availability of rainfall. Therefore, it is further suggested that water saving practices or techniques for water conservation should be adopted for irrigation on rice and wheat crops.

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