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Comparison of Different Methods for Estimating Potential Evapotranspiration in a Regional Area of Andhra Pradesh

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Abstract: The estimation of Potential Evapotranspiration (PET) is an important factor due to scarcity of water and increase in population, a thereby inflated supply of food, and this obligated for the accuracy in demand of agricultural water requirements. Although, PET got its enactments in the role of modelling and simulation of structural water bodies, hydrologic cycle and ecosystem balance. The Bandar canal system is one of the major sources of irrigation canals in the region of Andhra Pradesh, and the PET is estimated with respect to few prominent methods. FAO-56 endorsed Penman-Monteith equation as a standard in estimating the PET, and few other recycled methods, namely Blaney Criddle, Hargreaves and Thornthwaite are adopted for a comparative study, for assessing 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 the modelled data in this region of Andhra Pradesh State, India.

Keywords: *Potential Evapotranspiration, Penman-Monteith equation, Hargreaves, Thornthwaite, Blaney Criddle.*

1. Introduction

The hydrologic balance study for an area comprises of both evaporation and transpiration losses, termed together as evapotranspiration. According to Langbein and Iseri (1960) potential evapotranspiration as the water deficiency in the soil for vegetation present at no time at which evapotranspiration occurs. The soil and vegetation has considerable influence over potential evapotranspiration. The surface evapo-transpiration from land, relocates massive extent of water from vegetation via transpiration and soil via evaporation to the atmosphere. The consumption of water over irrigated projects, planning of water resources, hydrologic water balance is to be quantified for the management of water rights (Allen *et al.,* 2007). Apart its prominent role in global water balance, its influence is felt on global energy balance, thereby for optimal water resources management, irrigation scheduling and environment assessment, quantification of evapotranspiration is required (Jensen *et al*., 1990). The estimation of potential evapotranspiration can be computed using several approaches, radiation based, water budget based, combination based and temperature based. The extensive data needed to get proficiency and to implement them with precision make the selection procedure critical for determining the optimistic method (Xu C.Y and Singh V.P. 2002). Th developed methods may be inconsistent as they require different inputs and are based on varied assumptions (Grismer *et al*., 2002). Instinctive selection of method is preferred rather than perceptive. This answers the fact that, data dependency and availability with study objectives got a key function to play in selection of a method (Verstraeten *et al*., 2008). Nonetheless, few methods such as the Penman-Monteith method are authentic atop a comprehensive range of climates, with tested reliability at distributed parts across the globe they have got a contracting results with the field observed data (Nurul Nadrah Aqilah Tukimat *et al*., 2012). The only constraint is the extensive data, a problem for estimation of PET at regions of data meagre. So, this study aims at that fact that, the usage of empirical methods which consume less data and gets its results accurately close enough to the comprehensive ranged ones.

1.1. Study Area

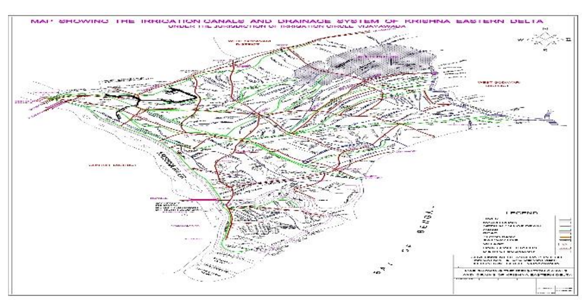

Figure 1 *Krishna Eastern Delta Map*

The Bandar canal is one of the oldest among the supply canal system from Krishna River for irrigation in the recently reformed state of Andhra Pradesh with area of 160,205 sq. km. The preset study region is the region of this canal extending itself in region of Andhra Pradesh, with possessed data from Indian Meteorological Department.

2. Methodology

The spatial distribution of estimation of potential evapotranspiration is still has been scope of study in spite of the achieved global predominance. This can be explained by the hardly handy data at main stations. The performance of the empirical equations with reference to Penman-Monteith method is the main objective of this study. The Penman-Monteith method is FAO recommended standard and requires data as input at a greater extent. Daily meteorological data of maximum and minimum temperatures, wind speed, relative humidity, sunshine hours and solar radiation data is required by this standard method, and CROPWAT software is used for computation of potential evapotranspiration using the Penman-Monteith method easily. The method which juxtaposes with the Penman-Monteith method is chosen, with data requirement as a primary function. Extensively used and well known methods Thornthwaite, Blaney-Criddle, Hargreaves which are primarily temperature based are adopted in this study for comparison. The period of study being 2012 to 2014. The monthly meteorological data is obtained from Indian Meteorological Department for the same purpose.

2.1. PET Methods

2.1.1. Blaney-Criddle method

The Blaney-Criddle is popular method developed in 1950, is widely known for its simplicity till the development of Penman Monteith. The temperature changes at a site are the feed for the method. The equation is given as:

$$ET_o = p(0.46T_{mean}+8.13) \qquad (1)$$

2.1.2. Hargreaves-method

The Hargreaves *et al.* Method developed in 1985 is an empirical relation which entails daily air temperature in addition to global radiation (Ra). This method is regression analysis of relative humidity factor and temperature reduction co-efficient, and used when the data is meagre. It is given as:

$$ET_o=0.0023(T_{max}-T_{min})^{0.5}(T_m+17.8)\,Ra \qquad (2)$$

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

2.1.3. Penman-Monteith Method

The FAO-56 recommended method is chosen as standard for its accuracy in estimation of Potential evapotranspiration. The temperature and radiation parameters, both are required for the computation of PET. The equation is given as

$$ET_o = \frac{0.408\Delta(R_n-G)+\gamma\frac{900}{T+273}U_2\,(e_s-e_a)}{\Delta+\gamma(1+0.34U_2)} \qquad (3)$$

2.1.4. Thornthwaite method

The Thornthwaite method developed in 1948 is an empirical study, between mean air temperature and Evapotranspiration.

It is known for the under-estimation in the arid and overestimation in the humid areas, requiring only sunshine hours besides the temperature for computation. The equation is given as:

$$ET_o = ET_{gr}\left(\frac{N}{12}\right)\left(\frac{d_m}{30}\right) \qquad (4)$$

$$ET_{gr} = 16\left(\frac{10\,T_m}{I}\right)^{\alpha} \qquad (5)$$

$$I = \sum_{i=1}^{12}\left(\frac{T_m}{5}\right)^{1.514} \qquad (6)$$

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;

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

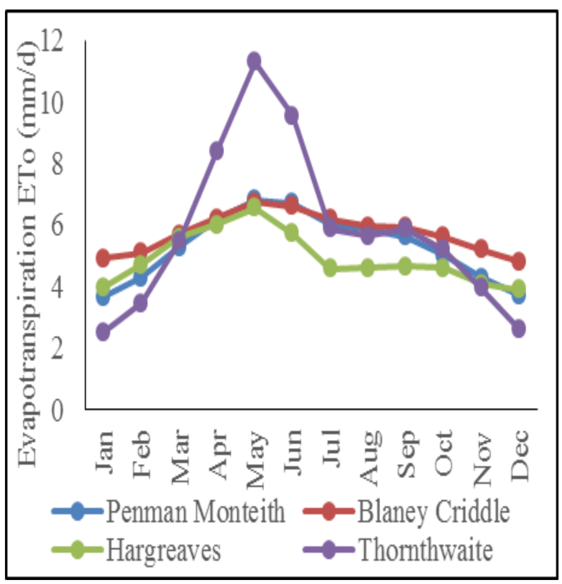

***Figure 2** Mean daily ET_o simulated by Penman Monteith and three simple methods*

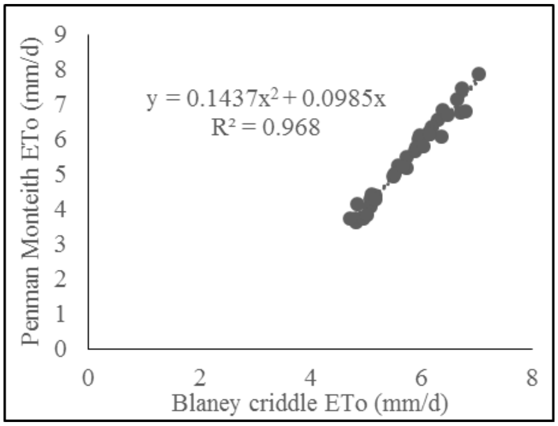

Figure 3 *Relationship between Blaney -Criddle and Penman-Monteith*

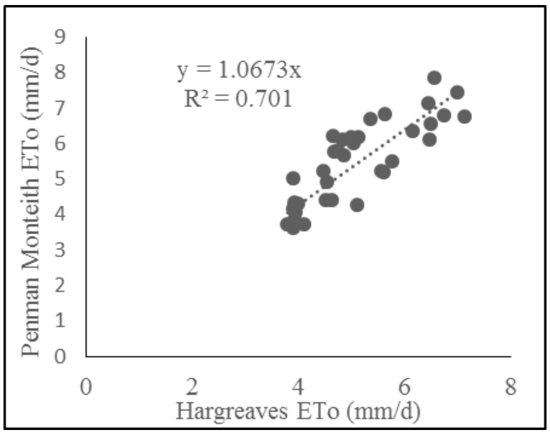

Figure 4 *Relationship between Hargreaves and Penman-Monteith*

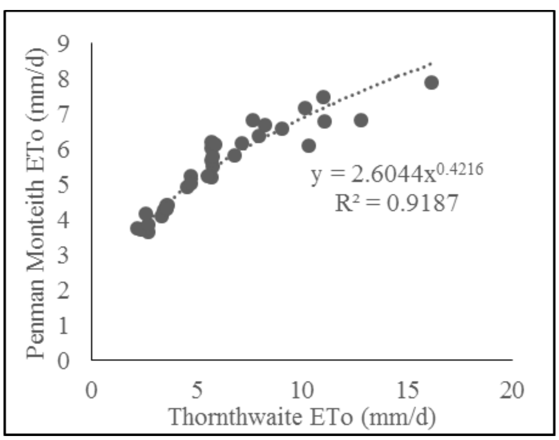

Figure 5 *Relationship between Thornthwaite and Penman-Monteith*

3. Results & Discussion

The data obtained from Indian Meteorological Department for the years 2012-2014 for a region of command area of Bandar canal in Andhra Pradesh State, India has been used for assessment of Evapotranspiration by the three methods, namely Blaney-Criddle, Hargreaves and Thornthwaite methods which are primarily temperature based. The results of these methods were correlated with Penman-Monteith method computed using CROPWAT 8.0 software. The Penman-Monteith method which is FAO-56 recommended requires information regarding wind speed, maximum and minimum temperatures, relative humidity, sunshine hours and solar radiation. The Evapotranspiration (ET_o) requirement of all the methods month wise is compared and shown in Figure – 1 for a typical year. It can be observed that Thornthwaite method has shown maximum values of ET_o during May and June months. The average of daily data is used as monthly value for all the methods for regression and error analysis. The developed equations can be used to predict the ET_o using more acceptable Penman-Monteith method, which is more data intensive with less data intensive models like Blaney-Criddle, Hargreaves and Thornthwaite methods. The assessment of regression and error analysis indicates that the Blaney-Criddle method performed best with the least root mean square error (RMSE) of 0.3143, Mean Absolute deviation (MAD) of 0.275 Regression coefficient (R^2) of 0.968 for monthly evapotranspiration value estimations. The developed equation between Blaney-Criddle and Penman-Monteith is shown in Figure – 2 and the regression equation is shown in equation 8. The relationship between Hargreaves and Penman-Monteith is shown in Figure – 3 and the regression equation is shown in equation 9. The Root Mean Square Error (RMSE) of 0.6437, Mean Absolute deviation (MAD) of 0.561 Regression coefficients (R^2) of 0.701. The relationship between Thornthwaite and Penman-Monteith is shown in Figure – 4 which is a non-linear relationship and the regression equation is shown in equation 10. The Root Mean Square Error (RMSE) of 0.898, Mean Absolute deviation (MAD) of 0.783 Regression coefficients (R^2) of 0.9187.

$$Y = 0.1437\,x^2 + 0.0985\,x \qquad (8)$$

Where

Y is Evapotranspiration (ET_o) using Penman –Monteith method

X is Evapotranspiration (ET_o) using Blaney-Criddle method

$$Y = 1.0673\,x \qquad (9)$$

Where

Y is Evapotranspiration (ET_o) using Penman –Monteith method

X is Evapotranspiration (ET_o) using Hargreaves method

$$Y = 2.6044\,x^{0.4216} \qquad (10)$$

Where

Y is Evapotranspiration (ET_o) using Penman –Monteith method
X is Evapotranspiration (ET_o) using Thornthwaite method

4. Conclusions

Determination of correct evapotranspiration is an important aspect in water management. In the present study a highly data intensive, well known FAO-56 Penman-Monteith method has been used to compute reference evapotranspiration ET_o for a canal command area. Three different methods which are less data intensive and empirical are also used to compare the ET_o with the Penman-Monteith as standard, using the meteorological data acquired from Indian Meteorological Department. The Penman-Monteith is taken as standard as recommended by FAO-56 for estimating Evapotranspiration (ET_o) for command area of a major canal namely Bandar canal under river Krishna command in Andhra Pradesh. The empirical relationships developed will be useful to assess the Evapotranspiration (ET_o) using less data intensive methods like Blaney-Criddle, Hargreaves Thornth-waite methods in the region selected for the study.

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