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Research Article

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Estimation of Reference Evapotranspiration (ET_0) for Gird Region of Madhya Pradesh

Yadvendra Pal Singh[1*], H. K. Mittal[2], P. K. Singh[3] and S. R. Bhakar[4]

[1]Research Scholar, [2,3,4]Professor

Department of Soil and Water Engineering, Collage of Technology,

Maharana Pratap Technical University, Udaipur, Rajasthan

*Corresponding Author E-mail: yadvendrapalsingh@gmail.com

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ABSTRACT

The reference evapotranspiration (ET_0) for three district in Madhya Pradesh have been estimated using three evapotranspiration based methods like Hargreaves Samani, Caprio, trabert and Makkink-Hansen under local conditions. Comparison was also made between the estimated ET_0 by using different evapotranspiration based method and the observed ET_0 by using FAO-56-PM Method. Regression analysis revealed that estimated ET_0 values were highly correlated with observed ET_0 values. In addition, linear regression relationships between ET_0 values estimated by the Penman monteith method and other methods were determined. The result of this study shows that the travert method can be indicate the best result compression to other method and this method could be used for the estimation of ET_0 values in all district in the gird region of Madhya Pradesh.

Keyword: *Reference Evapotranspiration by FAO-56 Penman Monteith, other ET_0 methods and Gird region.*

INTRODUCTION

growing population (Hussein M. Al-Ghobari, 2000), irrigated agriculture and urbanization in sub-tropic regions in general and in Madhya Pradesh in particular, water shortages are increasing. As a result of increasing demand for water resources, competition for existing water supplies is becoming more critical each year, calling for wiser use of the limited available water. In agriculture sector accounts for more than 80% of the total annual water consumption. As demand intensifies the effective conservation of water is of primary importance to agricultural development. Finding methods that increase water use efficiency and reduce the excessive application of Water are of importance for conserving water. The knowledge of crop evapotranspiration (ET) is one of the most important factors in irrigation scheduling, proper water management and water conservation.

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The estimation of reference evapotranspiration (ET_0) involves calculating the potential evapotranspiration (ET) or the actual evapotranspiration (ET), and then applying a suitable crop coefficient (K_c). Potential ET is defined as the rate at which water would be removed from wet soil and plant surfaces expressed as the rate of latent heat transfer per unit area, or as a depth of water per unit time. ET_0 is defined as the rate at which water would be removed from the soil and plant surfaces expressed as the rate of latent heat transfer per unit area, or as a depth of water per unit time evaporated and transpired from a reference crop. The use of ET_0 for a specified crop surface has largely replaced the use of the more general potential crop ET. This is because of the ambiguities involved in the interpretation of potential ET. Also, the use of a reference crop ET permits a physically realistic characterization of the effect of the microclimate of a field on the evaporative transfer of water from the soil-plant system to the atmospheric air layers overlying the field (Uright, 1996).

Numerous scientists and specialists worldwide was developed many methods for estimating of reference evapotranspiration (ET_0) over the last 50 years. These methods were subject to rigorous local calibration and proved to have limited global validity (Smith et al., 1996). Doorenbos & Pruitt (1977) adopted the concept ET_c and adjusted several existing methods to yield identical ET_0 estimates varying from complex energy balance techniques requiring detailed climatological data to simpler methods with limited data requirements. The accuracy of ET_0 estimates depends primarily on the ability of the methods being used to describe the physical laws governing the processes and the accuracy of the meteorological and cropping data (Jensen et al., 1990). Since the existing methods of estimating ET_c from meteorological data involve empirical relationships, some local or regional verification or calibration is advisable with any selected method. Tanner (1967) emphasized that any empirical equation for estimating ET_0 needs to be calibrated, particularly in sub-tropic and semi-arid regions, because of the increased ET_c due to the adjective energy from dry surroundings.

A few studies have been conducted to calculate ET_0 for some selected areas in Madhya Pradesh (Saeed 1986; Al-Omran and Shalaby 1992; Mohammad and Abo-Ghobar 1994;). The previous studies have concentrated on the central and eastern regions and the literature lacks the estimation of ET_0 in the gird region of Madhya Pradesh, which is considered to be some of the main agricultural regions in the country. Accordingly, the objective of this study was to determine ET_0 for four major locations namely, Ashok Nagar, Shivpuri and Bhind (sub-tropic condition) in the gird region of Madhya Pradesh using four different ET_0 based methods. In addition, estimated ET_0 for the different locations were compared with that estimated and observed.

MATERIALS AND METHODS

In this study to carry out, mean monthly climatological data, *viz.*, maximum temperature (Tmax), minimum temperature (Tmin), mean relative humidity (RHmean), solar radiation (Sr) and wind speed (WS) were collected from global weather data site, Ashok Nagar, Bhind and Shivpuri District of Madhya, for the duration of seven eleven (2004-2014). Other parameters like geographic locations, *viz.*, latitude and longitude, as can be seen from Table 1.

Table 1: Details of the selected stations in study area

District	Longitude (E)	Latitude (N)	Altitude (m)
Ashok Nagar	77°43' E	24°34' N	499
Bhind	78°48' E	26°34' N	159
Shivpuri	77°39' E	25°25' N	457

The availability of meteorological data is a major consideration in the selection of a method for calculating ET_0. Selection of the appropriate method for a specific location is a difficult task because unique guidelines are not available for defining the method of application most likely to give the best estimates. The methods considered in this study include those ranging from temperature, radiation and mass transfer-based methods to the more data-intensive combination methods. The methods are (1) FAO-56 Penman monteith method; (2) Jensen-Haise (J-H) method; (3) caprio method (4) traver method (5) Hargreaves-samani (H-S) method for gird region climatic conditions. These methods were chosen for this study to estimate the ET_0 for each district and also to make a comparison among them in order to select the most suitable method for each area. The following methods are given below:

FAO-56 Penman Monteith method

According to Allen et al. (1998), recommended form of FAO56-PM model consisting of aerodynamic and surface resistance terms is:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T_{av}+273}\right)U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots (1)$$

Where,

ET_0 is reference evapotranspiration (mm d^{-1}), R_n is net radiation at crop surface (MJ m^{-2} d^{-1}), G is soil heat flux density (MJ m^{-2} d^{-1}), T_{av} is mean daily air temperature (^oC), U_2 is wind speed at 2 m height (m s^{-1}), e_a is actual vapour pressure (kPa), e_s is saturation vapour pressure (kPa), e_s-e_a is vapour pressure deficit (kPa), Δ is slope of vapour pressure curve (kPa^{o}C^{-1}), and γ is psychrometric constant (kPa^{o}C^{-1}).

Caprio (1974) method

$$ET_0 = 6.1 \times 10^{-6} \times R_s \times (1.8 \times T_{av} + 1) \quad \ldots (2)$$

Where,

ET_0 is reference evapotranspiration (mm d^{-1}), R_s is solar radiation (KJ m^{-2} d^{-1}), and T_{av} is mean temperature (°C).

Trabert method

$$ET_0 = 0.3075 \times \sqrt{U_2} \times (e_s - e_a) \quad \ldots (3)$$

Makkink-Hansen method

This is a new simple formula formed by simplifying standardized form of Penman equation to calculate ET_0 values and is given as:

$$ET_0 = 0.0393\left[R_s \times \sqrt{T_{av} + 9.5} - 4.83461 \times {R_s}^{0.6} \times \varphi^{0.15} + 1.22137 \times (T_{av} + 20) \times \left\{1 - \left(\frac{RH}{100}\right)\right\} \times {U_2}^{0.7}\right] \quad \ldots (4)$$

Where,

ET_0 is reference evapotranspiration (mm d^{-1}), T_{av} is average daily air temperature (°C), R_s is solar radiation (MJ m^{-2} d^{-1}), U_2 is wind speed at 2 m height (m s^{-1}), ∅is latitude (radian), and RH is relative humidity (%).

Hargreaves-Samani (1985)

$$ET_0 = 0.408 \times 0.0030 \times R_a \times (T_{av} + 20.0) \times (T_{max} - T_{min})^{0.4} \quad \ldots (5)$$

ET_0 is reference evapotranspiration (mm d^{-1}), T_{av} is mean temperature (^oC), T_{max} is maximum temperature (^oC), T_{min} is minimum temperature (^oC), R_a is water equivalent of extra-terrestrial radiation (mmd^{-1}), and 0.408 is constant to convert MJ m^{-2} d^{-1} into mm d^{-1}

RESULTS AND DISCUSSION

Computer programs have been written to calculate the reference evapotranspiration (ET_0) values on a monthly basis for each method using the meteorological data for each district. The mean monthly ET_0

estimated by the different evapotranspiration based methods for each of the districts are plotted in Figs. 1−3. Taking each figure separately, it can be seen that there are some differences in the ET_0 values estimated by the various methods in one district. These variation increases or decreases between the methods depending on the type of method used and the climatic parameters included in the method. Also there is variation between the values of ET_0 estimated by the different methods when compared among FAO56 Penman Method; this can be attributed to the different methods of estimation used and to the natural variation in climatic parameters influencing ET that occur in each area.

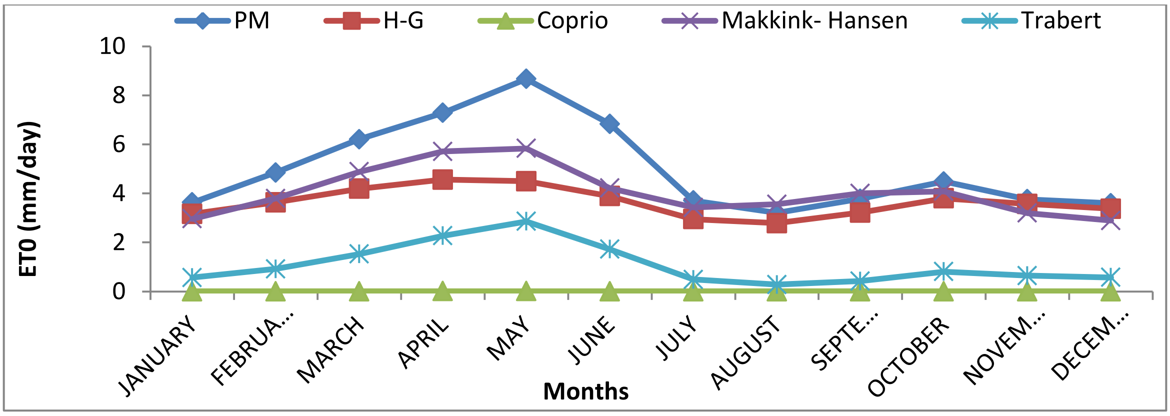

Fig. 1: Comparison of Average monthly ET0 value by estimate different evapotranspiration-based models with FAO56-Penman-Monteith Model for Ashok Nagar station

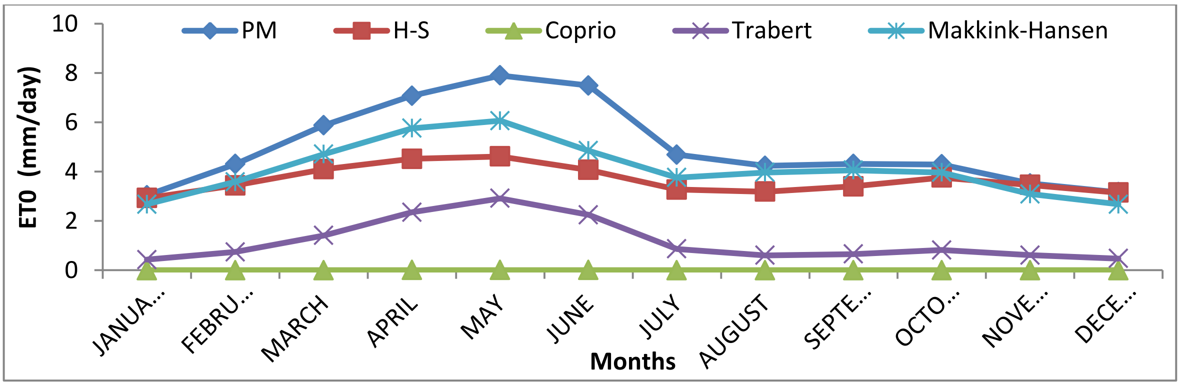

Fig. 2: Comparison of Average monthly ET0 value by estimate different evapotranspiration-based models with FAO56-Penman-Monteith Model for Shivpuri station

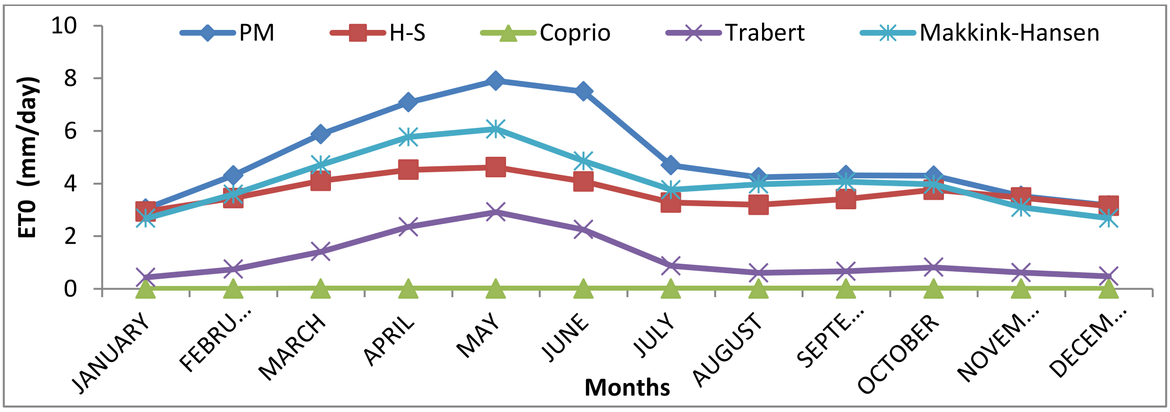

Fig. 3: Comparison of Average monthly ET0 value by estimate different evapotranspiration-based models with FAO56-Penman-Monteith Model for Bhind station

Consequently, there will be differences in the ET_0 values as can be seen in the figures. Thus, some methods underestimate ET it. This is due to different methods of accounting for the effects of many factors influencing ET. These factors include air temperature, wind speed, relative humidity and solar radiation. Also, the ET_0 observed from the FAO-56 Penman monteith method were averaged, and the results are presented graphically in Fig. 1 to 3. It can be seen that the variations between the observed and estimated values are small, and the Trabert method gave the results closest to the observed ET_0 values. Therefore, linear regression analyses were made between the observed ET_0 from Penman Monteith values and the estimated ET_0 values from the selected different ET_0 based methods for each district, and the results of these regressions are given in Table 2.

There is a high degree of correlation (R^2) between observed and estimated ET0 values for all the districts. This implies that the observed ET_0 from these areas. It can be concluded that the Trabert for all area ranked first, and it had the highest correlation with lower absolute intercept values of the regression lines for the three areas compared with the other methods, which for the most part gave comparable results. Fig. 1to 3 shows that the Trabert method gives the closest estimates to the observed values in comparison to the other methods. Therefore, from these results, the Trabert method was thought the most suitable for computing ET_0 for all districts.

Table 2: Simple linear regression (y =a + bx) between observed ET_0 of FA0-56PM method and ET0 estimated by other method from all districts

Districts/ Methods	Ashok Nagar			
	Hargreaves-Samani	Caprio	Trabert	Makkink-Hansen
Interception	0.290	0.001	0.452	0.494
Slope	2.182	0.000	-1.170	1.576
R2	0.642	0.792	0.939	o.787
Shivpuri				
Interception	0.241	0.001	0.428	0.464
Slope	2.370	0.000	-1.103	1.578
R2	0.534	0.840	0.956	0.828
Bhind				
Interception	0.292	0.000	0.492	0.612
Slope	2.168	0.001	-1.281	1.040
R2	0.541	0.848	0.920	0.845

CONCLUSION

Four methods for the estimation of reference evapotranspiration (ET_0) were evaluated under a Sub-humid climate, by using over 11 years of meteorological data for each of the all districts under study. The results indicated that Trabert method provided the best results under condition. However, it was found that the ET_0 estimated by the different methods was closely correlated with the ET_0 observed from the FAO-56 Penman Monteith in the three districts. As per the compression of metrological data base models, Trabert model was found the best performance on the bases of coefficient of determination for Ashok Nagar, Bhind and Shivpuri station. Therefore, from these results, it is concluded that the Travert can be recommended for computing ET0 for all areas in the gird region of Madhya Pradesh.

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