Reckoning of Potential Evapotranspiration by using Different Methods

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Abstract—*Reckoning of Potential Evapotranspiration(PET) is a crucial factor due to population explosion and scarcity of water,thereby inflated food supply and this obligated for the accuracy in agricultural water requirements. Although PET got its approval in modelling and simulation of structural water bodies,ecosystem balance and hydrological cycle. PET is estimated with respect to few prominent methods. FAO-56 enacted Penman Monteith equation as a standard in estimating PET, and few other recycled methods namely as Blaney Criddle,Hargreaves, Throntwaite are adopted for comparative study for gauging Evapotranspiration value with reference to Penman Monteith method. Blaney Criddle method has been proved to be better correlated method and is followed by Hargreaves with fewer data requirement and with moddled data in the region of Andhra Pradesh.*

Keywords*: Potential Evapotranspiration, Penman Monteith Equation,Blaney Criddle,Hargreaves,Throntwaite.*

1. INTRODUCTION

Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour throughstomatain its leaves. Evapo-transpiration is an important part of the hydrological cycle and controls Runoff volume of river discharge, requirement of irrigation water and soil moisture contents (Mohan & Arumugam, 1996). The precipitation on the surface of the earth gets to the atmosphere at a percentage of sixty-five (Kite, 2000).

PET is actually the consignment of water that can evaporate potentially and transpire from vegetation, with atmospheric demand as its only restriction (Lu *et al.*, 2005). The conception of PET is to designate the micrometeorological environment with the demand the evaporation rate of atmosphere is proficient in extricating from an area considering its surface properties (Hillel, 1998). The number of approximation methods available to estimate PET turned to be around fifty. These methods are developed for distinct climatic regions, and are inconsistent due to the input requirements and varied assumptions (Grismer *et al.*,2002). The method of selection is innate and is not perceptible, rather relying on the study objectives and data availability (Verstraeten et al.,2008). The recently developed Penman-Monteith method requires temperature, humidity, sunshine hours, wind speed data and solar radiation, hence making it highly data oriented. But this complexity of data has made it reliable and used as a criterion for comparison of the other empirical equations. The Penman- Monteith combination has got eminent dispatch, both in arid and humid climates (Jensen etal., 1990). The applications of PET include development of water resources, irrigation scheduling, study of climate changes, design and planning of reservoir, hydrologic models, land use studies, hydrologic balance (Dai et al., 2013; 2010; Harder etal., 2007; McKinney and Rosenberg, 1993; Prudhomme and Williamson, 2013). The past few decades saw the development of many hydrologic models to simulate water flow in the subsurface with considering the proper losses of evapotranspiration. MIKE SHE (Danish Hydraulic Institute, 1998), and HEC-HMS (US Army Corps of Engineers, 2000) watershed models are such hydrologic models.

1.1 STUDY AREA

The Andhra Pradesh state is a newly forged state after detachment from Combined states of Andhra Pradesh and Telangana states and the area constituting total area of 160,205 km^2. The present study area is a region in the state along Bandar canal, data possessed from Indian Meteorological department.

2. METHODOLOGY

In spite of global predominance for estimation of Evapotranspiration, its spatial distribution is still fragmentary. This can be justified as it relies on numerous meteorological parameters, available only at staple stations. The objective is set to contrast the performance of the empirical equations with the Penman-Monteith method, computed using CROPWAT, at thisregion of Andhra Pradesh. The Penman-Monteith method is a standard recommended by FAO and is valid globally for reference crop Evapotranspiration, but require daily

meteorological data of maximum and minimum temperatures, wind speed, relative humidity, and sunshine hours and solar radiation. The various empirical methods were compared with Penman-Monteith method can solve the issue of data constraint. The methods that are available from literature, Thornthwaite,Blaney-criddle,Hargreaves are adopted in this paper for comparison, for years 2010and 2014. For the same purpose, monthly meteorological data is collected form Indian Meteorological Department.

2.1 PET Methods

2.1.1 Hargreaves-method

The Hargreaves *et al*., (1985) equation is an empirical relation which demands daily air temperature in concomitance with global radiation (Ra), acquired from site location and time of the year. It is given as:

$$ET_o = 0.0023(T_{max} - T_{min})^{0.5}(T_m + 17.8)R_a \quad (1)$$

Where R_a is the extra-terrestrial radiation of the crop surface (MJ/m^2 /day) ; T_m , T_{max} and T_{min} refer to mean, maximum and minimum temperatures respectively (^0C).

2.1.2 Thornthwaite method

The Thornthwaite (1948) method, a relation between ET and mean air temperature, requiring only sunshine hours besides the temperature for computation. The equation is:

$$ET_o = ET_{gr}\left(\frac{N}{12}\right)\left(\frac{d_m}{30}\right) \quad (2)$$

$$ET_{gr} = 16\left(\frac{10\,T_m}{I}\right)^{\alpha} \quad (3)$$

$$I = \sum_{i=1}^{12}\left(\frac{T_m}{5}\right)^{1.514} \quad (4)$$

Where N is the maximum number of sunny hours in function of the month latitude; d_m is the number of day per month; ET_{gr} is the gross evapotranspiration;T_m is the mean temperature (^0C); I is the monthly heat index;

$$\alpha = 0.49239 + 1792\times10^{-5}I - 771\times10^{-7}\,I^2 + 675\times10^{-9}\,I^3 \quad (5)$$

2.1.3 Blaney-Criddle method

The Blaney-Criddle (1950) is popular in western part of USA for its simplicity until Penman-Monteith equation took its place. The reference ET is measured referring to temperature changes at respected site. It is given as:

$$ET_o = p(0.46T_{mean} + 8) \quad (6)$$

Where, T_{mean} is mean temperature (^oC), and; p is the mean daily percentage of annual daytime hours due to the latitude of region.

2.1.4 Penman-Monteith method

The (FAO-56) Penman-Monteith equation is ex-pressed as:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2\,(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2} \quad (7)$$

where R_n is the net radiation at the crop surface (MJ m^{-2} d^{-1}),Gis the soil heat flux density (MJm^{-2} d^{-1}),Tis the air temperature at 2 m height (°C),Δ is the slope vapor pressure curve (kPa $°C^{-1}$),u2 is the wind speed at 2 m height (m s^{-1}), es is the saturation vapor pressure (kPa), ea is the actual vapor pressure (kPa), γ is the psychrometric constant (kPa $°C^{-1}$), and $e_s - e_a$ is the saturation vapor pressure deficit (kPa) .

3. RESULTS & DISCUSSIONS

The available data for 2010 and 2014 for a region of Andhra Pradesh were used for computation of Evapotranspiration by three methods on temperature basis and contrasted with Penman-Monteith method which is both temperature and radiation based, and recommended by FAO. The daily data is averaged for monthly values, for estimating the ETo by Thornthwaite, Blaney-criddle, and Hargreaves which are empirical. The estimation of Penman-Monteith method is done using CROPWAT 8.0 software. Data of monthly meteorological data of maximum and minimum temperatures, wind speed, relative humidity, and sunshine hours and solar radiation is used for the same purpose. After computing the ET_0 using temperature based models like Blaney-Criddle, Hargrieves and Thornwaite equations, comparision has been made with Modified-Penman method to compute the relationship between each method with that of Penman-Montieth method for the specified data used to develop the models. A typical comparison has been shown in Fig. – 1

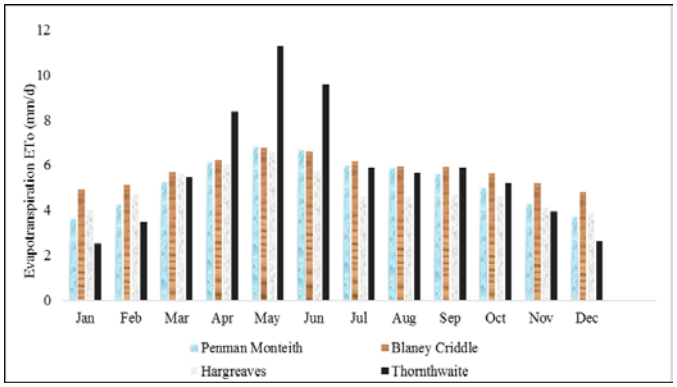

Fig. 1: Mean daily ETo simulated by Penman Monteith and three simple methods

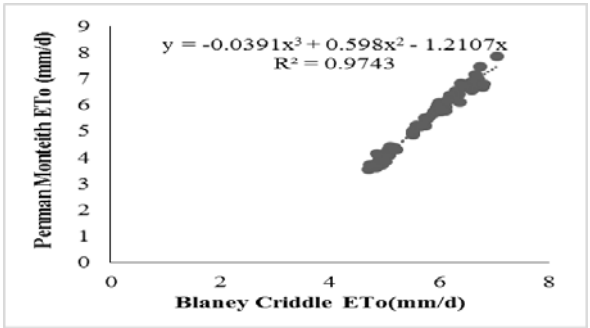

Fig. 2

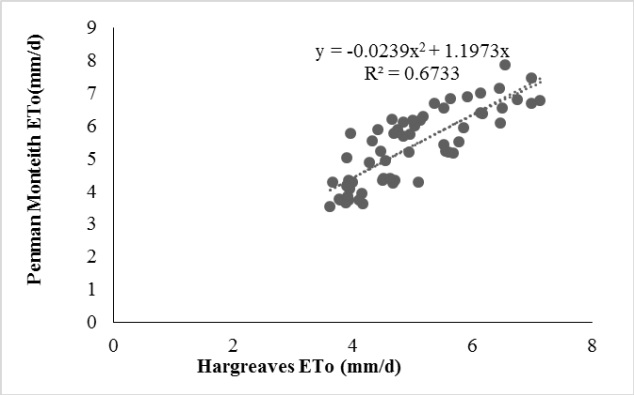

Fig. 3

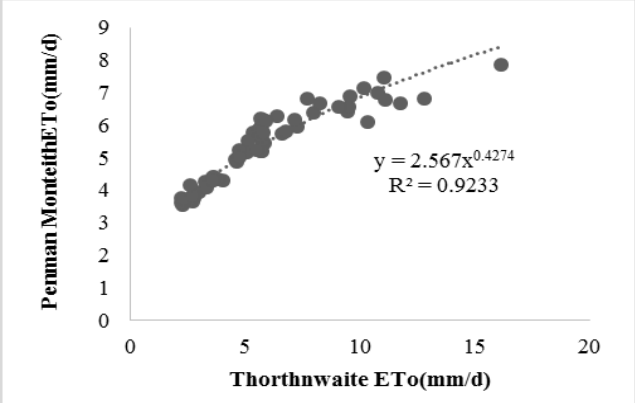

Fig. 4

In order to assess the ET_0 value with less data intense methods more accurately, relationships have been developed between Blaney-Criddle and Penman Montieth and similarly Hargreaves and Thornhwaite methods as well. The resulted equations have shown non-linear relationship with fairly good co relationship. All these equations have been indicated in equations 8 to 10.

$$y = -0.0391\,x^3 + 0.598\,x^2 - 1.2107x \quad (8)$$

Where

Y is Evapotranspiration (ET_0) using Penman –Montieth method

X is Evapotranspiration (ET_0) using Blaney-Criddle method

$$y = -0.0239\,x^2 + 1.1973\,x \quad (9)$$

Y is Evapotranspiration (ET_0) using Penman –Montieth method

X is Evapotranspiration (ET_0) using Hargrieves method

$$y = 2.567\,x^{0.4274} \quad (10)$$

Y is Evapotranspiration (ET_0) using Penman –Montieth method

X is Evapotranspiration (ET_0) using Thornthwaite method

Blaney-Criddle method when compared with Penman Montieth method has resulted in correlation of 0.9743, Hargreaves method is compared with Penman Montieth yielded a correlation of 0.6733.Thornthwaite method when compared with Penman Montieth has regression coefficient value of 0.9233 with a non-linear relationship. All these relationships have been shown with relevant equations and regression coefficients in Figures 2 to 4.

4. CONCLUSIONS

In the present studyestimation of Evapotranspiration for the cardinal position of Andhra Pradesh state with less data intensive models and successfully compared with high data intensive model like Penman-Montieth equation. The relationship equations developed will be useful to compute accurate estimation of ET_0 with less data. The resulted equations have produced good correlation coefficient when compared with standard Penman-Montieth equation forET_0.The corelationship obtained varies from 0.60 to 0.97.

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