

Original Research Article

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Estimation of Reference Evapotranspiration (ET_o) and Crop Water Requirement of Major *Kharif* Cereals of Marathwada Region, Maharashtra

S.V. Phad*, K.K. Dakhore and R.S. Sayyad

Department of Agricultural Meteorology, Vasant Rao Naik Marathwada Krishi Vidyapeeth,
Parbhani 431 402, Maharashtra, India

*Corresponding author

ABSTRACT

The reference evapotranspiration (ET_o) is an important agrometeorological parameter which has been used in a number of applications. In present study daily ET_o was determined for seven districts of Marathwada region having long period (29-35 years) weather data by Hargreaves method. The Kc values for *kharif* sorghum, maize and pearl millet as given in FAO-56 paper was used to calculate the daily crop water requirement (ET_c). The results revealed that, ET_o reaches to its peak value during 28th April to 18th May at all the districts of marathwada region. Among the districts, Parbhani had highest ET_o and Aurangabad had lowest ET_o followed by Nanded, Latur, Osmanabad, Beed and Jalna. The mean water requirement (ET_c) of *kharif* sorghum during initial stage was found to be lower (1.83 to 2.0 mm day⁻¹) and it increased during developmental stage (3.34 to 3.70 mm day⁻¹) and during mid season stage (4.70 to 5.10 mm day⁻¹) and decreased during late-season stage (2.91 to 3.13 mm day⁻¹). The total water requirement across the districts varies between Parbhani (436.04 mm) to Aurangabad (399.42 mm). The mean water requirement of *kharif* maize during initial stage (1.59 to 1.74 mm day⁻¹), during developmental stage (2.77 to 3.08 mm day⁻¹), during mid season stage (5.07 to 5.54 mm day⁻¹) and during late season stage it decreases (1.55 to 1.67 mm day⁻¹). The total water requirement of *kharif* maize varies between Parbhani (373.13 mm) and Aurangabad (340.74 mm). The mean water requirement of *kharif* pearl millet during initial stage (1.85 to 2.03 mm day⁻¹), during developmental stage (2.82 to 3.13 mm day⁻¹), during mid season stage (4.21 to 4.64 mm day⁻¹) and during late season stage it decreases (1.29 to 1.38 mm day⁻¹). The total water requirement of *kharif* pearl millet varies between Parbhani (291.69 mm) and Aurangabad (265.02 mm).

Keywords

Evapotranspiration (ET_o) and Crop Water, *Kharif* Cereals

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Introduction

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).

In planning and management of available water resources for agricultural sector, the defining strategies become a national and global priority. The reference evapotranspiration (ET_o) 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. The prediction of evapotranspiration is based on meteorological variables like temperature, humidity, sunshine hour, wind speed. By applying a crop coefficient (K_c) values, this E_{To} can be used to estimate the crop evapotranspiration (E_{Tc}), (Doorenbos and Pruitt, 1975). The adoption of exact or 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. Estimation of crop water requirements (E_{Tc}) is one of the main components used in irrigation planning, design and operation (Rowshon *et al.*, 2013). Jensen *et al.*, (1990), provided detailed reviews of the methods commonly used to determine evapotranspiration and estimated crop water requirements.

In this paper attempt has been made to determine reference evapotranspiration (E_{To}) and crop water requirement (E_{Tc}) of major *kharif* cereals (Sorghum, Maize and Pearl millet) using long period weather data (1982-2017) of different districts of Marathwada region.

Materials and Methods

Location of study area

The Marathwada region of Maharashtra states comprises of eight districts total area of 64818 sq km geographically lies between 17°35' to 20° 40' latitude and 74° 40' to 78°10' longitude. The altitude ranges between 300 and 900 meter above mean sea level (MSL). The present study is conformed to Marathwada region comprising of 8 districts with total geographical area is 64.5 lakh ha with 57.0 lakh ha land suitable for agriculture. Table 1 shows detailed information of different districts of Marathwada Region

Collection and processing of meteorological data

Daily weather data of maximum and minimum temperature of selected districts for at least 29 to 35 years period was collected from India Meteorological Department (IMD), Pune. The collected data of each district were used to work out mean of each parameter of each district and then those daily mean data used to calculate reference evapotranspiration (E_{To}). The daily crop water requirement (E_{Tc}) was determined by multiplying daily E_{To} of each districts with K_c , determined for each crop. Thus daily E_{Tc} computed were summed for different growth stages of crop and total seasonal crop water was determined.

Estimation of reference evapotranspiration (E_{To})

Hargreaves method

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

$$E_{To} = 0.0023 R_A T_d^{0.5} (T_m + 17.8)$$

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

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

T_d is difference between maximum and minimum temperature ($^{\circ}\text{C}$)

T_m is mean temperature ($^{\circ}\text{C}$)

Crop evapotranspiration/crop water requirement (E_{Tc})

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. The crop evapotranspiration differs distinctly

from the reference evapotranspiration (ET_o) as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass.

$$ET_c = K_c \times ET_o$$

Where,

ET_c = crop evapotranspiration/Crop water requirement, (mm day⁻¹),

ET_o = reference evapotranspiration, (mm day⁻¹),

K_c = crop coefficient.

The total duration of these crops were 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 (groundcover 70-80%). The mid-season stage is the stage from attainment of effective full groundcover to the start of maturity, as indicated by discolouring of leaves or falling of leaves. The late season stage runs from the start of maturity to harvest or full senescence. Table 2 shows FAO crop coefficients (K_c) values and Table 3 shows Crops, their season and length of crop growth stages for various Sowing periods (days).

Results and Discussion

Reference evapotranspiration (ET_o) for Marathwada region

Variation of ET_o on daily basis

The daily variation of ET_o for seven districts of marathwada region observed that there is large fluctuation in daily ET_o at different districts of marathwada region. Although the daily ET_o increases continuously from January and reaches to its maximum during

May, but there is quite differences among the districts. The ET_o reaches to its peak value during 28th April to 18th May at all the districts of marathwada region. During June ET_o decreases sharply and remains low during July and August and with slight increase during month of September, it decreases afterwards (Fig. 1). The Hargreaves method shows, range of ET_o 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 4) (Mehta R. (2015))

Crop Evapotranspiration/Crop Water Requirement (ET_c)

ET_c of Kharif Sorghum

The daily ET_c of sorghum determined for seven districts along with the mean values by Hargreaves method revealed that,. During initial stage of crop, total water requirement in region varies between 36.59 to 40.09 mm with mean water requirement varies between 1.83 to 2.0 mm day⁻¹, During developmental stage of crop, total water requirement in region varies between 116.75 to 129.65 mm with mean water requirement varies between 3.34 to 3.70 mm day⁻¹, During the mid stage of crop, total water requirement in region varies between 187.95 to 203.84 mm with mean water requirement varies between 4.70 to 5.10 mm day⁻¹, During the late-season stage of crop, total water requirement in region varies between 55.23 to 59.51 mm with mean water requirement varies between 2.91 to 3.13 mm day⁻¹. It is found from above discussion that the variation in ET_c is more at developmental and mid-season stages as compared to initial and maturity stages of the sorghum crop across the districts. Among the

different districts, the highest ET_c is observed at Parbhani (436.04 mm) while the lowest value is at Aurangabad (399.42 mm) followed Jalna (411.27 mm), Nanded (430.78 mm), Osmanabad (423.73 mm), Latur (417.21 mm), Beed (418.02 mm). (Table 5) (Chavan M.L., 2009)

ET_c of Kharif maize

The daily ET_c of maize determined for seven districts along with the mean values by Hargreaves method revealed that During initial stage of crop, total water requirement in region varies between 23.84 to 26.08 mm with mean water requirement varies between 1.59 to 1.74 mm day⁻¹, During developmental stage of crop, total water requirement in region varies between 82.98 to 92.28 mm with mean water requirement varies between

2.77 to 3.08 mm day⁻¹, During the mid stage of crop, total water requirement in region varies between 202.90 to 221.79 mm with mean water requirement varies between 5.07 to 5.54 mm day⁻¹, During the late-season stage of crop, total water requirement in region varies between 31.03 to 33.40 mm with mean water requirement varies between 1.55 to 1.67 mm day⁻¹. It is found from above discussion that the variation in ET_c is more at developmental and mid-season stages as compared to initial and maturity stages of the sorghum crop across the districts. Among the different districts, the highest ET_c is observed at Parbhani (373.13 mm) while the lowest value is at Aurangabad (340.74 mm) followed Jalna (351.94 mm), Nanded (370.32 mm), Osmanabad (364.22 mm), Latur (357.79 mm), Beed (360.62 mm). (Table 6) (Chavan, 2009).

Table.1 Detailed information of different districts of Marathwada Region

Districts	Latitude	Longitude	Altitude(m)	Data Availability
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 FAO crop coefficients (K_c) for non stressed, well-managed crops in semi-arid climates (RH_{min}= 45%, u₂ = 2 m s⁻¹) (Source: FAO-56 Allen *et al.*, 1998)

<i>Kharif</i> Cereals	K _c ini	K _c mid	K _c end
Sorghum	0.35	1.10	0.65
Maize	0.30	1.20	0.35
Pearl millet	0.35	1.00	0.30

Table.3 Crops, their season and length of crop growth stages for various Sowing periods (days)

Sr. No.	Crops	Season	Length of growth stages (days)				Sowing dates		Duration (days)
			Initial	Developmental	Mid-season	Late-season	Sowing	Harvesting	
1	Sorghum	<i>Kharif</i>	15	30	40	20	15-Jun	27-Sep	105
2	Maize	<i>Kharif</i>	15	30	40	20	15-Jun	27-Sep	105
3	Pearlmillet	<i>Kharif</i>	15	25	35	15	15-Jul	12-Oct	90

Table.4 Ranges of daily ETo (mm day⁻¹) by Hargreaves method at different districts of Marathwada region

District	Max	Min	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.5 ETC of *kharif* sorghum 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	40.09	2.00	129.65	3.70	203.67	5.09	59.51	3.13	436.04
AURANGABAD	36.59	1.83	116.75	3.34	187.95	4.70	55.23	2.91	399.42
JALNA	36.96	1.85	119.22	3.41	196.65	4.92	55.53	2.92	411.27
NANDED	39.60	1.98	127.98	3.66	203.19	5.08	57.04	3.00	430.78
OSMANABAD	36.91	1.85	123.17	3.52	203.84	5.10	56.83	2.99	423.73
LATUR	39.21	1.96	124.88	3.57	194.60	4.86	55.59	2.93	417.21
BEED	38.93	1.95	124.22	3.55	196.77	4.92	55.26	2.91	418.02

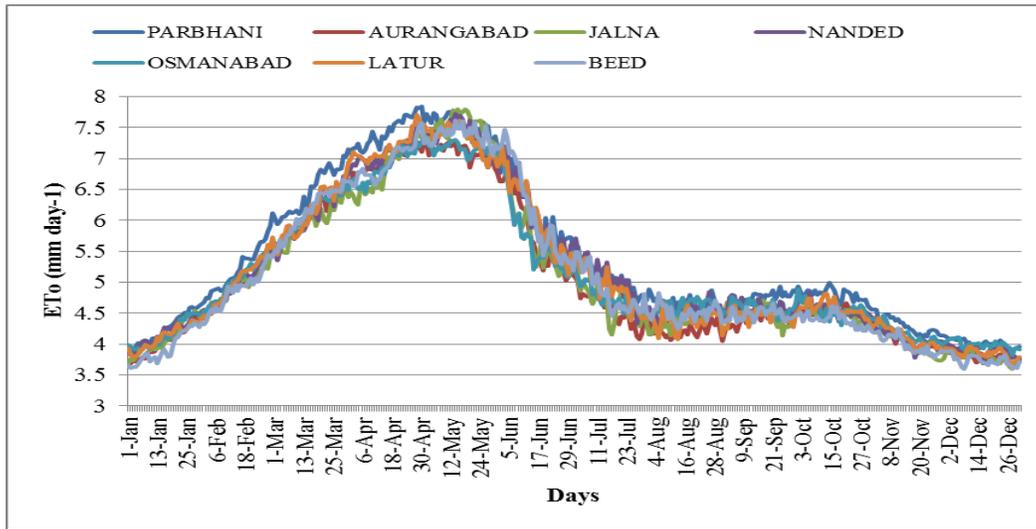
Table.6 ETc of *kharif* maize by Hargreaves method at different districts of Marathwada region

District	Initial Stage		Developmental Stage		Mid-Season Stage		Late-Season Stage		Total
	Total	Mean	Total	Mean	Total	Mean	Total	Mean	
PARBHANI	26.08	1.74	92.28	3.08	221.37	5.53	33.40	1.67	373.13
AURANGABAD	23.84	1.59	82.98	2.77	202.90	5.07	31.03	1.55	340.74
JALNA	23.99	1.60	85.02	2.83	211.68	5.29	31.26	1.56	351.94
NANDED	25.66	1.71	91.90	3.06	220.63	5.52	32.14	1.61	370.32
OSMANABAD	23.98	1.60	86.45	2.88	221.79	5.54	32.01	1.60	364.22
LATUR	25.52	1.70	89.73	2.99	211.26	5.28	31.28	1.56	357.79
BEED	25.31	1.69	87.88	2.93	215.96	5.40	31.46	1.57	360.62

Table.7 ETc of *kharif* pearl millet 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	30.42	2.03	81.16	3.12	162.47	4.64	20.76	1.38	291.69
AURANGABAD	27.81	1.85	73.21	2.82	147.48	4.21	19.33	1.29	265.02
JALNA	27.98	1.87	74.62	2.87	153.31	4.38	20.28	1.35	273.33
NANDED	29.93	2.00	81.32	3.13	160.66	4.59	20.68	1.38	289.46
OSMANABAD	27.97	1.86	75.61	2.91	161.73	4.62	20.76	1.38	283.16
LATUR	29.78	1.99	79.24	3.05	154.33	4.41	19.95	1.33	280.25
BEED	29.53	1.97	77.07	2.96	158.40	4.53	20.08	1.34	282.11

Fig.1 Daily variation of ETo (mm day⁻¹) by Hargreaves method at different districts of Marathwada region



ETc of *Kharif* Pearlmillet

The daily ETc of pearlmillet determined for seven districts along with the mean values by Hargreaves method revealed that, During initial stage of crop, total water requirement in region varies between 27.81 to 30.42 mm with mean water requirement varies between 1.85 to 2.03 mm day⁻¹, During developmental stage of crop, total water requirement in region varies between 73.21 to 81.32 mm with mean water requirement varies between 2.82 to 3.13 mm day⁻¹, During the mid stage of crop, total water requirement in region varies between 147.48 to 162.47 mm with mean water requirement varies between 4.21 to 4.64 mm day⁻¹, During the late-season stage of crop, total water requirement in region varies between 19.33 to 20.76 mm with mean water requirement varies between 1.29 to 1.38 mm day⁻¹. It is found from above discussion that the variation in ETc is more at developmental and mid-season stages as compared to initial and maturity stages of the sorghum crop across the districts. Among the different districts, the highest ETc is observed at Parbhani (291.69 mm)

while the lowest value is at Aurangabad (265.02 mm) followed Jalna (273.33 mm), Nanded (289.46 mm), Osmanabad (283.16 mm), Latur (280.25 mm), Beed (282.11 mm) (Table 7) (Chavan, 2009).

It is concluded 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. In *summer* season when the temperature and wind speed both are highest so the total ETo was maximum, while in *kharif* season there may be wind speed is high but temperature comparatively lower than the *summer* due to rainfall thereby less ETo. Among the districts Parbhani had highest ETo and Aurangabad had lowest ETo followed by Nanded, Latur, Osmanabad, Beed and Jalna. The crop water requirement (ETc) of major *kharif* cereals 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 major *kharif* cereals found highest at Parbhani and lowest at Aurangabad followed by Nanded, Latur, Osmanabad, Beed and Jalna.

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