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# COMPARISON OF METHODS FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION ($ET_0$) OF RICE CROP IN BHUBANESWAR REGION OF ODISHA

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## ABSTRACT

A field experiment was conducted at Central Research Farm, OUAT, Bhubaneswar on rice grown in Rabi, 2015 with two soil moisture regimes (flooding and aerobic) and four cultivars of various maturity duration. Daily Meteorological data of OUAT observatory during the crop season January to May, 2015, were used in estimating the $ET_0$ using 15 empirical models. The objective of the work was to estimate the $ET_0$ rates using different empirical methods and compare with the estimated $ET_0$ with open pan evaporation and crop transpiration. As per estimated $ET_0$ in January, Turc method did not correlate with Businger-van-Bavel, FAO-24 and Christiansen methods. Pan Evaporation was correlated with estimated $ET_0$ by Penman-Monteith, Hargreaves, Turc, Priestly-Taylor and FAO-56 methods. For the month of February, the estimated $ET_0$ highly correlated among all the methods as well as with pan evaporation. For the month of March pan evaporation correlated only with Kimberly-Penman, Penman 1963, FAO-24 Penman and Christiansen methods. For the month of April and May, pan evaporation correlated well with estimated ET by FAO 24 and Christiansen method. For the season as whole, all the methods except Christiansen method were correlated with the pan evaporation. Regression analysis showed that pan evaporation could be estimated by different methods for different months. For the month of January, five methods namely Penman-Monteith, Turc, Priestly Taylor and FAO-56 Penman-Monteith estimated the pan evaporation with $R^2$ ranging for 0.193 to 0.688. February pan evaporation could be estimated by any of the 15 methods. However, for the month of March, April and May, only two methods, namely FAO 24 and Christiansen were useful in estimating pan evaporation. On the other hand, for the season as a whole, these two methods were unable to estimate the pan evaporation rate. Transpiration was more under the continuous flooding than under the aerobic. Cultiver Naveen recorded highest transpiration rate, while Khandagiri recorded the lowest transpiration rate both at flowering and physiological maturity. Transpiration rate was highest in maturity stage ($1.4\times10^{-3}$ µmoles $m^{-2}$ $sec^{-1}$) than the flowering stage ($1.0\times10^{-3}$ µmoles $m^{-2}$ $sec^{-1}$).

**KEYWORDS:** Reference Evapotranspiration ($ET_0$), Fao-56 Penman Monteith, Turc, Fao 24 Penman, Priestly Taylor

## INTRODUCTION

Water plays a vital role for every living being in agriculture, most of the water is lost due to evapotranspiration by the canopy cover of the plant and surface evaporation. It is the combination of soil evaporation and crop transpiration process. About 70% of the water loss from the earth's surface occurs as evaporation (Almhab and Busu, 2008). Thus, accurate estimation of evapotranspiration is very important for studies. In evapotranspiration studies, Allen et al., (1998) defined $ET_0$ as "the evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 $sm^{-1}$ and albedo of 0.23, closely resembling the evapotranspiration from an extensive surface

of green grass of uniform height, actively growing, completely shading the ground and with adequate water". It can be either directly measured by using lysimeter or water balance approaches, or estimated indirectly using empirical equations. Direct measurement of Evapotranspiration using the lysimeter or water balance approach seems to be the most accurate. However, it is a time-consuming method and needs precisely and carefully planned experiments for which empirical formulas can be used. Numbers of empirical equations have been used for $ET_0$ estimation methods and these methods are mainly grouped into radiation, temperature, pan evaporation based and combination methods. Pan evaporation is widely used in a agricultural meteorology due to simplicity low cost, area of application for irrigation scheduling (Stanhill, 2002). Estimation of reference evapotranspiration requires number of parameters, so it is very difficult to estimate it accurately. Therefore, it becomes impractical for many users to select the best $ET_0$ estimation method for the available data and climatic condition. To overcome this problem, Reddy (1999) developed a decision support system consisting of nine widely used $ET_0$ estimation methods. Bandopadhyay et al., (2008), further improved this model. The DSS_ ET model can be used to identify the best $ET_0$ method for different climatic conditions. These available methods can be used for estimating daily and monthly $ET_0$ values for the time interval considered in this study. The objectives of the present work were to estimate the $ET_0$ rates using different empirical methods and to compare the estimated $ET_0$ with open pan evaporation. Find out the suitable method. The FAO 56 method is established as the standard method of estimating $ET_0$, attempt was made to estimate it from the other methods.

## MATERIALS AND METHODS

The experiment was conducted in the Agro met Research Block, Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar during Rabi season (January -May) 2015. Bhubaneswar situated at an elevation of 26 m above mean sea level at $20^0 16' N$ latitude and $85^0 50' E$ longitude. It is in the East and South East Coastal Plain of Odisha, which falls under hot par humid climate. Agronomic data were collected for the crop growing period during Rabi season (January -May) 2015. The experiment taken In Central Rice Research farm in OUAT, Rice is mostly cultivated during Rabi season. In different variety of rice grown in the field eg. long, short and medium variety. Almost equally cultivated during the month of January. The treatments were comprised of (a) four varieties of rice and (b) two soil moisture regimes, namely aerobic and conventional flood irrigation. The four varieties were Khandagiri($v_1$), Lalat($v_2$), Naveen($v_3$), Satabdi ($v_4$).

### Methods for Estimating of $ET_0$

The daily Reference Evapotranspiration were estimated by using following methods, he methods given below are taken for estimation for $ET_0$ for present study:

- Standardized form of FAO-56 Penman-Monteith by ASCE 2005
- Penman Monteith Method (Monteith (1965), Allen (1986), Allen *et al*. 1989
- Hargreaves Temperature Method
- Priestly-Taylor Radiation & Temperature Method
- Turc Radiation and Temperature Method
- 1972 Kimberly-Penman Method

- 1982 Kimberly-Penman Method
- CIMIS Penman method
- FAO-PPP-17 Penman ($ET_0$) method
- FAO-24 Penman (c=1) ($ET_0$) method [Doorenbos and Pruitt (1975, 1977)]
- Businger-van Bavel ($ET_0$) method
- Penman 1963 VPD ≠1 method
- Penman 1963 method
- Christiansen pan method
- FAO-24 pan method

The computer program written in DSS_ET is a Decision Support System developed at IIT Kharagpur for estimation of crop evapotranspiration. The DSS_ET model (Reddy, 1999) developed in Microsoft Visual Basic 6.0 is used in this present study to estimate reference evapotranspiration By using the available daily climatological data, the daily reference evapotranspiration ($ET_0$) values were estimated using fifteen available methods in crop growing season of rice crop from January to may, 2015.

**Evaluation of Methods**

$ET_0$ estimates from all methods were compared by using simple error analysis and linear regression. For location, the following parameters were calculated:

- Standard Error Estimate (SEE)
- Root Mean Square Error (RMSE)
- Percentage Error Estimate (PE)
- Mean Bias Error (MBE)
- Coefficient of Determination ($R^2$)
- Regression Coefficient (b)
- Monthly Mean (mm/d)

The performance of a model is good when regression coefficient (b) is close to 1.0, $R^2 > 0.6$, RMSE < 0.6 mm $d^{-1}$ and PE < 20%.

## RESULTS AND DISCUSIONS

**Comparison of Error of Different $ET_0$ Estimation Methods**

Since FAO 56 method is now established as the standard method of estimating $ET_0$, attempt was made to estimate it from the other methods. Idea was that FAO 56 method requires six number of parameters, which are not available for many places. In Table 1 gives the mean values of $ET_0$ estimates along with the different error. The mean values of $ET_0$

showed that FAO 24 Pan method gave the highest rate of 8.57 mm/day, while Penman-Monteith method gave the lowest rate of 4.54 mm/day. All other methods gave moderate values around 5.5 mm/day. These values were compared with the Open pan evaporation method to determine more correct method. The RMSE values did not vary much among the methods. It ranged between 3.0 and 3.1 mm/day. Similarly, the mean bias error (MBE) did not vary among the methods. Of course, these were the negative values. Percent error estimates were also very conservative. It varied from -91.28 to -82.27.

**Table 1: Comparison of $ET_0$ Estimation Methods with Error Analysis for Mean $ET_0$ During the Growing Season at Bhubaneswar**

| Method | Mean (mm/d) | SEE (mm/d) | B | PE | MBE | RMSE (mm/d) |
|---|---|---|---|---|---|---|
| Penman Monteith | 4.54 | 0.98 | 1.021 | -90.84 | -0.5977 | 3.009 |
| Kimberly Penman | 5.24 | 0.99 | 0.886 | -89.44 | -0.5885 | 3.008 |
| FAO-PPP 17 Penman | 5.09 | 1.13 | 0.912 | -89.75 | -0.5905 | 3.008 |
| Penman 1963 VPD#1 | 5.36 | 1.09 | 0.866 | -89.20 | -0.5869 | 3.007 |
| Penman 1963 | 5.02 | 1.15 | 0.925 | -89.89 | -0.5914 | 3.008 |
| Kimberly Penman(1972) | 5.85 | 1.27 | 0.79 | -88.21 | -0.5804 | 3.006 |
| FAO-24 Penman | 5.39 | 1.13 | 0.861 | -89.14 | -0.5865 | 3.007 |
| Hargreaves | 5.52 | 1.25 | 0.842 | -88.89 | -0.5848 | 3.007 |
| Businger Bavel | 5.13 | 1.47 | 0.905 | -89.66 | -0.5444 | 3.008 |
| FAO 24 Pan | 8.57 | 10.04 | 0.541 | -82.74 | -0.6006 | 3 |
| Christiansen Pan | 4.33 | 0.91 | 1.072 | -91.28 | -0.5950 | 3.01 |
| Turc | 4.75 | 1.01 | 0.977 | -90.43 | -0.5867 | 3.009 |
| Priestly Tailor | 4.75 | 1.01 | 0.977 | -90.43 | -0.5867 | 3.009 |
| CIMIS Penman | 5.37 | 1.15 | 0.861 | -84.17 | -0.5464 | 3.007 |

**Ranking of Different $ET_0$ Estimation Methods**

Ranking of $ET_0$ estimation methods was done to judge the accuracy of a method which helps to find out the next best method for accurate estimation. Among the combination based methods, the FAO-56 PM method (Allen et al., 1998) was taken as the standard method for comparison as it is considered as the sole standard method to estimate $ET_0$ in all types of climatic conditions. The ranking of different $ET_0$ estimation methods for Bhubaneswar region of Odisha was done with respect to the FAO-56 PM $ET_0$ on the basis of their mean SEE values and the results are presented in Table 2. From this table showed that Turc method ranked the top most, while FAO 24 Penman was ranked as poorest performer in estimating FAO 56 Penman Monteith Reference Evapotranspiration rate during the summer season.

**Table 2: Ranking of Different ET Estimation Methods**

| Method | Average Factor | See Value | Ranking |
|---|---|---|---|
| Turc | 0.70 | 0.91 | 1 |
| Penman | 1.16 | 0.98 | 2 |
| Kimberly-Penman | 1.01 | 0.99 | 3 |
| Priestly-Taylor | 0.74 | 1.01 | 4 |
| Penman 1963 VPD#1 | 0.90 | 1.09 | 5 |
| Kimberly Penman(1972) | 0.97 | 1.10 | 6 |
| Fao-PPP 17 Penman | 0.90 | 1.13 | 7 |
| CIMIS Penman | 0.79 | 1.15 | 8 |
| Hargreaves | 0.57 | 1.15 | 9 |
| Penman 1963 | 0.87 | 1.15 | 10 |
| Businer Bavel | 0.85 | 1.25 | 11 |
| FAO-24 Penman | 0.85 | 1.27 | 12 |
| FAO-24 Pan Method | 0.55 | 1.47 | 13 |
| Christiansen Pan | 0.57 | 10.04 | 14 |

## ESTIMATION OF EVAPOTRANSPIRATION RICE CORP

### Correlation among the Different Methods

For the month of January correlation between Penman- Monteith, FAO 56 Penman Moteith and Open pan were significant and positive. In February, all the methods of $ET_0$ estimation were positively and significantly correlated. Correlation between Open pan, FAO 24 Pan and Businger- Bavel methods were significant and positive for three months, March, April and May. Taking the whole season from January to May, all the methods were positively and significantly correlated. The results showed that correlation was similar for February and the season as a whole. Thus February had a greater weight age over the seasonal performance of the methods. Moreover, correlation was almost similar for three months namely, March, April and May. Thus when temperatures were higher in the summer season, the three methods, namely Open pan, FAO 24 Pan and Businger -Bavel methods FAO56 Penman Monteith method was found better correlated with the Open Pan method, which is the only method that measures. The consistency in correlation of FAO56 Penman Moteith with Open pan is not surprised because it is a combination approach plus the plant factors are considered too. Thus, FAO56 Penman Monteith can be used in place of Open pan, taking a suitable correction factor.

### Regression Analysis of Open Pan Measurements with Different Methods of Estimation

Estimation of Open pan Evaporation rate from the other methods was done by regression analysis. The results showed that for the month of January Open Pan rate could be estimated from the Penman-Moteith, Turc and Priestly Taylor methods. However, for the months of February, March, April and May three methods, namely, FAO 24 Pan, Cristiansen and FAO 56 methods could estimate the Open Pan prate. For the season as whole, it followed the trend of January month i.e. Open Pan rate could be estimated from the Penman Moteith, Turc and Priestly Taylor methods. Thus no particular method was found to perform consistently over all the months or the season as a whole.

### Crop Transpiration

Transpiration rate was more under continuous standing water than under aerobic condition at both 40 and 70 DAT. Naveen variety had higher transpiration rate than Khandagiri and Satabdi but did not differ from Lalat.

**Table 3: Transpiration (Micro Moles/$m^2$ Leaf/s) as Influenced by Two Soil Moisture Regimes and Four Cultivars of Summer Rice at Bhubaneswar in 2015**

| Treatment | Transpiration 40 Dat | Transpiration 70 Dat |
|---|---|---|
| Continuous Standing Water | $4.75\times10^{-3}$ | $5.92\times10^{-3}$ |
| Aerobic | $1.67\times10^{-3}$ | $3.67\times10^{-3}$ |
| Total | $3.21\times10^{-3}$ | $4.79\times10^{-3}$ |
| LSD | $1.0\times10^{-3}$ | $1.4\times10^{-3}$ |
| Variety | Transpiration 40 Dat | Transpiration 70 Dat |
| Khandagiri | $2.13\times10^{-3}$ | $3.63\times10^{-3}$ |
| Lalat | $3.75\times10^{-3}$ | $5.92\times10^{-3}$ |
| Naveen | $4.47\times10^{-3}$ | $5.57\times10^{-3}$ |
| Satabdi | $2.51\times10^{-3}$ | $4.06\times10^{-3}$ |
| Mean | $3.21\times10^{-3}$ | $4.79\times10^{-3}$ |
| LSD | $1.5\times10^{-3}$ | $2.0\times10^{-3}$ |

## CONCLUSIONS

Taking the whole season from January to May, all the methods were positively and significantly correlated. For

the season as whole, Open Pan rate could be estimated from the Penman Moteith, Turc and Priestly Taylor methods. Thus no particular method was found to perform consistently over all the months or the season as a whole. Turc method ranked the top most, while FAO 24 Penman was ranked as poorest performer in estimating FAO 56 Penman Monteith Reference Evapotranspiration rate during the summer season. In this study, the 15 reference evapotranspiration methods were tested during the crop-growing period. The daily data used in this study are temperature, relative humidity, wind speed, bright sunshine hour and pan evaporation. The $ET_0$ estimated by all these methods shows the same trend throughout the crop growing period. Transpiration rate was more under continuous standing water than under aerobic condition at both 40 and 70 DAT. Naveen variety had higher transpiration rate than Khandagiri and Satabdi but did not differ from Lalat.

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