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Reference evapotranspiration (ETo) and irrigation water requirement of different crops in Bihar

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ABSTRACT

For irrigation scheduling and better management of the water, estimation of irrigation water requirement of the crop is essentially required. The study was conducted for estimation of daily reference evapotranspiration (ETo) by FAO Penman-Monteith method using 30 years (1985-2015) mean meteorological data of two locations Sabour (zone III A) and Patna (zone III B) in Bihar. The crop evapotranspiration was estimated using crop coefficients of different crops like rice,*kharif* maize, wheat, *rabi* maize, green gram and summer maize at Sabour and Patna locations. Irrigation water requirement for different crops was estimated based on crop evapotranspiration and effective rainfall during the growing period of the crop. The mean annual reference evapotranspiration (ETo) was found 3.6 mmday^{-1} at Sabour and 4.1 mmday^{-1} at Patna. The total crop evapotranspiration was maximum for rice crop in *kharif* season 546.0 and 607.3 mm at Sabour and Patna respectively and lowest for wheat crop in *rabi* season 212.9 mm and 243.3 mm at Sabour and Patna respectively. Net irrigation water requirement was maximum for summer maize366.3at Sabour and 508.2 mm at Patna for rice crop whereas lowest in *kharif* maize 67.5 and 161.4 mm at Sabour and Patna respectively.

Key words: Reference evapotranspiration (ET_O), crop evapotranspiration (ET_C), crop coefficient (K_C), net irrigation requirement, Penman-Monteith method

Water is one of the most essential natural resource which plays a vital role in maintaining biodiversity, our health, social welfare and our economic development (Donald, 1968). The reference evapotranspiration (ET_o) plays an importantrole in estimating net irrigation requirement of crops for agricultural planning, irrigation scheduling, regional water balance studies and agro-climatic zoning (Samani, 2000) and hence, accurate estimate of ET_O is a key component in hydrological studies. The reference evapotranspiration is defined as the loss of water to the atmosphere by evaporation and transpiration from an extended surface of 8-12 cm tall green grass cover, usually a well-watered, actively growing and completely shading the ground. By applying a crop coefficient (K_C) values, this ET_O can be used to estimate the crop evapotranspiration (ET_C), (Doorenbos and Pruit, 1975). The crop coefficient is obtained with respect to type of plant, maturity of the plant and local factors such as soil type (Jensen *et al.* 1990). The adaptation of exact correct amount of water and correct timing of application is very essential for scheduling irrigations to meet the crop's water use demands and for optimum crop production. As reported by Brutsaert (1982) and Jensen *et al.* (1990) numerous methods have been proposed for estimating reference evapotranspiration. Reference evapotranspiration is either measured by weighing lysimeter or estimated from climatological data or water balance method. The different methods of ET_O estimation can be grouped into temperature methods, radiation methods, combination theory types and pan evaporation methods. The combination of energy balance and aerodynamic equations generally provides the most accurate results as a result of their foundation in physics and basis of rotational relationship (Jensen *et al.* 1990). The evapotranspiration demand depends on temperature, solar radiation, humidity, wind speed and plant characteristics such as stomatal conductance and leaf area index (Priya *et al.,* 2014). Among all the methods Penman-Monteith method (Allen *et al.*,1998) has been reported to yield more accurate reference evapotranspiration (ET_O) estimates across a wide range of climate condition (Jensen *et al.,* 1990). Mehta and Pandey (2015) used Penman-Monteith method for estimation of reference evapotranspiration for wheat and maize crop in Gujarat. Net irrigation requirement for different crops in *kharif, rabi* and summer seasons in Gujarat was estimated by Khandelwal and Dhiman (2015).Hence Penman-Monteith method was adopted for (ET_O) estimation of the study area which was used for the estimation of net irrigation water requirement of different crops in different seasons.

Table 1: Stage wise crop coefficients (Kc), crop duration and height of different crops in Bihar (Allen *et al.* 1998)

Crops	Kc_{ini}	Kc_{mid}	Kc_{end}	Duration (days)	Height (m)
			Kharif season		
Rice	1.1	1.2	1.05	145	1.0
Maize	0.3	1.2	0.35	105	1.5
			Rabi season		
Wheat	0.4	1.15	0.41	125	1.0
Maize	0.3	1.2	0.35	150	2.0
			Summer season		
Green gram	0.4	1.05	0.60	90	0.4
Maize	0.3	1.2	0.35	105	1.5

Table 2: Mean monthly reference evapotranspiration (ET_O) ($mmday^{-1}$) at Sabour and Patna

Months	Sabour	Patna
January	1.7	1.8
February	2.4	2.8
March	4.1	4.7
April	5.3	6.2
May	6.2	7.3
June	5.1	6.4
July	4.3	4.5
August	3.8	4.2
September	3.5	3.8
October	3.0	3.3
November	2.0	2.3
December	1.4	1.5

MATERIALS AND METHODS

Study area

Two different stations Sabour and Patna were selected for the study. The major crops of the area, rice and *kharif* maize in the *kharif* season (June-September), wheat and *rabi* maize in *rabi* season (November-March) and green gram and summermaize in summer season (March-May) were studied at both the stations. The climatic data pertaining to rainfall, temperature, relative humidity etc. of the stations were collected from India Meteorological Department, Pune for 30 years (1985-2015).

Estimation of reference evapotranspiration (ET_O)

The FAO Penman-Monteith method (Allen *et al.*, 1998) was used to compute the reference evapotranspiration (ET_O).

Estimation ofcrop evapotranspiration (ET_C)

The crop coefficient approach was used to determine ET_C.

$$ET_C = K_C * ET_O$$

Where, ET_C = crop evapotranspiration ($mmday^{-1}$), ET_O = reference evapotranspiration ($mmday^{-1}$), K_C = crop coefficient (Table 1).

Estimation of net irrigation requirement of the crop

Net irrigation requirement (NIR) of the crop was determined by the following relationship:

$$NIR = ET_C - R_{eff}$$

Where, NIR = net irrigation requirement (mm); ET_C = potential crop evapotranspiration (mm/day); R_{eff} = effective rainfall (mm).

Effective rainfall (R_{eff}) was determined by evaporation precipitation ratio methods. (FAO-http:// www. Fao.org/docrep/x5560e/x5560e03.htm). This method gives the value of effective monthly rainfall and mean monthly consumptive use (ET_C). If the NIR values are negative (for $R_{eff} > ET_C$), then the NIR of the crops was computed by adding the monthly NIR of corresponding crops.

RESULTS AND DISCUSSION

Variation of mean monthly (ET_O)

The variation of ET_O during different months at Sabour and Patna stations of Bihar are presented in Table 2. At both the stations the lowest reference evapotranspiration was in the month of December and highest in the month of May. The mean monthly reference evapotranspiration at Patna was slightly higher than Sabour in all the months.

ET_C and NIR for kharif crops

In *kharif* season crops, crop evapotranspiration for

Table 3: Total crop evapotranspiration (ET_C), effective rain and net irrigation water requirement of different crops at Sabour and Patna

Crop	Sabour			Patna		
	ET_C(mm)	Effective rain(mm)	Irrigation water requirement(mm)	ET_C(mm)	Effective rain (mm)	Irrigation water requirement(mm)
			***Kharif* season**			
Rice	546.0	487.9	363.7	607.3	319.1	508.2
Maize	291.6	354.7	67.5	318.7	256.1	164.1
			***Rabi* season**			
Wheat	212.9	44.1	173.7	243.3	2.8	240.5
Maize	323.0	57.3	275.5	372.1	9.7	362.0
			Summer season			
Green gram	404.8	97.8	315.0	476.3	67.9	410.5
Maize	500.1	156.8	366.3	590.6	82.1	507.1

rice crop was 546.0 mm and 291.6 mm for maize crop at Sabour station whereas at Patna station it was 607.3 mm and 318.7 mm for the same crops. Net irrigation water requirement for rice crop was 363.7 mm and for maize crop it was 67.5 mm at Sabour station and it was higher at Patna station for the same crops i.e. 508.2 and 164.1 mm respectively (Table 3).

ET_C and NIR for rabi crops

The total seasonal crop evapotranspiration varied between 212.9 and 243.3 mm for wheat and 323.0 and 372.1 mm for maize crop at Sabour and Patna respectively (Table 3). The net irrigation water requirement for wheat crop varied between 173.7 and 240.5 mm and for maize crop it varied between 275.5 and 262.0 mm at Sabour and Patna location respectively. It may be due to long duration of the maize crop than wheat crop (125 day for wheat and 150 days for maize crop) and more height of maize crop (2.0 m) than wheat crop (1.0 m). There was large difference between total crop evapotranspiration of wheat and maize crop at both the locations Sabour and Patna.

ET_C and NIR for summer crops

During summer season the crop evapotranspiration and net irrigation water requirement for all the crops is higher than *kharif* and *rabi* seasons. It was observed that total crop evapotranspiration was higher in maize crop than green gram at both the locations. The total crop evapotranspiration varied between 404.8 -476.3 mm for green gram and 500.1 and 590.6 mm for maize crop at Sabour and Patna locations respectively. The net irrigation water requirement for maize crop in summer season ranged between 366.3-507.1 mm which is higher than green gram (315-410.5 mm) at different locations. It was observed that summer maize needs higher net irrigation water requirement than *kharif* and *rabi* crops and it may be due to high temperature and lower available moisture in the soil during the period.

CONCLUSION

It was observed that lowest reference evapotranspiration was in the month of December and highest in the month of May and there was slightly higher mean monthly reference evapotranspiration at Patna station than Sabour in all the months. The crop evapotranspiration ETc and net irrigation water requirement was found to vary not only with the crops, but also with the season and locations as well. Rice in *kharif* season has highest crop evapotranspiration and net irrigation water requirement followed by summer maize and lowest crop evapotranspiration and net irrigation water requirement was for wheat. The selection of crops and seasons for different location in Bihar can be completed depending on the net irrigation water requirement and also for scheduling irrigation for different crops in Bihar.

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