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Research Paper :

Determination of pan coefficients for Jalgaon district in Maharashtra

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ABSTRACT

This study was undertaken to determine monthly, seasonal and annual pan coefficients of Jalgaon district. Climatic parameters (maximum and minimum temperature, maximum and minimum relative humidity, bright sunshine hours, wind speed and open pan evaporation) for 11 years *i.e.*1998-2008 were collected from agriculture meteorological observatory, Jalgaon. Reference evapotranspiration (ET_o) was determined by FAO-56 PM method (ET_{opm}). Pan coefficients were estimated by using Doorenbos and Pruitt equation. Estimated pan coefficients were evaluated and compared with FAO-56 PM method for the year 2007 and 2008. It was found that ET_{opc} and ET_{opm} had a very good correlation between them. Mean absolute error (MAE), mean absolute relative error (MARE) and root mean square error (RMSE) were also found to be minimum for all the analysis.

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Key words : Pan evaporation, Pan coefficient, Reference evapotranspiration

Evapotranspiration (ET) refers to the total atmospheric loss of water from plant and soil surface. The evapotranspiration rate from a reference surface, not short of water is called the reference crop evapotranspiration or reference evapotranspiration (ET_o). The concept of reference evapotranspiration was introduced to study evaporative demand of the atmosphere independently of crop type, crop development and management practices. It is useful in determining seasonal water requirement to plan crop irrigation. It is an immediate tool for irrigation planners, researchers to design water storage reservoirs and select crop or cropping pattern, which can give maximum benefit. ET data are frequently needed at short notice for projects planning or irrigation scheduling design, however, it is not easy to measure. Specific devices and accurate measurement of various physical parameters are required. Numerous scientist and specialists worldwide have developed large number of empirical methods to estimate ET from different climatic variables.

ET_o can be computed from meteorological data by large number of empirical or semi empirical equations. Some of the methods are valid only under specific climatic and agronomic conditions and cannot be applied under conditions different from those under which they were originally developed. Large number of data requirement also limits the application of many of these methods.

Keeping in view the complexity, accuracy and data requirements of prediction methods, pan evaporation method is comparatively less expensive and easy. A pan coefficient has been used successfully to estimate ET_o. Appropriate pan coefficient selection depends upon, pan type, environment, ground cover in its surrounding, wind and humidity conditions. Therefore it was decided to determine monthly, seasonal and annual reference evapotranspiration, class 'A' pan coefficients and evaluate their suitability to compute reference evapotranspiration for Jalgaon district's climatic condition.

Michael (1978) stated that the pan have higher rates of evaporation than a large free water surface and a factor of about 0.7 was recommended for converting the observed evaporation rate to those of large water surface area. Several researcher studied factors affecting evapotranspiration and reference evapotranspiration, Singh and Kumar (1993) reported the ratio of actual ET_o to class A pan evaporation and actual ET for different wheat cultivators were influenced by rainfall pattern, irrigation, ground water table depth and soil and plant factors addition to class A pan evaporation. Some studies also reported the effect of degree of soil cover with vegetation (Redersma and Ridder, 1996), radiation, air temperature, relative humidity, wind speed, sunshine hours (Allen *et al.,* 1998; Bhakar, 2000; Goyal, 2004).

Many scientists used Hargreave method, Blaney Criddle, Radiation, Modified Penman method to compute evapotranspiration which was reported to be overestimated by 50.5 to 75% and Epan method by which ET_o was underestimated by –5.56% (Singandhupe and Sethi, 2004). Similarly, reference evapotranspiration has been computed by Modified Blaney Criddle, Modified Radiation, Modified Penman, Pan Evaporation and Jensen Haise methods (Hussain and Mushabbir, 1990).

Harmsen *et al.* (2003) estimated long-term average monthly evapotranspiration from pan evaporation data to update pan evaporation coefficient (Kp) values. Tomar and Ranade (2001) determined site specific pan coefficient for rainy, winter and summer season and *Kharif* and *Rabi* copping seasons at Indore, Madhya Pardesh to compute reference evapotranspiration (ET_o) for calculating optimum irrigation water. Greismer *et al.* (2002) studied method for conversion of pan evaporation to reference evapotranspiration and concluded that reference evapotranspiration (ET_o) is often estimated from evaporation pan data as they are widely available. Estimation of ET_o (Kp Epan) by pan relies on determination of the pan coefficient (Kp). Irmark *et al.* (2002) evaluated class A pan coefficient for estimating reference evapotranspiration in humid location. However, reliable estimation of ET_o using pan evaporation (Epan) depends on the accurate determination of pan coefficients (Kpan).

METHODOLOGY

Study area and data collection:

Jalgaon is situated in tropical agro climatic zone at 21^0 03' N latitude and 75^0 34' E longitude at an altitude of 206 m above mean sea level. An average annual rainfall of Jalgaon is 740.7 mm. Mean monthly maximum (T_{max}) and minimum temperature (T_{min}), relative humidity at morning (RH-1) and evening (RH-2), wind speed (WS), bright sunshine hours (BSH) and open pan evaporation (OPE) were collected from Agricultural Meteorological Observatory, Jalgaon for 1998-2008. Mean seasonal and annual data were calculated from the mean monthly meteorological data. Other parameters like geographic locations *viz.,* latitude, longitude and altitude were also obtained.

Pan evaporation observations were taken with standard US Weather Bureau class A open pan. Air temperature data were recorded by thermometers housed in Stevenson Screen. Relative humidity was calculated from the dry and wet bulb temperature observations. Wind speed was measured by anemometer. Bright sunshine hour was measured by sunshine recorder.

Determination of reference evapotranspiration:

Monthly, seasonal and annual reference evapotranspiration for Jalgaon were calculated using FAO-56 Penman-Monteith model expressed as:

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

where,

ETo=Reference evapotranspiration (mm/day)

Rn =Net radiation at crop surface (M J/m^2/day)

G=Soil heat flux density (M J/m^2/day)

T=Main daily air temperature at 2 m height (^{o}C)

u=Wind speed at 2 m height (m/s)

e_s=Saturation vapour pressure (K Pa)

e_a=Actual vapour pressure (K Pa)

(e_s–e_a)=Saturation vapour pressure deficient (K Pa)

Δ=Slope of vapour pressure curve (K Pa/^{o}C)

γ=Psychometric content (K Pa/^{o}C)

Latent heat of vaporization (γ) varies only slightly over normal temperature range hence single value of 2.45 MJ Kg^{-1} was used in the FAO Penman – Monteith equation. The other atmospherical parameters were calculated by using various standard numerical equations.

Determination of pan coefficients:

Computed monthly, seasonal and annual ET_O values were used to compute the pan coefficient by using Doorenbos and Pruitt (1997) equation.

$$K_P = \frac{ET_o}{E_p}$$

where,

K_P = Pan coefficient

ET_O =Reference ET (mm day^{-1})

E_P = Pan evaporation (mm day^{-1})

Evaluation of computed pan coefficient:

Computed pan coefficients were proposed to estimate reference ET for year 2007 and 2008. Reference ET values estimated by using computed pan coefficient (ET_{opc}) were compared with the ET_O values estimated by FAO-56 Penman Monteith equation (ET_{opm}). Distribution of ET_{opc} and ET_{opm} around 1:1 line were plotted. Degree of correlation between ET_{opc} and ET_{opm} were studied for its significance. Other statistical parameters like mean, standard error, standard 't' were evaluated for studying suitability and feasibility of developed pan coefficients to estimate ET_O.

Similarly, performance of estimated pan coefficients were evaluated by determining mean absolute error

(MAE), mean absolute relative error (MARE) and root mean square error (RMSE) between ET_{opc} and ET_{opm}. The formulae has been given below:

$$MAE = \frac{\sum_{i=1}^{n} |ET_{opc} - ET_{opm}|}{n}$$

$$MARE = \frac{\sum_{i=1}^{n} \frac{|ET_{opc} - ET_{opm}|}{ET_{opm}}}{n}$$

$$RMSE = \frac{\sqrt{\sum_{i=1}^{n} (ET_{opc} - ET_{opm})^2}}{N}$$

where,

ET_{opm}=Estimated ET_o using Penman Monteith equation

ET_{opc}=Computed ET_o using estimated pan coefficient

N =Number of ET_o values

RESULTS AND DISCUSSION

This study has examined monthly, seasonal, and annual reference evapotranspiration (ET_O) rates for Jalgaon. Monthly, seasonal and annual class A pan coefficients were determined by using reference evapotranspiration (ET_O) data. Estimated pan coefficients were evaluated for computing reference evapotranspiration (ET_O) of the region for the years 2007 and 2008.

In order to find degree of association between reference evapotranspiration determined by using FAO-56 Penman Monteith method (ET_{opm}) and respective (ET_O) determined by using estimated pan coefficients (ET_{opc}) the statistical parameters like correlation coefficient (r), standard error (SE), mean absolute error (MAE), mean absolute relative error (MARE) and root mean square error (RMSE) has been used for studying suitability and feasibility of developed pan coefficients to estimate ET_O of the region.

Determination of monthly pan coefficients:

Monthly data for the period of 1998-2006 (9 years) were used to determine monthly pan coefficients for Jalgaon station (Table 1). Table 1 reveals that August and September had higher values of pan coefficients *i.e.* 1.1 similarly, March had lowest pan coefficient of 0.5. Higher value indicate that the moisture loss from the reference crop was equal or higher than the evaporation from the open water surface for the same area throughout the year which was in contradiction with concept of ETo.

Table 1: Estimated monthly pan coefficients for Jalgaon

Month	Pan coefficient	Month	Pan coefficient
January	0.8	July	0.9
February	0.7	August	1.1
March	0.5	September	1.1
April	0.6	October	0.8
May	0.6	November	0.8
June	0.7	December	0.7

Evaluation of estimated monthly pan coefficients:

Estimated monthly pan coefficients of Jalgaon were evaluated by estimating ETo using FAO-56 Penman Monteith method and coefficients for the year 2007 and 2008. Fig. 1 and 2 show the variation of monthly ETopm and ETopc for 2007 and 2008 at Jalgaon, respectively.

It is seen from the Fig. 1, 2 and Table 2 that monthly ET_{opc} was found closer to monthly ET_{opm} throughout the year for both the year. MAE, MARE and RMSE between ET_{opc} and ET_{opm} were found very low for both the years. It was, therefore, concluded that the determination of monthly ETo using estimated pan coefficients gave almost similar values throughout the year with only pan

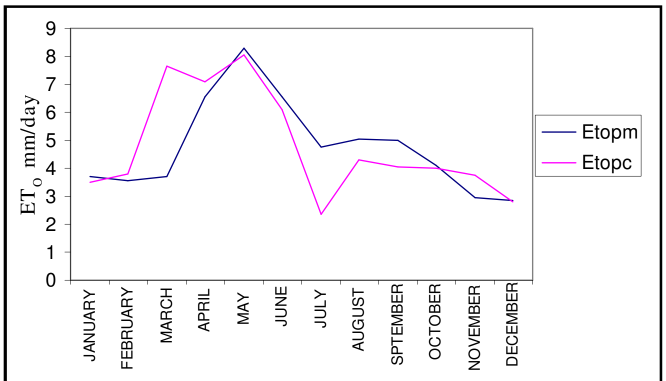

Fig. 1 : Variation of monthly ETopm and ETopc for 2007 at Jalgaon

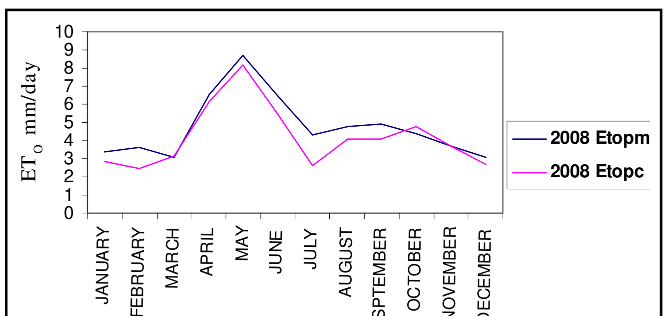

Fig. 2 : Variation of monthly ETopm and ETopc for 2008 at Jalgaon

Table 2 : Performance indices of monthly pan coefficients for Jalgaon				
Sr. No.	Year	Mean absolute error (MAE), mm/day	Mean absolute relative error (MARE)	Root mean square error (RMSE), mm/day
1.	2007	0.0235	0.00041	0.0233
2.	2008	0.5633	0.01121	0.5633

evaporation required for calculations.

Determination of seasonal pan coefficients:

Seasonal analysis was carried out for *Kharif* and *Rabi* season using seasonal data for 1998-2006 to estimate pan coefficients. Table 3 shows seasonal estimated pan coefficients for Jalgaon, which was minimum of 0.7 for *Rabi* and maximum of 0.8 for *Kharif* season.

Table 3: Seasonal pan coefficients estimated for Jalgaon		
Sr. No.	Season	Pan coefficient
1.	*Kharif*	0.8
2.	*Rabi*	0.7

Evaluation of estimated seasonal pan coefficients:

Estimated seasonal pan coefficients of Jalgaon were evaluated by determining ETo using FAO-56 PM method and estimated pan coefficients for 2007 and 2008. Table 4 shows the performance indices of seasonal pan coefficient for Jalgaon. Fig. 3 and 4 show the variation of seasonal ETopm and ETopc for 2007 and 2008, respectively.

Fig. 3, 4 and Table 4 show the seasonal ET_{opc} was found to be very close to seasonal ET_{opm} for both the years. It was also seen that MAE, MARE and RMSE between ET_{opc} were considerably low for both the years.

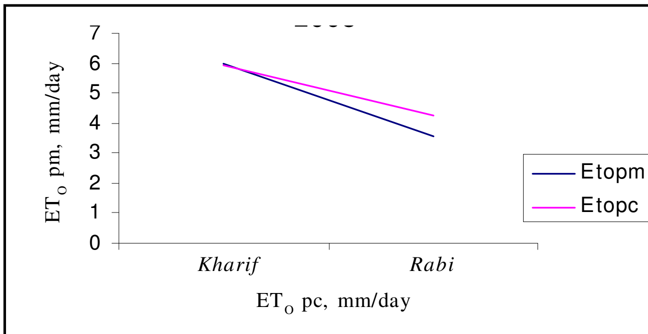

Fig. 4 : Variation of seasonal ET_o pm and ET_o pc for 2008 at Jalgaon

It was, therefore, concluded that estimated seasonal pan coefficients may be used for determination of seasonal ETo with better degree of accuracy.

Determination of annual pan coefficients:

Annual pan coefficients were determined using mean annual meteorological data of 1998-2006. Table 5 shows the performance indices of annual pan coefficient for Jalgaon. Fig. 5 shows the variation of annual ET_{opm} and ET_{opc} at Jalgaon.

Annual pan coefficient obtain from analysis was found to be 0.8. It is seen from the Fig. 5 and Table 5 that annual ET_{opc} obtained for Jalgaon was more close to annual ET_{opm}. It was also found that MAE, MARE and RMSE

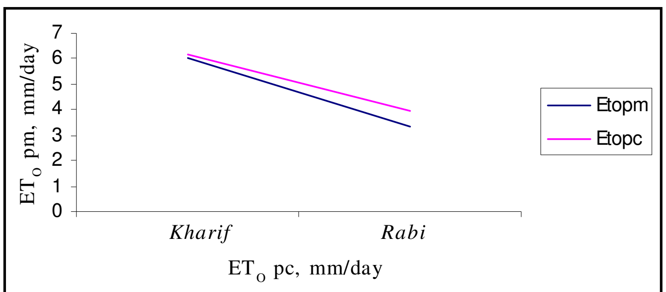

Fig. 3 : Variation of seasonal ET_o pm and ET_o pc for 2007 at Jalgaon

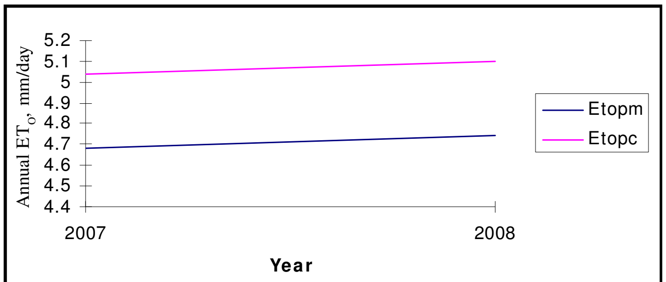

Fig. 5 : Variation of annual ET_o pm and ET_o pc at Jalgaon

Table 4 : Performance indices of seasonal pan coefficient for Jalgaon				
Sr. No.	Year	Mean absolute error (MAE), mm/day	Mean absolute relative error (MARE)	Root mean square error (RMSE), mm/day
1.	2007	0.05991	0.00041	0.05991
2.	2008	0.0658	0.01523	0.0658

Table 5 : Performance indices of annual pan coefficient for Jalgaon

Sr. No.	Station	Mean absolute error (MAE), mm/day	Mean absolute relative error (MARE)	Root mean square error (RMSE), mm/day
1.	Jalgaon	0.36	0.0710	0.36

were considerably and comparatively low for Jalgaon. Therefore, it may be concluded that estimated annual pan coefficient for Jalgaon may be suitable for determining annual ETo.

Conclusion:

This study was conducted for Jalgaon district by using 11 years (1998-2008) mean monthly meteorological data. Highest monthly pan coefficient was found to be 1.1 for August and September and the lowest (0.5) was for March. Monthly ET_{opc} and ET_{opm} were found with very low standard errors. MAE, MARE and RMSE were also found very low for both the years. The seasonal pan coefficient for *Kharif* and *Rabi* was found to be 0.8 and 0.7, respectively. Significantly high correlation was observed between seasonal ET_{opc} and ET_{opm} with very low standard errors. MAE, MARE and RMSE were found to be very low for both the years. Annual pan coefficient was found to be 0.8. Annual ET_{opc} obtained for Jalgaon was found closer to annual ET_{opm} with comparatively high MAE, MARE and RMSE. Therefore, estimated monthly, seasonal and annual pan coefficients may be used for determination of monthly seasonal and annual ET_O instead of FAO-56 Penman Monteith method, because of its simplicity in calculation and requirement of one parameter (pan evaporation) for calculation.

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