



## Calculation of Reference Evapotranspiration ( $ET_0$ ) for Chhattisgarh Plains

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### ABSTRACT

The evapotranspiration (ET) for Balaghat district was estimated using different evapotranspiration based methods like Meyer, Hargreaves and Valiantzas under local conditions. Comparison was also made between the observed  $ET_0$  by Penman Monteith (FAO-56) and the estimated  $ET_0$  by different other model. 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 valaintzas 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 Balaghat district in the Chhattisgarh plane of Madhya Pradesh.

**Keyword:** Chhattisgarh Plains, evapotranspiration by FAO-56 Penman Monteith, other  $ET_0$  methods.

### INTRODUCTION

Growing population, urbanization and irrigated agriculture in sub-tropic regions in general and in particular, water shortages are increasing (Allen et al., 1989 & Hussein M. Al-Ghobari, 2000). 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.

The calculating reference evapotranspiration (ET) involves estimated the actual evapotranspiration (ET) or the potential evapotranspiration (ET), and then applying a suitable crop coefficient ( $K_c$ ).

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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).

(Allen et al., 1996 & Smith et al., 1996) specialists worldwide was developed many methods for estimating of reference evapotranspiration ( $ET_0$ ) over the last 60 years. These methods were subject to rigorous local calibration and proved to have limited global validity. 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. According to 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.

The different studies were conducted to estimated  $ET_0$  for some selected areas in

Chhattisgarh Plains (Saeed 1986, Al-Omran & Shalaby 1992, Mohammad & 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 Chhattisgarh Plains of Madhya Pradesh, which is considered to be some of the main agricultural regions. Accordingly, the objective of this study was to determine  $ET_0$  for single major locations for Balaghat (sub-tropic condition) in the Chhattisgarh Plains of Madhya Pradesh using different  $ET_0$  based methods. In addition, estimated  $ET_0$  for the particular location was compared with that estimated and observed.

## MATERIALS AND METHODS

The weather average monthly data used in this stud , 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 at balaghat District located on Chhattisgarh Plains of Madhya, for the period of twenty years eleven (1993-2013). The site is an elevation of 279 m above mean sea level and lies at a longitude of 80°31' E and a latitude of 21°69' N. the annual rainfall range between 1200 to 1600mm.

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) Hargreaves method; (3) Meyer method (4) Valiantzas 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

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

Where,

$ET_0$  is reference evapotranspiration ( $\text{mm d}^{-1}$ ),  $R_n$  is net radiation at crop surface ( $\text{MJ m}^{-2} \text{d}^{-1}$ ),  $G$  is soil heat flux density ( $\text{MJ m}^{-2} \text{d}^{-1}$ ),  $T_{av}$  is mean daily air temperature ( $^{\circ}\text{C}$ ),  $U_2$  is wind speed at 2 m height ( $\text{m s}^{-1}$ ),  $e_a$  is actual vapour

$$ET_0 = Ch(T_{max} - T_{min})^{EH}(T_{mean} + 17.8)R_a \quad \dots (2)$$

Where,

$ET_0$  is reference evapotranspiration ( $\text{mm d}^{-1}$ ),  $R_a$  is extra-terrestrial radiation ( $\text{mm d}^{-1}$ ),  $T_{max}$ ,  $T_{min}$  and  $T_{mean}$  temperature ( $^{\circ}\text{C}$ ), value of constant  $C_h$  and  $E_H$  are 0.003 and 0.5 respectively.

**Meyer's Formula (1915)**

$$EL = KM(e_s - e_a)(1 + u_2/16) \quad \dots (3)$$

In which,  $u_2$  = monthly mean wind velocity in  $\text{km/h}$  at about 2 m above ground and  $KM$  =

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

**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 balaghat district. The mean monthly  $ET_0$  estimated by the different evapotranspiration based methods are plotted in Fig. 1. It can be seen that there are some differences in the  $ET_0$  values estimated by the various methods. These variation increases or decreases between

consisting of aerodynamic and surface resistance terms is:

pressure (kPa),  $e_s$  is saturation vapour pressure (kPa),  $e_s - e_a$  is vapour pressure deficit (kPa),  $\Delta$  is slope of vapour pressure curve ( $\text{kPa}^{\circ}\text{C}^{-1}$ ), and  $\gamma$  is psychrometric constant ( $\text{kPa}^{\circ}\text{C}^{-1}$ ).

**Hargreaves method**

coefficient accounting for various other factors with a value of 0.36 for large deep and 0.50 for small shallow waters.

**Valiantzas (2013)**

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

the methods depending on the type of method used and the metrological 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.

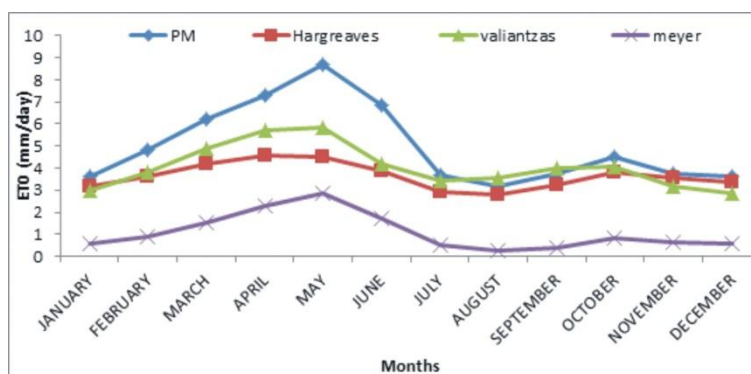


Fig. 1: Comparison of Average monthly  $ET_0$  value by estimate different evapotranspiration-based models with FAO56-Penman-Monteith Model

Consequently, there will be differences in the  $ET_0$  values as can be seen in the figures. Thus, some methods underestimate  $ET_0$ . This is due to different methods of accounting for the effects of many factors influencing  $ET_0$ . 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. It can be seen that the variations between the observed and estimated values are small, and the Valiantzas 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 1.

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

**Table 1: Simple linear regression ( $y = a + bx$ ) between observed  $ET_0$  of FAO-56PM method and  $ET_0$  estimated by other method from all districts**

Districts/ Methods	Balaghat		
	Interception	Slope	$R^2$
Meyer	0.290	0.199	0.829
Hargreaves	0.312	-0.980	0.971
Valiantzas	0.142	1.792	0.980

### CONCLUSION

Three methods for the estimation of reference evapotranspiration ( $ET_0$ ) were evaluated under a Sub-humid climate, by using over 20 years of meteorological data for each of the all districts under study. The results indicated that valiantzas 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, valiantzas model was found the best performance on the bases of coefficient of determination for balaghat station. Therefore, from these results, it is concluded that the valiantzas can be recommended for computing  $ET_0$  for balaghat in the Chhattisgarh plains of Madhya Pradesh.

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