

Original Research Article

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Estimation of Irrigation Scheduling for Different Cropping Pattern at Different Growth Stage of Crop by using the CROPWAT Model

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ABSTRACT

Keywords

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The available water decreases as world demand for water increases for various purposes such as industrial, agriculture hydropower. To improve the water use efficiency, there is a need to modify traditional irrigation scheduling. In the present study, the CROPWAT model was used to estimation the irrigation scudding for rice and cotton crop to improve water use efficiency. From the analysis, it was found that reference evapotranspiration was almost directly proportional to the radiation and sunshine hours and inversely proportional to the relative humidity. The crop evapotranspiration, effective rainfall and the crop water requirement varied from 0.74 -5.57 mm/day, 0.1-55.1 mm/dec and 0-157 mm/dec, respectively. The CROPWAT model appropriately estimate the reference evapotranspiration, effective rainfall and other parameter for irrigation scheduling, which makes this model as a best tool for irrigation planning and management for all crop and climatic condition.

Introduction

Rice is the stable food for all most half of the world population. The rice crop approximately consumes two to five time more water as compare to other cereal crop. In northern India next to rice cotton crop also consider a major crop. In traditional rice method, 5-15 cm of standing water was maintained throughout the rice growing season and consume 50-300 cm to total seasonal water (Bouman and Tuong, 2001). Whereas, 60-90 cm of water applied throughout the growing season for cotton crop (Sankaranarayanan *et al.*, 2007). The global irrigation water is declining with increasing

the demand of water due to growing population for various purpose such as industrial, agriculture hydropower. The irrigation practice uses about 80% of the total available water resource of the area, out of which 70% of irrigation water is lost as deep percolation, because of poor management practices and only 30% of water was used by plant (Feng *et al.*, 2007). Whereas, Shah *et al.*, (2015) documented that about 40-60% of water used by plant and rest of water lost from the field (evapotranspiration, deep percolation, etc.). The production can be increased by improving the irrigation scheduling method. Increase the crop production with these

limited water resource is the challenge for coming decades. Therefore, there is a need to modified traditional irrigation scheduling.

A well management of irrigation water involves precise irrigation scheduling which involves when to irrigate and how much to irrigate. The proper irrigation scheduling promote application of water at right time with right quantity in order to improve water use efficiency and productivity. Insufficient irrigation or over irrigation could be responsible to reduce crop yields, quality, and poor nutrient use efficiency (Shah *et al.*, 2015). However, accurate estimation of the crop water requirement is necessary to determine when and how much to irrigate. The irrigation scheduling plays a major role to increase the water use efficiency. Jones (2004) documented that slight moisture deficiency of plant (irrigation scheduling) can improves the plant growth and plant productivity. But irrigation scheduling still has been not widely adopted: many of these are based on sensing the plant response to water deficits rather than sensing the soil moisture status directly (Jones, 1990: Jones, 2004).

The water use efficiency can be increased by optimizing three factor such as specific amount of water applied, timing of the application, and efficiency of the irrigation method. Shah *et al.*, (2015) documented that about 40-60% of water used by plant and rest of water lost from the field (evapotranspiration, deep percolation, etc). These water losses can be minimized by irrigation scheduling. The irrigation scheduling is important to understand the behavior of crop growth and productivity with water flow. Mathematical models could be a good tool to understand the crop behavior and to decide when to irrigate and how much to irrigate without conducting expensive and time-consuming field experiments. The CROPWAT model is an irrigation

management tool which is based on crop, soil and climate parameters (major parameters). The CROPWAT model was devolved by the Land and Water Development Division of Food and Agriculture Organization of the United States. CROPWAT model estimates the reference evapotranspiration, crop evapotranspiration, irrigation scheduling, and agricultural water requirements for different crops (Nazeer, 2009). The crop evapotranspiration, crop water requirement and scheduling are difficult to obtained during the field experiment. Therefore, irrigation scheduling model is necessary to increase the irrigation efficiency and crop productivity. The objective of the study was to analyze the reference evapotranspiration and effective rainfall for the study area and to simulate the irrigation scheduling for rice and cotton crop by using CROPWAT model.

Materials and Methods

Study area

The study area comprises of Lucknow district, Utter Pradesh, India (Fig. 1), the site receives average annual rainfall of 992 mm. The average maximum and minimum temperature was 19.4 and 32.3°C, respectively. The average annual wind speed, humidity and radiation were 52 km/day, 58% and 18.5 MJ/m²/day, respectively.

Data collection

The meteorological data such as rainfall, maximum and minimum temperature, wind speed, humidity, sunshine hour and radiation was collected from the customized rainfall information system (CRIS), climate data website and climate2.0for CROPWAT model. The crop and soil parameter initially taken from the publish literature (Ko *et al.*, 2009; Montazar *et al.*, 2017; Gill *et al.*, 2017) and optimized during the modeling.

CROPWAT model and setup

CROPWAT model (Smith, 1992) is a decision supporting tool developed by water development division of FAO in computer programming language for calculating crop water requirement using soil, crop and climatic data.

Reference evapotranspiration

Penman–Monteith equation was used in CROPWAT model for calculating daily reference evapotranspiration (ET_0). The daily reference evapotranspiration (Allen *et al.*, 2006) was expressed by:

$$ET_0 = \frac{0.408 \Delta R_n + \gamma \left(\frac{900}{T_{mean} + 273.15} \right) u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_2)} \quad (1)$$

Where, R_n is the net radiation at the crop surface ($MJ/m^2/day$), T_{mean} is the mean of the daily maximum and minimum temperature ($^{\circ}C$), u_2 is the wind speed at slanted 2 m height (m/s), e_s is the saturation vapor pressure (kPa), e_a is actual vapor pressure (kPa), Δ is the slope of vapor pressure curve ($kPa/^{\circ}C$), and γ is the psychrometric constant ($kPa/^{\circ}C$).

Effective rainfall

The CROPWAT model determines the effective rainfall based on rainfall data. The effective rainfall is a portion of rainfall which is effectively used by plant. This effective rainfall was used to determine the irrigation requirement. The effective rainfall was determined by based on four methods, which is expressed as:

Fixed percentage method

In this method some threshold value was fixed to decide an effective rainfall.

Dependable rainfall

$$Effective\ rainfall = 0.6 \times rainfall - 10/30 \quad for\ rainfall \leq 70/3\ mm \quad (2)$$

$$Effective\ rainfall = 0.8 \times rainfall - 24/30 \quad for\ rainfall > 70/3\ mm \quad (3)$$

Empirical formula

$$Effective\ rainfall = 0.5 \times rainfall + 0.5/3 \quad for\ rainfall \leq 50/3\ mm \quad (4)$$

$$Effective\ rainfall = 0.7 \times rainfall + \frac{20}{3} \quad for\ rainfall > 50/3\ mm \quad (5)$$

USDA soil conservation service

$$Effective\ rainfall = (rainfall \times (125 - 0.2 \times 3 \times rainfall)) / 125 \quad for\ rainfall \leq 250/3\ mm \quad (6)$$

$$Effective\ rainfall = 125/3 + 0.1 \times rainfall \quad for\ rainfall \leq 250/3\ mm \quad (7)$$

Crop and soil parameter

The crop and soil parameters such as crop coefficient, root length, ponding depth, transplanting date, harvesting date, field capacity, permanent wilting point were given as an input shown in Figure 2. These inputs also play an important role to decide an irrigation interval or crop water requirement.

Crop pattern

During the present manuscript the pattern of crop was selected rice and cotton for estimation of irrigation scheduling or crop water requirement.

Results and Discussion

Effective rainfall

Figure 3 shows variation of effective rainfall and rainfall with time. It evident from the Figure 3 that rainfall was less in non-rainy season (month of Nov-May) as compare to rainy season. Therefore, during the non-rainy season effective rainfall was almost equal to the rainfall due to less runoff, deep percolation, and seepage losses. Whereas, in

rainy season the effective rainfall was 7-49% less as compare to the rainfall due to the more losses.

maximum variation of sunshine hour and radiation.

Reference evapotranspiration

Figure 4 shows variation of reference evapotranspiration with time. The reference evapotranspiration was minimum in January and February month, and reached its peak during the month of March-October and further decline during the month of November and December. The reference evapotranspiration was varied from 1.8 (January) to 6.08 (May) mm/day presented in Figure 4. It is evident from the Figure 4a and 4b, the reference evapotranspiration was directly proportional to the radiation and sunshine hours. Whereas, it was inversely proportional to the relative humidity (Fig. 4d). From the Figure 4e and 4f, it is shown that the evapotranspiration was linearly increased with increase in temperature up to June month and then further decreased randomly due to the

Irrigation requirement

Table 1 shows the variation of crop evapotranspiration and irrigation requirement with time for rice and cotton crop. It is evident from the Table 1 that crop evapotranspiration (ETc) was less at initial stage, increased at the mid stage and declined at late stage. Shah *et al.*, 2015 had also reported that the crop evapotranspiration (ETc) was less at initial stage, increased at the mid stage and declined at late stage. The crop evapotranspiration was followed the same pattern as reference evapotranspiration (Fig. 4). It is also evident from the Table 1 that irrigation was applied, when there was less or no rainfall. The crop evapotranspiration, effective rainfall and the crop water requirement varied from 0.74 -5.57 mm/day, 0.1-55.1 mm/dec and 0-157 mm/dec, respectively (Table 1).

Table.1 Variation of crop evapotranspiration and irrigation requirement for rice and cotton crop

Rice					Cotton				
Month (Decade)	K _c	Et _c , mm/day	Effective rain, mm/dec	Irrigation Requirement, mm/dec	Month (Decade)	K _c	Et _c , mm/day	Effective rain, mm/dec	Irrigation Requirement, mm/dec
Jun (1)	1.05	0.74	11.3	0	Jul(2)	0.31	1.13	27.6	0
Jun(2)	1.05	4.14	26.3	157	Jul(3)	0.31	1.12	54	0
Jun(3)	1.05	5.57	34.8	121	Aug(1)	0.31	1.14	52.5	0
Jul(1)	1.05	4.76	45.6	1.9	Aug(2)	0.35	1.25	52.9	0
Jul(2)	1.1	4.01	55.1	0	Aug(3)	0.54	1.97	49.6	0
Jul(3)	1.1	3.99	54	0	Sep(1)	0.73	2.77	47.9	0
Aug(1)	1.1	4.05	52.5	0	Sep(2)	0.92	3.58	46.1	0
Aug(2)	1.1	3.96	52.9	0	Sep(3)	1.1	4.18	34.9	7
Aug(3)	1.11	4.08	49.6	0	Oct(1)	1.16	4.28	20.9	21.9
Sep(1)	1.11	4.19	47.9	0	Oct(2)	1.16	4.17	9.9	31.8
Sep(2)	1.11	4.3	46.1	0	Oct(3)	1.16	3.76	6.7	34.7
Sep(3)	1.11	4.2	34.9	7.1	Nov(1)	1.16	3.35	0.9	32.6
Oct(1)	1.09	4.03	20.9	19.4	Nov(2)	1.16	2.94	0	29.4
Oct(2)	1.04	3.74	9.9	27.5	Nov(3)	1.14	2.63	0.2	26.2
Oct(3)	0.98	3.19	6.7	28.4	Dec(1)	1.02	2.14	1.1	20.3
Nov(1)	0.95	2.75	0.1	2.7	Dec(2)	0.9	1.68	1.4	15.3
					Dec(3)	0.77	1.42	3.5	12.1
					Jan(1)	0.64	1.16	6.5	5.1
					Jan(2)	0.57	1.02	0.9	1

Table.2 Variation of irrigation scheduling with time

Precipitation deficit		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice		0	0	0	0	0	140.7	143.3	21.2	7.1	79.7	19.5	0.0
COTTON		3.3	0	0	0	0	0.0	0.0	0.0	6.9	87.4	86.8	44.5
Net scheme irr.req.	(mm/day)	0.1	0	0	0	0	2.3	2.3	0.6	0.2	2.7	1.8	0.7
	(mm/month)	1.7	0	0	0	0	70.4	71.6	18.0	7.0	83.6	53.1	22.3
	(l/s/h)	0.01	0	0	0	0	0.2	0.2	0.1	0.03	0.3	0.2	0.1
Irr.req. for actual area, (l/s/h)		0.01	0	0	0	0	0.54	0.53	0.06	0.03	0.31	0.2	0.17

Fig.1 Location map of study area



Fig.2 Crop and soil parameter with different growth stage

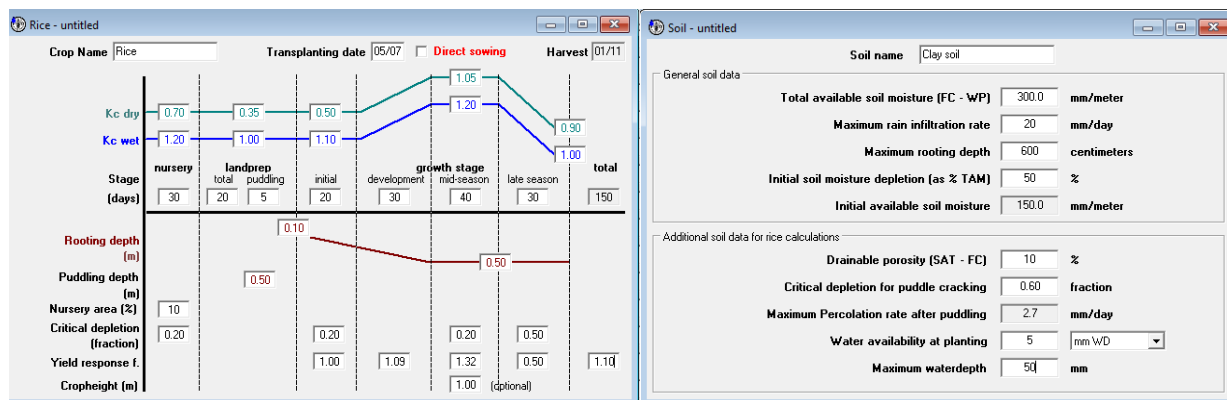


Fig.3 Monthly variation of effective rainfall and rainfall

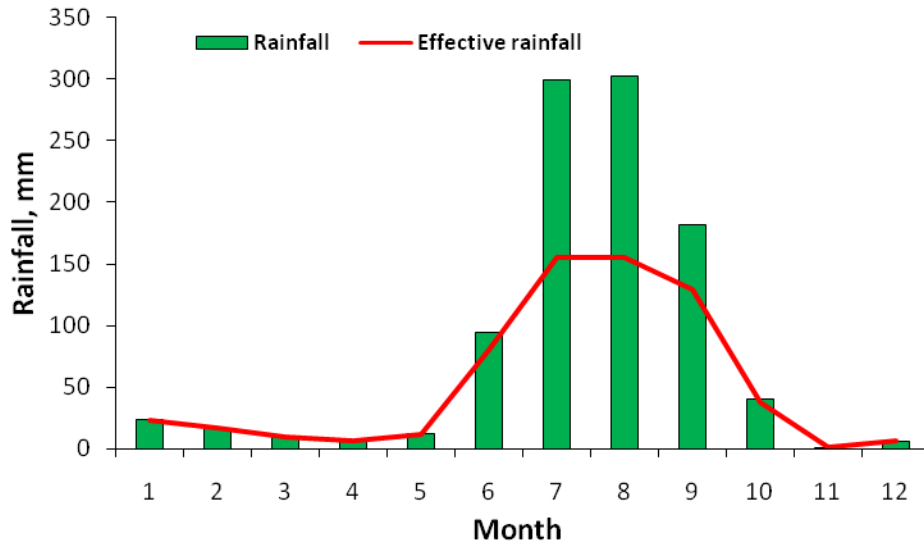
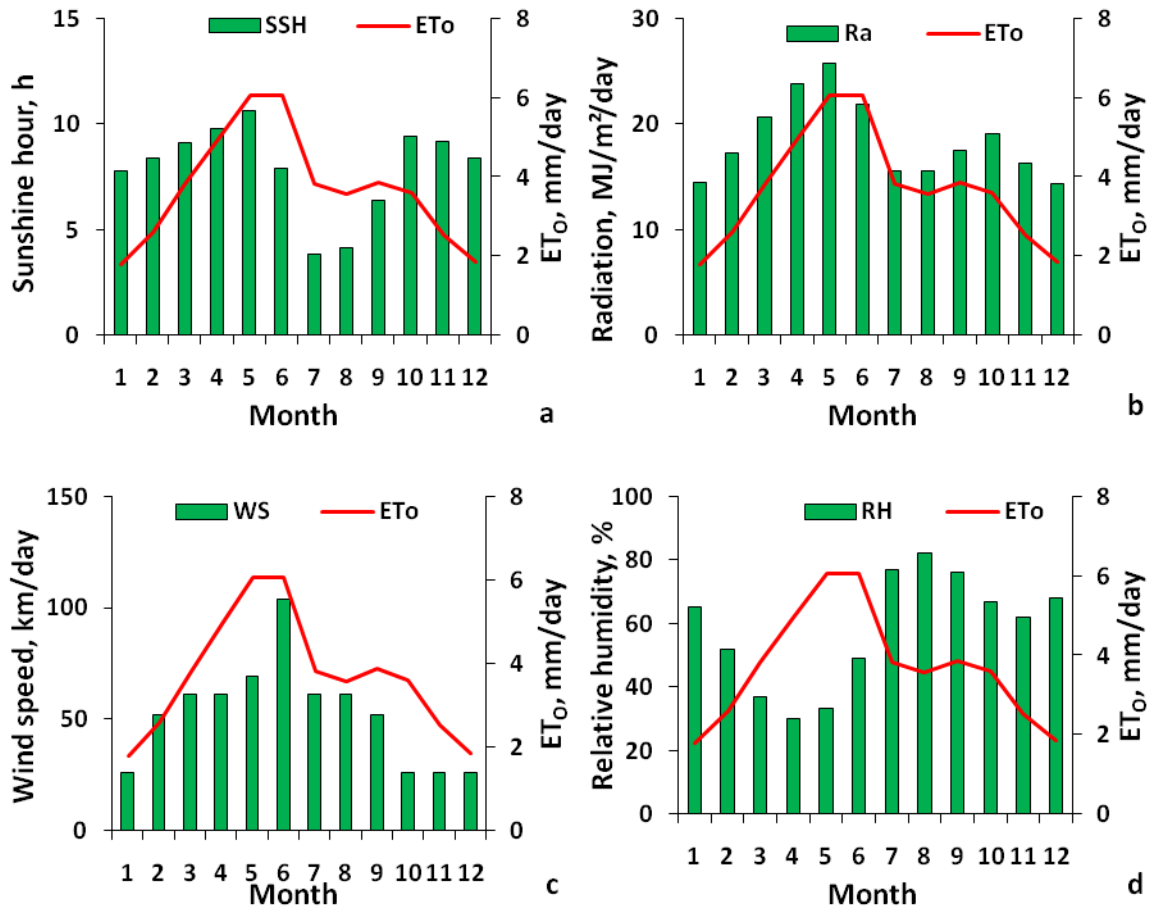
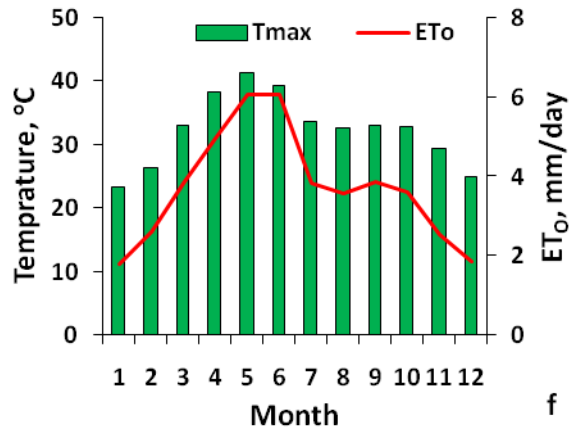
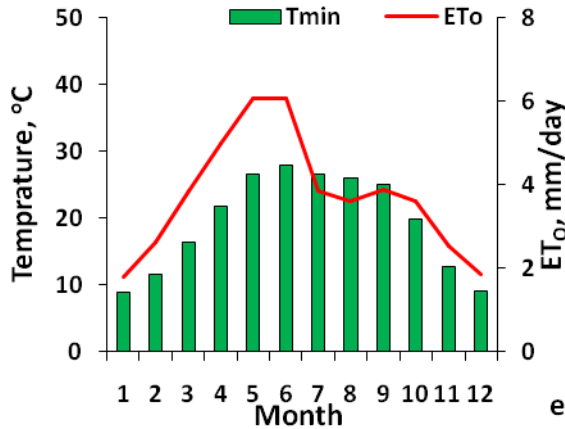


Fig.4 Monthly variation of evapotranspiration with (a) sunshine hour (b) radiation (c) wind speed (d) relative humidity (e) minimum temperature (f) maximum temperature





Irrigation scheduling

The estimation of actual irrigation scheduling was carried out for rice and cotton crop (Table 2). The total amount of water was applied for the 1000 mm (irrigation: 400 mm and rainfall: 600 mm) and 129 mm (irrigation: 29 mm and rainfall: 100 mm) for rice and cotton crop, respectively. The amount of water requirement for rice crop was higher but realistic because the rice crop was having the continuous standing water throughout the growing season. The irrigation water was applied for lowland rice was particularly lower because maximum water was taken by rice crop from rainfall. The irrigation water requirement was varied from 1.7-83.6 mm/month (Table 2).

The healthy crop required a best irrigation scheduling which could be calculated by using a mathematical model. In this study the CROPWAT model was used to estimate the irrigation scheduling for rice and cotton crop. The analysis of the reference evapotranspiration was almost directly proportional to the radiation and sunshine hours and inversely proportional to the relative humidity. The reference evapotranspiration was varying from 1.8 (January) to 6.0 (May) mm/day. Whereas, the crop evapotranspiration, effective rainfall and the crop water requirement varied from 0.74

to 5.57 mm/day, 0.1 to 55.1 mm/dec and 0 to 157 mm/dec, respectively. CROPWAT model appropriately estimate the reference evapotranspiration, effective rainfall and other parameter for irrigation scheduling, which makes this model as a best tool for irrigation planning and management for all the crop and climatic condition.

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