Original Research Article

Estimation of Crop Water Requirement of Soybean and Cotton Crops for Marathwada Region, India

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A B S T R A C T

The reference evapotranspiration (ETo) is an important agrometeorological parameter used for various agricultural & meteorological applications. In present study daily reference evapotranspiration (ETo) was determined by Hargreaves method for seven districts of Marathwada region by using long period weather data (29-35 years). The results revealed that, ETo increases continuously from January and reaches to its maximum during May, with quite differences among the districts. The ETo reaches to its peak value during 28th April to 18th May at all the districts. During June ETo decreases sharply and remains low during July, August and with slight increase during September, then it decreases afterwards. The mean water requirement (ETc) for soybean crop during initial stage was found to be lower (2.09 to 2.29 mm day^{-1}) then it increased during developmental stage (3.37 to 3.75 mm day^{-1}) and mid season stage (4.90 to 5.32 mm day^{-1}) again decreased during late-season stage (2.25 to 2.41 mm day^{-1}). The total water requirement of soybean varies between Parbhani (457.81 mm) to Aurangabad (419.60 mm). The mean water requirement of cotton during initial stage (1.77 to 1.95 mm day^{-1}), then after increases at developmental stage (3.42 to 3.78 mm day^{-1}), and mid season stage (5.09 to 5.46 mm day^{-1}) again during late season stage it decreases (1.94 to 2.09 mm day^{-1}). The total water requirement of cotton varies between Parbhani (687.88 mm) and Aurangabad (638.80 mm).

Introduction

Reference evapotranspiration (ETo) is a major component in agricultural water management, irrigation scheduling as well as water resource planning. The reference evapotranspiration (ETo) flux occurring from cropped land surfaces are essential in studies relating to hydrology, climate and agricultural water management.

By applying a crop coefficient (Kc) values, this ETo can be used to estimate the crop evapotranspiration (ETc).

Estimation of crop water requirement is one of the main components used in irrigation planning, design and operation (Rowshon *et al.,* 2013). Crop water requirement vary mainly due to variation in growth stages and climatic conditions. Understanding and

determining crop evapotranspiration (ETc) is essential for scheduling irrigation to meet the crop water use demand and to optimize crop production. Jensen *et al.,* (1990) provided detailed reviews of the methods commonly used to determine evapotranspiration and estimated crop water requirements.

Materials and Methods

Location of Study Area

The present study is conformed to Marathwada region lies between $17^o35'$ to 20° 40' latitude and 74° 40' to $78^o10'$ longitude. The altitude ranges between 300 to 900 meter above mean sea level (MSL) comprising of seven districts out of eight with a total geographical area is 64.5 lakh ha with 57.0 lakh ha land suitable for agriculture.

Collection of Meteorological Data

Daily weather data of maximum and minimum temperature of selected districts 29 to 35 years period was collected from India Meteorological Department (IMD), Pune. Due to unavailability of Hingoli district data, this district is not taken into study.

Selection of Crops

In order to workout crop water requirement Soybean and Cotton crops were selected.

Estimation of Reference Evapotranspiration (ETo)

Hargreaves method

Hargreaves developed a method in 1985 to estimate evapotranspiration is an empirical relation based on air temperature and radiation. (Bsanagouda, 2016). The Hargreaves method is given by:

$$ETo = 0.0023 \, R_A \, T_d^{0.5} \, (T_m + 17.8)$$

Where, ETo is reference evapotranspiration (mm day^{-1})

R_A is extra-terrestrial radiation (mm day^{-1})

T_d is difference between max. and min temp. (^{o}C)

T_m is mean temperature (^{o}C)

Crop Evapotranspiration/Crop Water Requirement (ETc)

Water requirement of encompass the total amount of water used in evapotranspiration. Out of the total evapotranspiration, evaporation account for about 10 percent and plant transpiration for the remaining 90 percent.

$$ETc = Kc \times ETo$$

Where,

ETc = crop evapotranspiration/Crop water requirement, (mm day^{-1}),

ETo = reference evapotranspiration, (mm day^{-1}),

Kc = crop coefficient.

The total duration of these crops was divided into four growth stages initial, developmental, mid-season and late-season. The initial stage refers to the germination and early growth stage when the soil surface is not or is hardly covered by the crop. The crop development stage is the stage from the end of the initial stage to attainment of effective full ground cover (ground cover 70-80%). The mid-season stage is the stage from attainment of effective full groundcover to the start of maturity, as indicated by discoloring of leaves or falling of leaves and late season stage of crop from maturity to harvest.

Results and Discussion

Reference Evapotranspiration (ETo) for Marathwada Region

Variation of ETo on Daily Basis

The daily variation of ETo for seven districts of marathwada region observed that there is large fluctuation in daily ETo at different districts of marathwada region. Although the daily ETo increases continuously from January and reaches to its maximum during May, but there is quite differences among the districts. The ETo reaches to its peak value during 28th April to 18th May at all the districts of marathwada region. During June ETo decreases sharply and remains low during July and August and with slight increase during month of September, it decreases afterwards. (Fig.

1). The result shows that, range of ETo was found highest at Parbhani 3.81 mm day^{-1} (26th Dec) to 7.84 mm day^{-1} (30th April) with mean annual value of 5.39 mm day^{-1} and lowest at Aurangabad 3.67 mm day^{-1} (28th and 29th Dec) to 7.28 mm day^{-1} (27th and 28th April), with mean annual value of 5.04 mm day^{-1} as compared to rest of the districts. (Table 2) (Hajare *et al.,* 2009; Bhere, 2012)

Crop Evapotranspiration/Crop Water Requirement (ETc)

ETc of Soybean

The daily ETc of soybean determined for seven districts revealed that, During initial stage, total water requirement in region varies between 41.82 to 45.82 mm with mean water requirement varies between 2.09 to 2.29 mm day^{-1}, During developmental, total water requirement in region varies between 101.10 to 112.46 mm with mean water requirement varies between 3.37 to 3.75 mm day^{-1}, During mid stage, total water requirement in region varies between 220.48 to 239.27 mm with mean water requirement varies between 4.90 to 5.32 mm day^{-1}, During late-season stage, total water requirement in region varies between 56.21 to 60.25 mm with mean

water requirement varies between 2.25 to 2.41 mm day^{-1}. It is found that, the variation in ETc is more at developmental and mid-season stages as compared to initial and maturity stages of the soybean crop across the districts. Among the different districts, the highest ETc is observed at Parbhani (457.81 mm) while the lowest value is at Aurangabad (419.60 mm) followed Nanded (452.26 mm), Osmanabad (445.0 3 mm), Beed (439.41 mm), Latur (438.50 mm), Jalna (431.74 mm) (Table.3) (Mehta, 2015; Chavan *et al.,* 2009).

ETc of Cotton

The daily ETc of soyabean determined for seven districts revealed that, During initial stage, total water requirement in region varies between 53.16 to 58.44 mm with mean water requirement varies between 1.77 to 1.95 mm day^{-1}, During developmental, total water requirement in region varies between 153.51 to 170.00 mm with mean water requirement varies between 3.42 to 3.78 mm day^{-1}, During mid stage, total water requirement in region varies between 331.12 to 355.12 mm with mean water requirement varies between 5.09 to 5.46 mm day^{-1}, During late-season stage, total water requirement in region varies between 97.14 to 104.32 mm with mean water requirement varies between 1.94 to 2.09 mm day^{-1}.

Table.1 Detailed information of different districts of Marathwada Region

Districts	Latitude	Longitude	Altitude(m)	Data Used
Parbhani	19°16'	76°46'	423.50	1982-2017
Aurangabad	19°51'	75°24'	586.60	1982-2010
Jalna	19°50'	75°48'	534.00	1982-2010
Nanded	19°05'	77°20'	358.40	1982-2010
Osmanabad	18°10'	76°03'	662.89	1982-2010
Latur	18°04'	77°07'	639.80	1982-2010
Beed	19°00'	75°43'	519.00	1982-2010

Table.2 Ranges of daily ETo (mm day-1) by Hargreaves method at different districts of Marathwada region

| District	Maximum	Minimum	Mean
Parbhani	7.84	3.81	5.39
Aurangabad	7.28	3.67	5.04
Jalna	7.79	3.59	5.08
Nanded	7.72	3.69	5.22
Osmanabad	7.32	3.82	5.15
Latur	7.71	3.64	5.18
Beed	7.62	3.59	5.12

Table.3 ETc of Soyabean by Hargreaves method at different districts of Marathwada region

District	Initial Stage		Developmental Stage		Mid-Season Stage		Late-Season Stage		Total
	Total	Mean	Total	Mean	Total	Mean	Total	Mean	
Parbhani	45.82	2.29	112.46	3.75	239.27	5.32	60.25	2.41	457.81
Aurangabad	41.82	2.09	101.10	3.37	220.48	4.90	56.21	2.25	419.60
Jalna	42.24	2.11	103.18	3.44	230.18	5.12	56.15	2.25	431.74
Nanded	45.26	2.26	111.24	3.71	238.09	5.29	57.67	2.31	452.26
Osmanabad	42.19	2.11	105.80	3.53	239.74	5.33	57.30	2.29	445.03
Latur	44.81	2.24	108.59	3.62	228.41	5.08	56.69	2.27	438.50
Beed	44.49	2.22	106.76	3.56	232.48	5.17	55.68	2.23	439.41

Table.4 ETc of Cotton by Hargreaves method at different districts of Marathwada region

District	Initial Stage		Developmental Stage		Mid-Season Stage		Late-Season Stage		Total
	Total	Mean	Total	Mean	Total	Mean	Total	Mean	
Parbhani	58.44	1.95	170.00	3.78	355.12	5.46	104.32	2.09	687.88
Aurangabad	53.16	1.77	153.91	3.42	332.89	5.12	98.84	1.98	638.80
Jalna	53.89	1.80	159.10	3.54	335.44	5.16	97.81	1.96	646.25
Nanded	57.97	1.93	168.72	3.75	341.28	5.25	100.40	2.01	668.36
Osmanabad	53.95	1.80	166.93	3.71	341.40	5.25	102.34	2.05	664.62
Latur	57.04	1.90	162.75	3.62	336.82	5.18	100.02	2.00	656.62
Beed	56.67	1.89	163.51	3.63	331.12	5.09	97.14	1.94	648.43

Figure.1 Daily variation of ETo (mm day-1) by Hargreaves method at different districts of Marathwada region
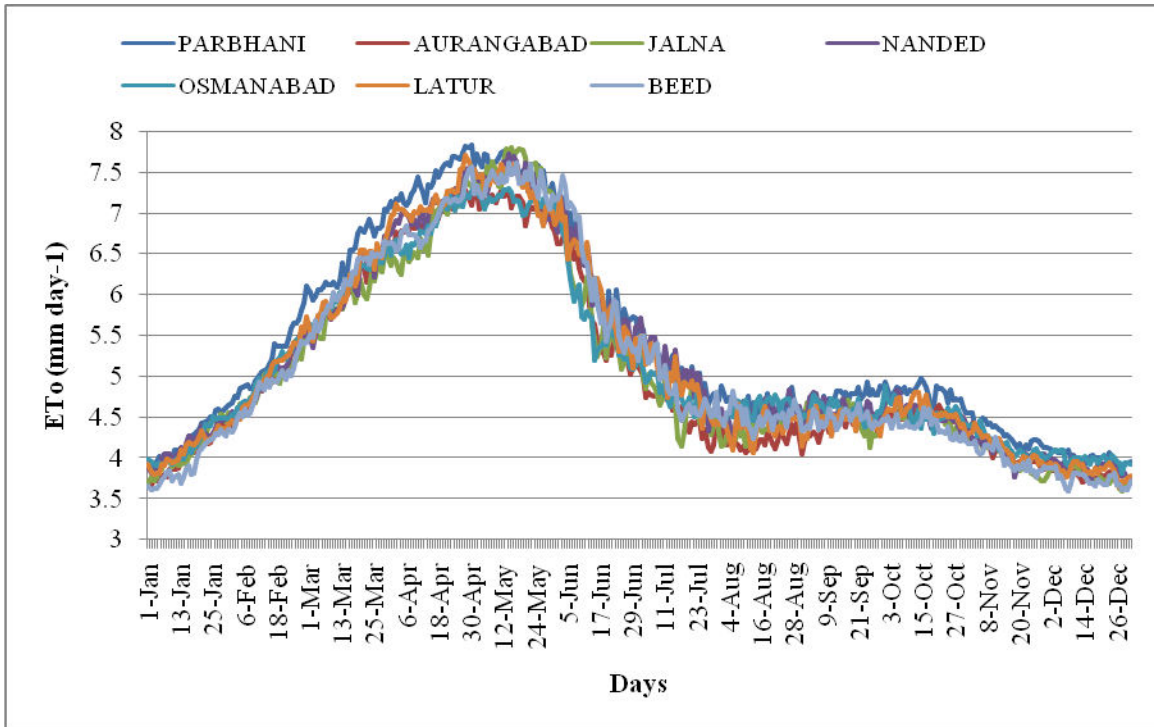
It is found that, the variation in ETc is more at developmental and mid-season stages as compared to initial and maturity stages of the soyabean crop across the districts.

Among the different districts, the highest ETc is observed at Parbhani (687.88 mm) while the lowest value is at Aurangabad (638.80 mm) followed Nanded (668.36 mm), Osmanabad (664.62 mm), Beed (648.43 mm), Latur (656.62 mm), Jalna (646.25 mm) (Table.4) (Mehta, 2015; Chavan *et al.,* 2010).

It was observed that, ETo increases continuously from January and reaches to its maximum during May then in the month of June ETo decreases sharply and remains low during July and August and with slight increase in the month of September, it decreases afterwards. The crop water requirement (ETc) of soybean and cotton was found to vary not only with the crops it's stage and duration, but also with the season as well. During initial stage of the crops, the ETc was less and increased during development stage, reached to its maximum values during mid season and reduced during crop maturation stages. Among the districts, crop water requirement for soybean and cotton crops found highest at Parbhani and

lowest at Aurangabad followed by Nanded, Latur, Osmanabad, Beed and Jalna.

Author Contribution

S. V. Phad: Investigation, formal analysis, writing—original draft. R. S. Sayyad: Validation, methodology, writing—reviewing. K. K. Dakhore:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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