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# Estimation of monthly average pet by various methods and its relationship with pan evaporation at Bhagalpur, Bihar

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## Abstract
Mesh covered pan evaporation at Bhagalpur was correlated with potential evapotranspiration (PET) computed by using empirical methods of FAO-Penmann Monteith (1998), Thornthwaite (1948), Papadakis (1965), Jensen and Haise (1963) and Modified Jenson and Haise (1975). Weather data for 4 years namely 2014-2017 for Bhagalpur was used to compute the potential evapotranspiration by different empirical methods. Linear regression equations were fitted between monthly PET by computed by different individual methods and the measured pan evapotranspiration. Pan evaporation showed good correlation with monthly PET having $R^2$ value of 92.8 for Jensen and Haise, 91.8 for modified Jensen and Haise, 90.8 for FAO-Penmann Monteith and moderate correlation was observed in case of Thorntwaite (58.7) and Papadkais Method (61.4). There exists biasness between estimated and observed pan evaporation. The biasness was positive when pan evaporation was on the higher sides and biasness was negative when the pan evaporation was on the lower side.

**Keywords:** Potential evapotranspiration, pan evaporation, empirical methods, linear regressions.

## Introduction
The state of Bihar is characterized by three distinct seasons, i.e. cool- day winter, hot-day summer and warm wet rainy season. Due to the very erratic pattern of rainfall farmers need to depend heavily upon irrigation. Thus, the judicious utilization of irrigation water is only way to enhance the potentiality of water enhancing the water use efficiency for raising crops. Evapotranspiration (ET) is an important component for assessing the actual crop need of the water (Rosenberg *et al*., 1983) [8]. Farmers often apply irrigation arbitrarily out of sense and not taking into account the actual crop's actual water need. Evapotranspiration is one of the principal component for calculating the water need and for timely and judicious use of water under water constraint scenarios.
Assessing the potential evapotranspiration (ET) by empirical formulae is of greater acceptance which do not require disturbance soil and plant health and thereby restoring the soil health. Though ET can be assessed by lsyimetric method but its difficulty in installation and high economic cost often restrict it's for scientific studies. The empirically developed models often holds good for the region where it has been developed. However, it gives an understanding for estimating the water needs and irrigation scheduling. Itenfisu *et al* (2003) [3] made comparison between various methods of reference evapotranspiration with ASCE-Penman-Montieth equations in the United States. Results showed that the ASCE standardized equation agreed best with full form of ASCE Penman-Montieth. Upadhyaya A (2016) [10] made a comparison of Different Methods to Estimate Mean Daily Evapotranspiration from Weekly Data at Patna and concluded that mean weekly evapotranspiration values obtained from Penman-Monteith method were very closer to FAO-56 Penman-Monteith method and values from all the other methods except FAO- 24 Pan, Christiansen Pan and Hargreaves methods generally predicted higher values of mean weekly daily $ET_0$ in comparison to FAO-56 Penman-Monteith method. Kingra *et al*. (2002) [5] estimated PET by various methods and concluded that pan evaporation correlated well with papadakis method ($R^2$=0.84) followed by Jensen and Haise and Modified Jensen and Haise ($R^2$=0.79) and least for Thorntwaite method ($R^2$=0.65).The paper thus, aims to focus on assessing the performance of five empirical methods for estimating PET and their comparison with mesh wired open pan evaporation (EP).

## Materials and methods
Daily Meteorological data (2014-207) were collected for Bhagalpur from agro meteorological observatory of Bihar Agricultural University, Sabour to compute monthly average PET using

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various methods. The monthly mean computations for the following years were made according to the following formulae:

**FAO- Penman Monteith Method**

The ETo was calculated with all necessary data according to FAO-PM, month to month for every year of the series, as well as using only the data from Tmax (maximum temperature) and Tmin (minimum temperature) of the air (hereafter). Simplified FAO-PM); finally it was analyzed by regression. According to Pereira *et al.* (1997) [7] and Allen *et al.* (1998) [1], the FAO-PM equation can be calculated from the given equations:

$$ETo = \frac{0.408\ \Delta(Rn - G) + \gamma\ \frac{900}{(T+273)} u_2 (es - ea)}{\Delta + \gamma(1 + 0.34u_2)} \quad (\text{mm d}^{-1}) \quad \ldots\ldots\ldots (1)$$

Where,
Each of the parameters of this equation is calculated by specific equations described by the same authors cited above.

**Papadakis Method**

$PET=0.5625\ (e_{max}-e_{min-2})*10$…………….. (2)

Where, PET=Monthly potential evapotranspiration (mm)
$e_{max}$ = Saturation vapour pressure at mean maximum temperature (mb)
$e_{min-2}$ = Saturation vapour pressure at mean minimum temperature minus $2^0$ C in (mb). Papadakis assumed that $2^0$ C is the usual temperature difference between minimum temperature and dew point temperature.

**Jensen and Haise Method**

$PET= (0.014T_A-0.37)*(R_S*0.000675*25.4)$………… (3)

Where,
PET= Daily potential evapotranspiration (mm)
$T_A$= Mean temperature ($^0$ F)
Rs= Solar Radiation in lyday$^{-1}$

**Modified Jensen and Haise**

PET= 0.012*(T-15.4)*Rs*0.171 (Clyma and Chaudhary, 1975)… (4)

Where,
PET=Daily Potential Evapotranspiration in mm
T= Mean Air Temperature ($^0$ F)
Rs= Solar Radiation in lyday$^{-1}$

**Thorntwaite Method**

$e=1.6*(10T/I)^a$ ………….. (5)

Where,
e= Unadjusted PET in cm/month
T= Mean air temperature in $^0$ C
I=Annual heat index== $\sum_1^{12}(i)$
i=Monthly heat indices = $(T/5)^{1.514}$
$a=0.000000675*I^3-0.000071*I+0.01792*I+0.049239$
Unadjusted PET is further adjusted modified by applying an adjustment factor 'k' for the table was given by Michael (1978).
Where,
PET=Monthly potential evapotranspiration in mm
k=Adjustment factor
e= Unadjusted monthly potential evapotranspiration in cm month
The relationship between computed PET and mesh covered pan evaporation (EP) was studied by regression analysis between PET computed with each method (y) and mesh covered pan evaporation (x). The evaporation pan refers to USDA open pan which was covered with a wire mesh. Similarly, t test was carried out between EP and all other empirical methods to find out test of significance.

**Results and discussion**

**Variation in PET and EP (mm)**

FAO- Penman Monteith Model estimated that the lowest values of EP as well as of PET (1.0 mm and 1.5 mm) were obtained during the months of December and the highest PET were obtained during the month of May (6.1 mm and 5.3 mm) (Table 1.0). Thorntwaite's method estimated PET value very close to EP. PET computed by Thorntwaite's method underestimated EP almost throughout the year except during February, March, April and May. PET estimations by Thorntwaite's method fluctuated from month to month sometimes overestimating and sometimes underestimating the PET. However, the model highly overestimated the PET during monsoon seasons. Papadakis method on the other hand over estimated PET during winter months but underestimated PET during the summer seasons. Similar, trend was observed by Kingra et. al (2004) [5]. Both Jensen and Haise and Modified Jensen and Haise showed similar kind off trend in estimating PET. They overestimated the PET throughout the years. Both the method estimated lowest PET during the month of January and highest during the month of May (Table 1.0).

**Table 1:** Monthly average values of mesh covered pan evaporation (EP) and monthly average potential evapotranspiration (PET) in mm computed by five empirical methods for the period (2014-2017).

| Month | Epan | FAO-Penmann Monteith | Thorntwaite | Papadakis | J & H | Modified J & H |
|---|---|---|---|---|---|---|
| January | 1.1 | 1.7 | 1.2 | 2.2 | 2.8 | 3.2 |
| February | 1.8 | 2.4 | 1.7 | 2.7 | 4.1 | 4.6 |
| March | 3.1 | 3.6 | 2.8 | 3.9 | 5.9 | 6.4 |
| April | 5.4 | 5.2 | 4.6 | 4.8 | 7.6 | 7.8 |
| May | 6.1 | 5.3 | 5.9 | 4.5 | 7.9 | 8.1 |
| June | 5.3 | 4.4 | 6.3 | 4.2 | 6.6 | 6.7 |
| July | 2.3 | 3.5 | 5.7 | 3.1 | 5.2 | 5.3 |
| August | 2.7 | 3.5 | 5.1 | 2.9 | 5.2 | 5.3 |
| September | 2.2 | 3.1 | 4.2 | 2.7 | 4.9 | 4.9 |
| October | 2.1 | 2.8 | 2.9 | 2.6 | 4.4 | 4.5 |
| November | 1.7 | 2.0 | 1.9 | 2.1 | 4.2 | 4.5 |
| December | 1.0 | 1.5 | 1.4 | 2.0 | 3.1 | 3.3 |

**Table 2:** Linear Relationship between Pan Evaporation and PET computed through various methods

| Sl. No. | Regression Equation. | $R^2$ | P Value | Methods |
|---|---|---|---|---|
| 1. | y = 0.6898x + 1.2511<br>y = 1.0136x | 90.8<br>64.1 | 0.28, t > 0.05 | FAO- Penman Monteith |
| 2. | y = 0.828x + 1.2253 y = 1.1451x | 58.747.3 | 0.16, t > 0.05 | Thorntwaite Method |
| 3. | y = 0.2846x + 2.0649y = 0.819x | 61.4-2.2 | 0.48, t > 0.05 | Papadakis Method |
| 4. | y = 0.8884x + 2.5803y = 1.5562x | 92.823.08 | 0.001, t < 0.05 | Jensen & Haise Method |
| 5. | y = 0.8672x + 2.8459y = 1.6038x | 91.80.03 | 0.000, t < 0.05 | Modified Jensen & Haise |

Where,
x: Monthly average Pan Evaporation (mm),
y: Computed average monthly PET (mm)

**Relationship between EP and PET**

The linear regression relationships of the form y=ax+b and y=ax was developed between PET computed with various methods and pan evaporation which has been depicted in Table 2.0. In this study we have tried to form the regression function of the form y=ax+b between PET computed by Jensen and Haise though gave highest $R^2$ =92.8 followed by Modified Jensen and Haise method ($R^2$ =91.8) yet the test of significance showed high variance between EP and PET in case of both the methods. The lowest $R^2$ value was obtained in case of Thorntwaite's method ($R^2$ =58.7). However, the test of significance was found to be at par with EP for all the estimated PET values estimated except for Jensen & Haise and Modified Jensen & Haise. We tried to analysis our data by regression through origin (y=ax), $R^2$ values was found to be significantly on the lower side as compared to $R^2$ values obtained through regression analysis in the form of y=ax+b. The difference indicates that there exists biasness between the PET computed empirically. The biasness was positive when pan evaporation was on the higher sides and biasness was negative when the pan evaporation was on the lower side (Fig. 1.0).

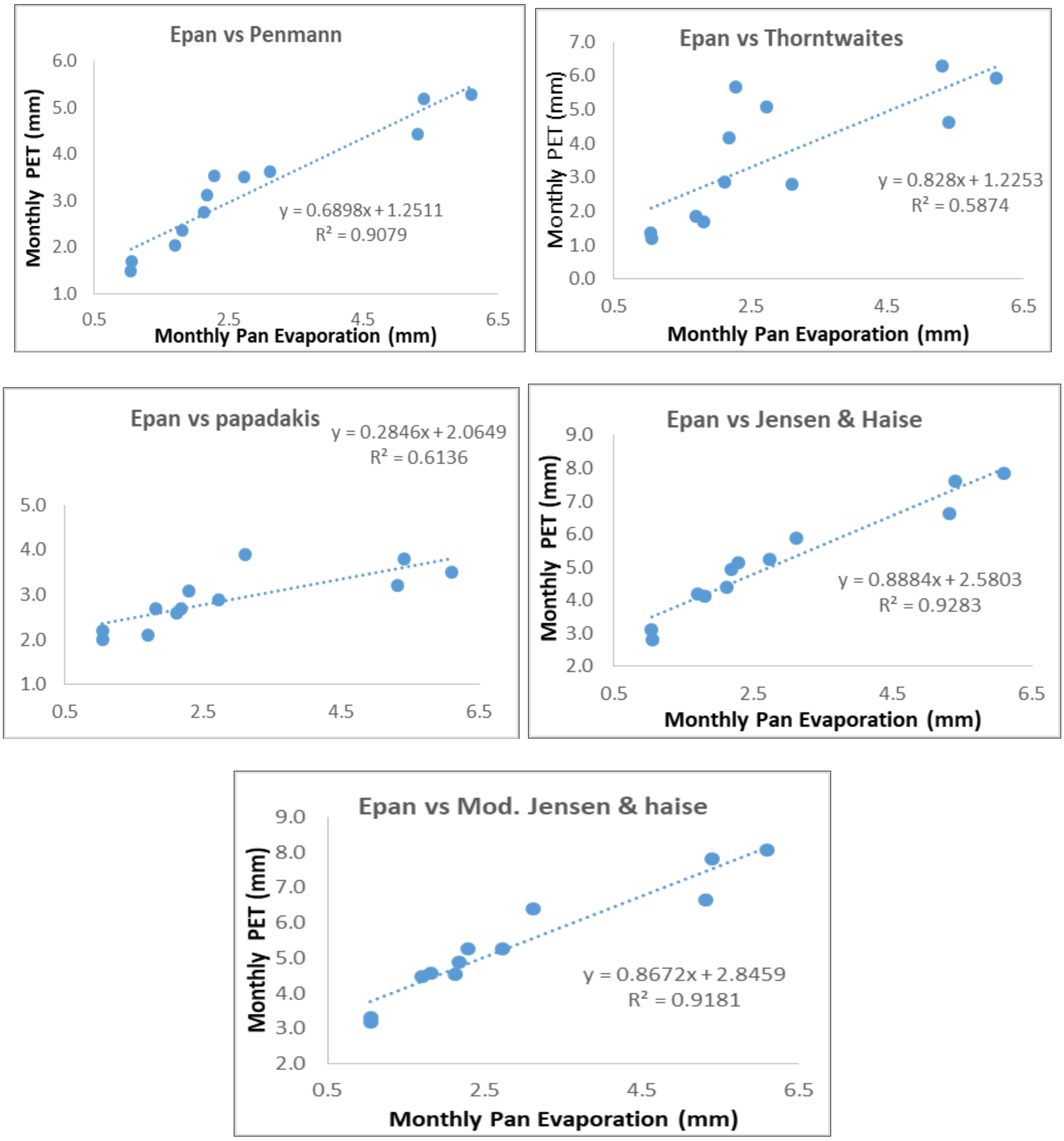


**Fig 1:** Relationship between Monthly PET and Pan Evaporation estimated by various methods.

## Conclusions

Five different methods of PET estimation were employed for climatic data of the period 2014 to 2017 and monthly average estimation of potential evapotranspiration were computed. The PET values were compared with EP (Pan Evaporation). Some models overestimated while some empirically calculated methods underestimated the potential evapotranspiration. Also, the linear regression relationships of the form y=ax+b and y=ax was developed between PET computed with various methods and pan evaporation. From the linear regression model it was observed that the Jensen and Haise method was the best fit model to estimate PET with level of accuracy followed by modified by Jensen and Haise Method. On the other side, Papadakis and Thorntwaites method was not able to estimate the PET quiet realistically under the study region and have very less $R^2$ value. These differences indicate that there exists some kind off biasness between the PET computed empirically through different methods. The biasness was positive when pan evaporation was on the higher sides and biasness was negative when the pan evaporation was on the lower side. Thus, this study can give a brief idea for using the correct method of estimating PET under Bhagalpur district which can act as a suitable tool for irrigation scheduling purpose.

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