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Estimation of reference evapotranspiration for Parbhani district

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■ **ABSTRACT :** Estimation of reference evapotranspiration (ET_o) is essential for planning the irrigation water use in arid and semiarid region. Estimation of reference evapotranspiration (ET_o) is an important part of agricultural water management in local and regional water balance studies. At the field scale, estimation of reference evapotranspiration (ET_o) is important in irrigation planning and scheduling and is an integral part of field management decision support tools. This study focuses on estimating the reference evapotranspiration (ETo) using 32 years meteorological data by CROPWAT software. The FAO-56 Penman–Monteith method has been recommended as the standard method for estimating reference evapotranspiration (ET_0) was used.

■ **KEY WORDS :** Evapotranspiration, CROPWAT, Agricultural water management

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Considering the current water resources problems and rapid increase in its demand, proper planning and management of water resources is of immense important to increase agricultural production. One of the basic components of the hydrologic cycle, evapotranspiration (ET), needs to be estimated accurately as it plays a significant role in regional and global climates, and its estimation is of great importance in assessing ground water recharge, predicting crop yield, planning land use, etc. (Zhan and Feng, 2003). Reference evapotranspiration (ETo) can be either directly estimated using lysimeter or water balance approach, or estimated indirectly using the climatological data. However, it is not always possible to obtain ETo value using lysimeter, as it is a time consuming method and needs precise and carefully planned experiments. Owing to the difficulty of obtaining accurate field measurements, ETo is generally estimated from weather parameters (Singh *et al.*, 2008). In the past few decades, several studies have been focused on the development of accurate methods for ETo estimation and improving the performance of existing methods, due to wide application of ETo data. A few empirical or semi empirical methods have been developed for estimating daily reference evapotranspiration from weather parameters (Jensen *et al.*, 1990).

The Penman-Monteith method ranked as the best method for all climatic conditions (Allen *et al.*, 1998 and Jensen *et al.*, 1990). FAO of United Nations has recommended the use of the Penman-Monteith (Smith *et al.*, 1998) method as the standard method for estimation of ETo. ET is a complex and non-linear phenomenon since it depends on several interacting factors such as temperature, humidity, wind speed, radiation, and type and growth stage of crop. Direct measurement of ET using the lysimeter or water balance approach is a time consuming and difficult process if we want accurate results. Thus, a common practice for estimating ET from a well-watered agricultural crop is to first estimate reference crop ET (ETo) from a standard surface and then to apply an appropriate empirical crop co-efficient (kc) (Bandyopadhyay *et al.*, 2000). For determination of reference evapotranspiration, CROPWAT model is used which was developed by the FAO Land and Water Development Division. Based on FAO Penman-Monteith method CROPWAT model has been developed. It requires some input meteorological parameter like maximum temperature, minimum temperature, relative humidity, sunshine hour, wind speed. After putting all the input parameters it calculates reference evapotranspiration for the plain and hilly region (Banik *et al.*, 2014). The purpose of the study was to estimate reference evapotranspiration (ET_0) using Penman-Monteith (FAO-56) method for determination of crop water demand and irrigation management.

METHODOLOGY

Study area :

Parbhani district is located in the Maharashtra state of India. The climate of the study area is characterized as semi-arid and tropical. Parbhani is intersected by 19^0 16' N latitude and 76^0 47' E longitude and located at an altitude of 409 m above mean sea level. It comes under moderate to moderately high rainfall zone with an average annual rainfall of 955 mm. The soil of the command area is medium deep black clay. The mean maximum and minimum temperature of the study area is 44.6^0C and 21.8^0C, respectively. The mean relative humidity ranges from 30 to 98 per cent.

Data collection :

The weather data on various meteorological parameters were collected from IMD recognized observatory located at Department of Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The daily maximum and minimum relative humidity, bright sunshine hours, wind speed, maximum and minimum temperature for 32 years (1983-2014) were collected. The data were used for estimation of reference crop evapotranspiration (ETo).

Reference evapotranspiration :

Determination of reference evapotranspiration (ETo) is a important aspect for computation of crop water requirement. The indirect ETo estimation methods ranges from simple pan evaporation-based methods to physically based computation methods, which include both energy and aerodynamic terms *i.e.* combination methods. Over the years, some important indirect methods developed for estimating reference evapotranspiration are as FAO-Penman, Penman-Monteith (FAO 56), Kimberly-Penman, Radiation, Hargreaves - Samani and FAO-Blaney-Criddle etc. Amongst these methods the FAO version of the Penman-Monteith method is accurate that it is recommended as the sole method of calculating ET_0 if weather data are available (Allen *et al.*, 1998) which was used for estimation.

Doorenbos and Pruitt (1977) defined ETo as "the ET from an extensive surface of 0.08 - 0.15 m tall, green grass cover of uniform height, actively growing, completely shading the ground, and not short of water". The daily reference evapotranspiration for the study area was estimated using CROPWAT computer software. Penman Monteith (FAO-56) method was used to estimate the reference evapotranspiration by the software. The Penman Monteith (FAO - 56) equation is given as;

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

where,

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

R_n=Net radiation at the crop surface ($MJm^{-2}day^{-1}$),

G = Soil heat flux density (MJ m^{-2} day^{-1}),

T = Mean daily air temperature at 2 m height (^{0}C),

u_2= Wind speed at 2 m height (m s^{-1}),

e_s= Saturation vapour pressure (k Pa),

e_a = Actual vapour pressure (k Pa),

e_s-e_a= Saturation vapour pressure difference (k Pa),

Δ= Slope of vapour pressure curve (k Pa $^0C^{-1}$),

γ= Psychometric constant (k Pa $^0C^{-1}$).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Study of weather parameter :

In order to demonstrate, monthly estimates of the weather parameters, daily values were averaged over 32 years and month-wise average of these values is presented in Table 1.

The data shown in Table 1 indicate that May is the hottest month of the year whereas December is the coldest month. Consequently April and May remain dry showing lowest values of relative humidity. December and January months are the coldest month of the year in which rate of evapotranspiration reduces in this region. The highest wind velocities more than 7.2 km hr^{-1} blow at Parbhani during pre-monsoon (May) as well as in monsoon period (June to August) whereas in the months of November, December and January wind velocities are slightly above 3.6 km hr^{-1}. The data in Table 1 clearly indicate that the highest average evapotranspiration rate is in the month of May (8.4 mm day^{-1}) might be resulted from high temperatures (mean air temperature 41^{o}C) and low humidity (mean humidity 34 %) and high wind speed (9 km hr^{-1}) in that month. The maximum average relative humidity (73%) found in the month of August, reduces the rate of evapotranspiration whereas the minimum average relative humidity (31%) was in the month of April which increases the evapotranspiration rate. The average wind speed increases from the month of February to June due to which evapotranspiration rate increases during this period, again wind speed increases in the month of August than July and then decreases from the month September to January due to which reduction in evapotranspiration rate takes place. During the month of February to May, the maximum average sunshine hours *i.e.* more than 10 hours was recorded whereas minimum average sunshine hours (4.7 hours) was observed in the month of August. The sunshine hours increases from the month of September to May and reduces from month of June to August causes similar change in the evapotranspiration. The average maximum temperature increases from January to May which increases the evapotranspiration rate similarly and decreases from June to August and it again slightly increases in the month of September and October causes increase in evapotranspiration rate.

Estimation of reference evapotranspiration :

The CROPWAT software which was used for estimation of ETo by Penman Monteith method. It offers best results with minimum possible errors in relation to living grass reference crop (Doorenbos and Pruitt, 1977 and Allen *et al.*, 1998). The daily average ETo values over 32 years are illustrated in Fig. 1. In general, it was observed that ETo at Parbhani is lowest in the month of December (3.27 mmday^{-1}) and it reaches to maximum in the month of May (8.4 mmday^{-1}). During 30th June to 3rd March, ET_o remained below 5 mm day^{-1}. The ET_o

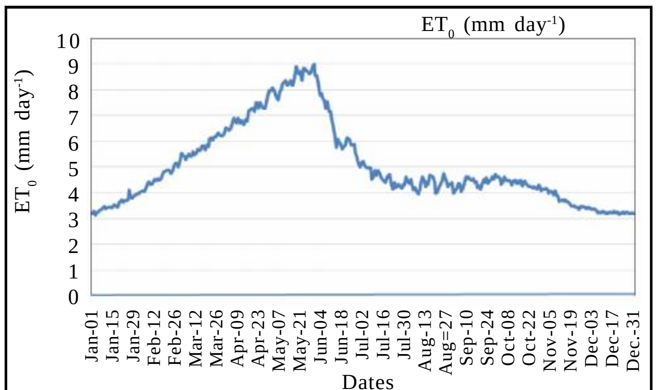

Fig. 1 : Daily average ETo by Penman Monteith method using CROPWAT software

Table 1 : Month-wise average daily climatic data for Parbhani from 1983-2014

Months	Min temp (°C)	Max temp (°C)	Humidity (%)	Wind speed (km hr^{-1})	Sunshine hours (hr)	Radiation (MJ m^{-2} day^{-1})	ETo (mm day^{-1})
January	11.5	30.0	52	3.60	9.9	19.1	3.57
February	13.4	32.7	45	4.32	10.3	21.7	4.58
March	17.4	36.5	36	5.04	10.6	24.2	5.82
April	21.6	40.0	31	6.12	10.7	25.8	7.07
May	24.9	41.2	34	9.00	10.5	25.7	8.40
June	23.9	36.4	56	10.08	7.2	20.7	6.51
July	22.5	32.0	70	8.64	4.8	16.9	4.64
August	22.0	30.7	73	9.36	4.7	16.6	4.38
September	21.7	31.8	71	5.40	7.0	19.2	4.42
October	18.4	32.5	60	4.32	8.9	20.3	4.38
November	14.0	30.9	56	3.96	9.3	18.8	3.73
December	10.9	29.5	55	3.60	9.5	18.0	3.27
Annual average	18.5	33.7	53	6.12	8.6	20.6	5.06

above 7.0 mm day^{-1} was observed during the period from 15th April to 8th June.

In the month of January, it varies in the range between 3.15 mm day^{-1} to 3.97 mm day^{-1}. It increases from 4.04 mm day^{-1} to 5.17 mm day^{-1} in February. Similarly it increases in March from 5.2 mm day^{-1} to 6.43 mm day^{-1}. In the month of April, ETo varies between 6.5 mm day^{-1} to 8.0 mm day^{-1}. In the month of May it ranges in between 8.0 to 8.9 mm day^{-1}. The maximum rate of evapotranspiration was found on 30th May (9.02 mm day^{-1}). In the month of June it suddenly reduces from 8.0 to 5.1 mm day^{-1}, this trend remains similar in the month of July which was up to 4.2 mm day^{-1}. In August, it remains in the range of 4.02 mm day^{-1} to 4.7 mm day^{-1}. The average rate of evapotranspiration slightly increases in the month of September (4.42 mm day^{-1}) than August (3.38 mm day^{-1}). In the month of October it ranges between 4.5 mm day^{-1} to 4.1 mm day^{-1}. It reduces from 4.1 mm day^{-1} to 3.5 mm day^{-1} in the month of November. Similarly, it reduces from 3.5 mm day^{-1} to 3.2 mm day^{-1} in the month of December.

During winter season the ETo was recorded to the tune of 3.27 to 4.58 mm day^{-1} during the period of November to February. Whereas in summer it was found in the range of 5.82 to 8.4 mm day^{-1}. The highest ET_o was recorded in the month of May *i.e.* 8.4 mm day^{-1}. In monsoon season, July to October, the ET_o ranged between 4.64 to 4.38 mm day^{-1}.

Conclusion :

The study provides useful information about daily ET_0 obtained by CROPWAT software using Penman-Monteith (FAO-56) method. The following important conclusions were drawn from this study as the average annual reference evapotranspiration (ETo) estimated by this software is 5.06 mm per day. The monthly average reference evapotranspiration was observed maximum in the month of May (8.4 mm day^{-1}) while minimum in the month of December (3.27 mm day^{-1}). This study provides the necessary information on water requirements for growing different crops in different season. It will be very important for researchers and farmers in planning irrigation scheduling, irrigation water management studies in different season.

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