

Original Research Article

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Prediction of Rice Water Requirement Using FAO-CROPWAT-8.0 Model in Dehradun, Uttarakhand, India

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Insufficient water supply is one of the most important factor governing agricultural productions. In addition to rainfall, a thorough knowledge of seasonal values of evaporation and crop transpiration, runoff, deep drainage and soil water storage is required to estimate the water need of crop. Water management is crucial to rightly offer and economize on water use in improvement of rice productivity. This paper aims to estimate Rice water requirement and irrigation water requirement in Dehradun district, based on the New Loc-Clim projected meteorological data. Rice water requirements are estimated by using crop coefficient approach. Reference evapotranspiration are calculated by FAO Penman-Monteith method. Moreover, the irrigation water requirements are simulated by calibrated CROPWAT-8.0 model using the meteorological parameters.

Introduction

Water demand has been growing rapidly due to population growth and increasing living standards and as a result, water shortage has become serious problem which have made it necessary to improve integrated technology and multidisciplinary water resources management capabilities. Proper water management practices are the need of the day to enhance food production while save water as much possible or in other words to increase water use efficiency of field crops. Besides the increasing demand of water for other

purposes (industry and domestic use), degradation of water quality will also limit the water availability for agriculture sector in the coming future (FAO, 56). So the only tool to overcome this phenomenon is enhancing the water use efficiency, it is also usually termed as water productivity. In many countries, particularly in India, water for agriculture is becoming increasingly scarce and serious water shortages are developing in the light of growing water demands from different sectors (IWMI 2010). Agriculture is the largest (81%) consumer of water (an essential input for crop production) and hence more efficient use of

water in agriculture needs to be top most priority in India (Surendran *et al.*, 2013). For the accurate planning and delivery of the necessary amount of the water in the time and space can conserve water. A scarce water resources and growing competitions for water will reduce its availability for irrigation. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. Prediction of the crop water requirement is of vital importance in water resources management. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm day^{-1} or mm period^{-1} . One of the major practices adopted by the researchers for estimating water requirement of crops is modelling. For determination of crop evapotranspiration and yield responses to water, CROPWAT-8.0 model is used which was developed by the FAO Land and Water Development Division (FAO 1992). It includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions based on well-established methodologies. Several researchers have used the model for analyzing crop water requirements in different parts of the world (Kar and Verma, 2005; Martyniak *et al.*, 2006; Dechmi *et al.*, 2003). The irrigation schedule recommendations for various crops should be location-specific, considering the soil types and agro-ecological conditions.

Materials and Methods

Study Area

Dehradun is one of the districts of Uttarakhand State of India. The district, located at 30.19°N latitude and 78.04°E longitude, comes under West Himalayan Region (I) with the cultivated area of 49.9×10^3 ha, as per the classification of Agro-

climatic zone by planning commission. The average normal annual rainfall of this area is about 2065.7 mm. The location map of the study area has been shown in fig 1.

Crop data

The major field crops in study area are Rice, Wheat, Barley, Maize, Arhar, Gram, Lentil, etc., fruit crops are: Apple, Pear, Peach, Plum, Apricot, Walnut, Citrus, Walnut, Mango, Litchi, Aonla and Guava. In this research for estimating the irrigation water requirement, the guidelines of Ministry of Irrigation, G.O.I and FAO, has been followed for using the salient details of crops considered for the study.

Metrological data

Metrological data given in Table 1, 2 and Figure 2.

CROPWAT-8.0 Model

The Model is a freeware for the calculation of crop water requirements based on soil, climate and crop data and existing or new irrigation climate data and crop needs (Doorenbos and Pruitt, 1976, 1977). In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of the supply system of the variety of cropping patterns. The model really helps irrigation engineers to analyze the use of crop water of an irrigation system with the different culture and can provide data that are essential for the design of channel. CROPWAT-8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions (Adriana and Cuculeanu, 1999). All procedures of calculation in CROPWAT-8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No.

56 “Crop Evapotranspiration – Guidelines for computing crop water requirements” and No. 33 titled “Yield response to water”.

Reference evapotranspiration

This parameter was calculated in CROPWAT-8.0 Model which uses the FAO Penman-Monteith method (Allen *et al.*, 1998). In this model, most of the equation parameters are directly measured or can be readily calculated from weather data.

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

Where, ET_0 is reference evapotranspiration (mm day^{-1}), R_n is net radiation at the crop surface ($\text{MJ m}^{-2} \text{day}^{-1}$), G is soil heat flux density ($\text{MJ m}^{-2} \text{day}^{-1}$), T is air temperature at 2 m height ($^{\circ}\text{C}$), u_2 is wind speed at 2 m height (m s^{-1}), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), $e_s - e_a$ is saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve ($\text{kPa } ^{\circ}\text{C}^{-1}$), γ is psychometric constant ($\text{kPa } ^{\circ}\text{C}^{-1}$).

Effective rainfall

It is the part of rainfall which is stored in the soil profile and helps in the growing of crops. Rainfall of Dehradun district is depicted in table no. 2. To calculate the effective rainfall the USDA Soil Conservation Service method was used (Smith, 1991), using the following equations:-

$$P_{\text{eff}} = P_{\text{tot}} \times (125 - 0.2P_{\text{tot}}) / 125 \quad \text{for } P_{\text{tot}} < 250^{\text{mm}}$$

$$P_{\text{eff}} = 125 + 0.1 \times P_{\text{tot}} \quad \text{for } P_{\text{tot}} > 250^{\text{mm}}$$

Where, P_{eff} represents effective rainfall (mm) and P_{tot} represents total rainfall (mm)

Crop Evapotranspiration

Crop coefficient approach is used by CROPWAT-8.0 Model for calculation of crop evapotranspiration and estimates by summing up the crop evapotranspiration in all growth stages, using the following equation:-

$$ET_{\text{crop}} = K_c \times ET_0$$

Where, ET_c represents crop evapotranspiration, K_c represents crop coefficient and ET_0 represents reference evapotranspiration.

Results and Discussion

Reference evapotranspiration

The simulated values of reference evapotranspiration (ET_0) through CROPWAT-8.0 model using Penman-Monteith equation along with the meteorological parameters for Dehradun district, is presented in table no. 1 and monthly distribution of Reference evapotranspiration is shown in the fig. 2. From the result, it is revealed that the maximum ET_0 was found high in the month of may (5.28mm/day), which is mainly due to high temperature and wind velocity, whereas it is minimum in the month of January (1.43 mm/day).

Effective Rainfall

The effective rainfall was calculated for the study area with the help of USDA, SCS method which is presented in table no.2 and fig. no. 3. This will help for the estimation of irrigation water requirement of Rice crop for the same area. From the analysis, it is found that the maximum effective rainfall is in month of the July (170.3 mm) and minimum in the month of December (22.3 mm).

Table.1 Reference evapotranspiration and meteorological parameters for the study area

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m ² /day	ETo mm/day
Jan	6	19.1	79	35	6.7	12.2	1.43
Feb	8.1	21.3	69	52	7	14.6	2.02
Mar	12.3	26.3	56	52	7.3	17.6	2.94
April	17	32	40	69	8.6	21.6	4.36
May	21.5	36.2	40	69	9.1	23.4	5.28
Jun	23.6	35.2	55	52	7.2	20.9	4.87
Jul	23.1	30.3	87	35	3.3	15	3.37
Aug	22.7	29.5	91	35	2.9	13.6	2.98
Sept	21.2	29.6	86	35	5.8	16.2	3.33
Oct	16.1	28.2	76	52	8.4	17	3.1
Nov	10.3	24.7	78	52	7.6	13.5	2.1
Dec	7	20.8	80	35	7.1	11.9	1.47
Avg.	15.7	27.8	70	48	6.8	16.4	3.1

Source: New Loc-Clim Software

Table.2 Month-wise Rainfall (mm) and Effective rainfall (mm)

Month	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rain (mm)	60	43	67	27	54	161	453	445	248	108	29	23	1718
Eff rain (mm)	54.2	40	59.8	25.8	49.3	119.5	170.3	169.5	149.6	89.3	27.7	22.2	977.3

Table.3 Monthly water requirement of rice crop in Dehradun district

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice	0	0	0	0	0	78.3	98	0	0	15.8	12.3	0

Table.4 Net scheme irrigation required

Net scheme irr.req.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
in mm/day	0	0	0	0	0	2.6	3.2	0	0	0.5	0.4	0
in mm/month	0	0	0	0	0	78.3	98	0	0	15.8	12.3	0
in l/s/h	0	0	0	0	0	0.3	0.37	0	0	0.06	0.05	0

Table.5 Net scheme irrigation required

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigated area(%)	0	0	0	0	0	100	100	0	0	100	100	0
Actual area (000Ha)	0	0	0	0	0	11.4	11.4	0	0	11.4	11.4	0
MCM	0	0	0	0	0	8.9	11.2	0.0	0.0	1.8	1.4	0

Table.6 Rainfall pattern of Dehradun district

Average Rainfall (mm)					
District	SW monsoon (June-Sep)	NE Monsoon (Oct-Dec)	Winter (Jan- March)	Summer (April-May)	Annual
Dehradun	1767.6	86.8	147.6	63.7	2065.7

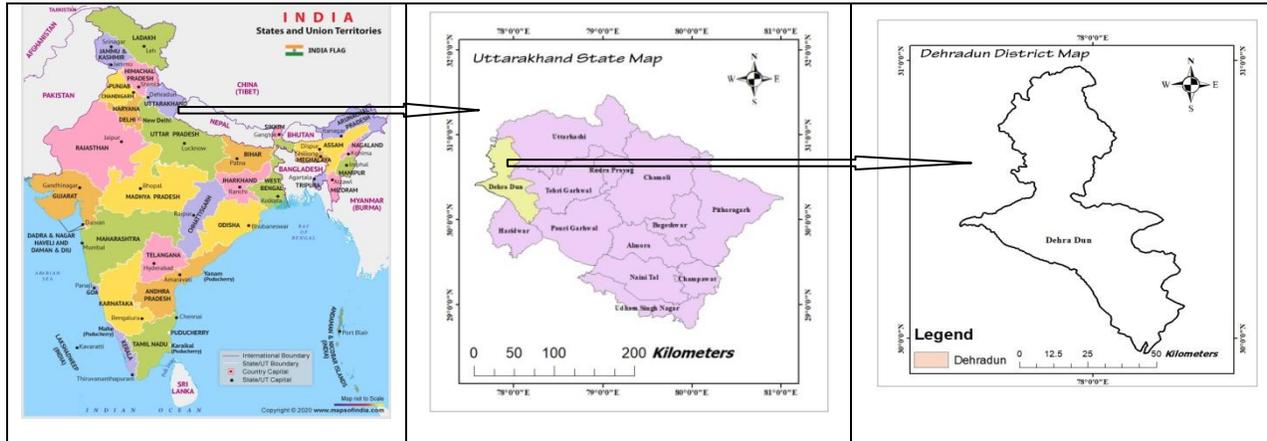


Fig.1 Location map of Dehradun District

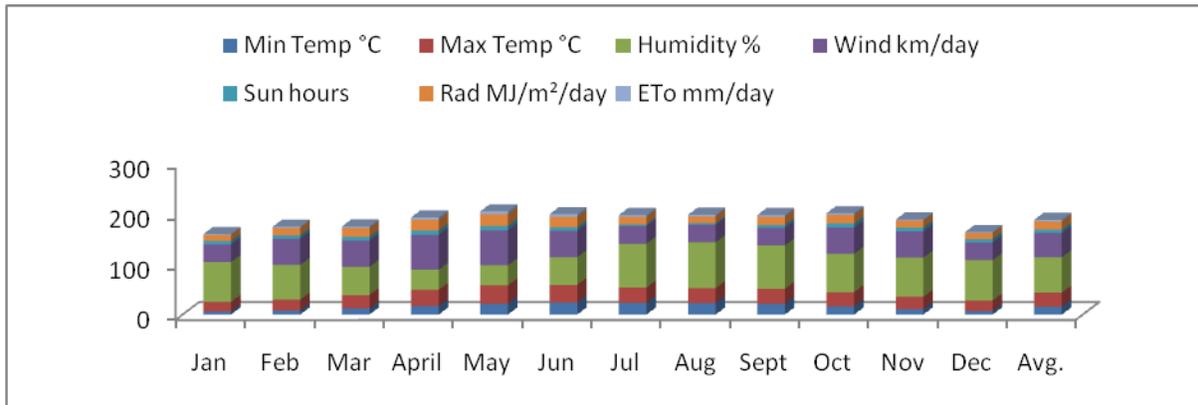


Fig.2 Monthly distribution of Reference evapotranspiration

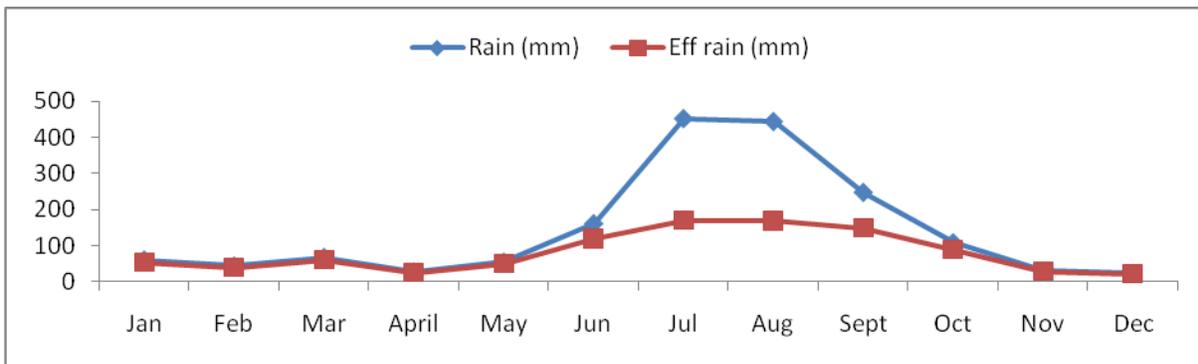


Fig.3 Month v/s Rainfall (mm) and Effective rainfall (mm)

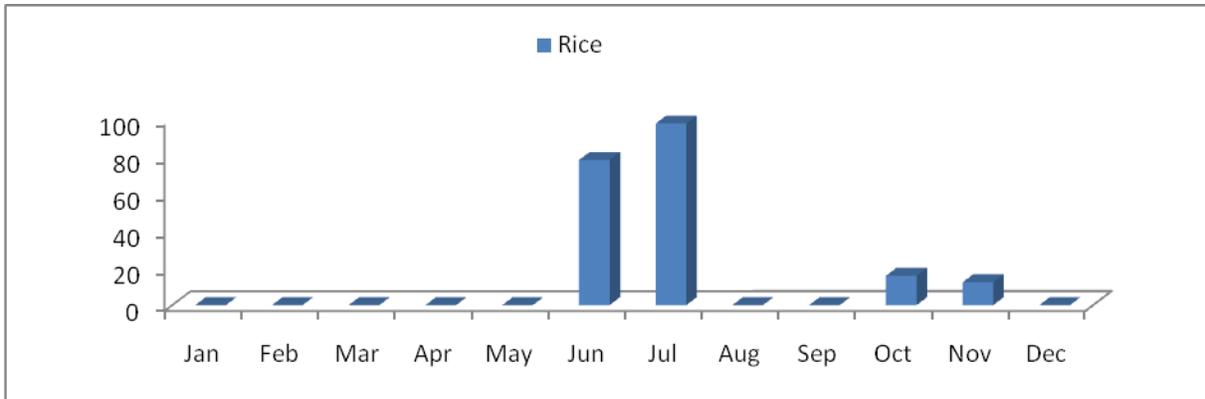


Fig.4 Month-wise crop water requirement of Rice Crop in Dehradun District

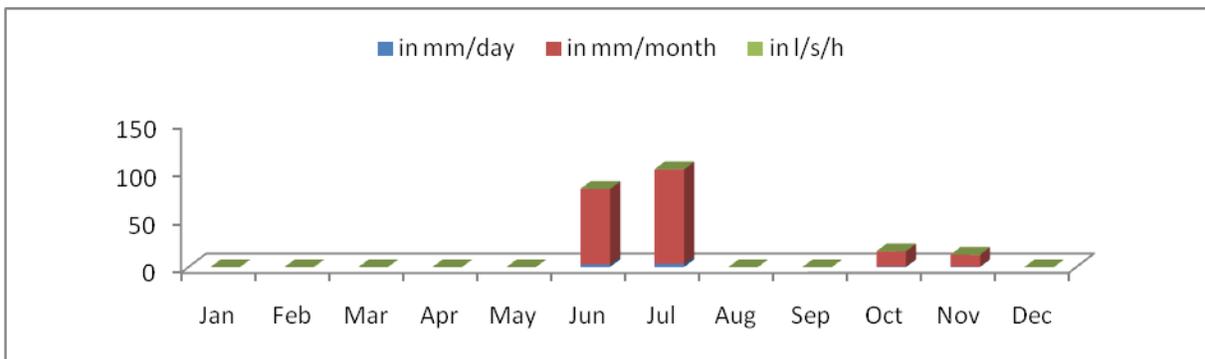


Fig.5 Net Scheme of Irrigation Required

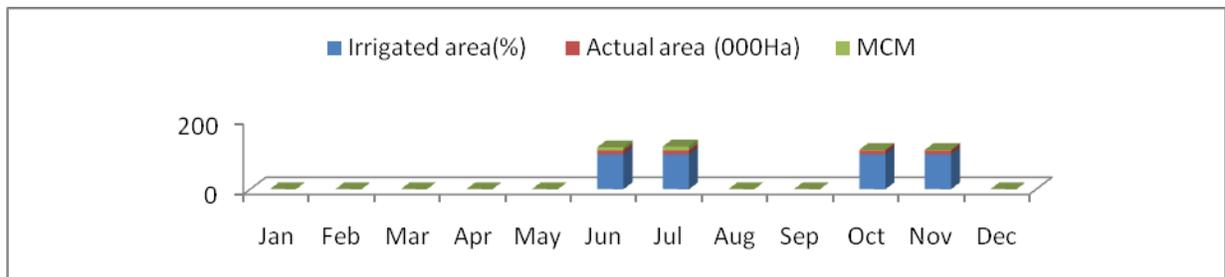


Fig.6 Net Scheme of Irrigation Required

Crop Water Requirement

The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). In simple form, the crop water need (ET crop) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. The water need is particularly function of the parameters

as: - (i) the climate; in a sunny and hot climate crops need more water per day than in a cloudy and cool climate (ii) the crop type; crops like maize or sugarcane need more water than crops like millet or sorghum (iii) the growth stage of the crop; fully grown crops need more water than crops that have just been planted. Apart from sunshine and temperature, other climatic factors like wind velocity and humidity also influence the crop water need. Estimated Crop water requirement of Rice crop for Dehradun

district in different months has been presented in table no.3 and the water demand of crops presented in the fig 4. The results show that the crop water requirement is more in the month of July followed by June month, for the study area, indicating high reference evapotranspiration in the same periods. This water demand for the crop will help in water management in the study area also assist in the scheduling of irrigation.

In conclusion, the research outcomes will provide a platform for efficient planning of water management and ultimately for increasing the water use efficiency. In other words, this research will help in the understanding the behaviour of weather parameter on reference evapotranspiration as well as in calculating net irrigation water requirement of rice crop in dehradun district.

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