

Original Research Article

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## Water Requirement for Different Crops in South Eastern Ghat Zone of Odisha, India

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### ABSTRACT

A study was conducted at College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar during 2014-15 to find out the water requirement of South Eastern Ghat zones of Odisha. Water plays a vital role for every living being. Water is and will become scarce natural resource in the near future. A clear understanding of the water balance is essential for exploring water saving measures. Due to economic and environmental constraints on new water resources developments, and increasing municipal and industrial needs, agriculture's share of water use is likely to go down day by day. Water resources management is due to the increase of the population and water demand especially in India, which is classified as arid and semi- arid regions. In India with such large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal distribution of freshwater resources. On an average South Eastern Ghat zone of Odisha receives about 1535mm of rainfall, which is uneven, erratic and uncertain in nature. Therefore efficient and effective water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. Agriculture is the one of important sector which utilizes around 60% of fresh water resource. Agriculture is the backbone of India. So it is needed to manage the water in the field of agriculture efficiently. Keeping the above in view, the following objectives are selected for this study, 1. Estimation of reference evapotranspiration for South Eastern Ghat zone of Odisha using weather data of the respective localities. 2. Screening of methods to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method. 3. Assessment of crop water requirement for major crops grown in agro-climatic zones of Odisha. Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches to one in most of the zones. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. The correction factor ranges from 0.759 to 1.261 all over the state. Water requirement was found out for all the major crops of this zone for all the seasons.

#### Keywords

Water Requirement, Crops in South Eastern Ghat Zone of Odisha

#### Article Info

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## Introduction

Water plays a vital role for every living being. Water is and will become scarce natural resource in the near future. A clear understanding of the water balance is essential for exploring water saving measures. Due to economic and environmental constraints on new water resources developments, and increasing municipal and industrial needs, agriculture's share of water use is likely to go down day by day. Water resources management is due to the increase of the population and water demand especially in India, which is classified as arid and semi-arid regions. In India with such large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal distribution of fresh water resources. On an average Odisha receives about 1500mm of rainfall, which is uneven, erratic and uncertain in nature. Therefore efficient and effective water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. Agriculture is the one of important sector which utilises around 60% of fresh water resource. Agriculture is the backbone of India. So it is needed to manage the water in the field of agriculture efficiently.

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, such as hydrologic water balance, irrigation system design and management, water resources planning and management, etc. The rate of evapotranspiration from an extensive surface

of 8-15 cm tall, green grass cover of uniform height actively growing, completely shading the ground and no shortage of water is called as the reference evapotranspiration (Doorenbos and Pruitt, 1977). 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  $70 \text{ sm}^{-1}$  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". The evapotranspiration rate is normally expressed in millimeters per unit time (mm/day). The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, decade, month or even an entire growing period or year, generally expressed in terms of days. Evapotranspiration is a complex and non-linear phenomenon since it depends on several interdependent parameters such as temperature, humidity, wind speed, radiation, and type of crop and growth stage of the crop. 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. Thus, for estimating ET from a well-watered agricultural crop, first reference evapotranspiration ( $ET_0$ ) from a standard surface is estimated and then an appropriate empirical crop coefficient for a particular crop is multiplied to determine the crop evapotranspiration ( $ET_c$ ). 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. Combination based ET estimation methods includes Penman vapour pressure deficit (VPD#1), Businger-van Bavel, Penman vapour pressure deficit (VPD#3), Penman-Monteith, 1972 Kimberly-Penman, FAO-24 Penman (c=1), FAO-24 Corrected Penman, FAO-PPP-17 Penman, 1982-Kimberly-Penman, CIMIS Penman and FAO-56 Penman-Monteith method. Radiation based methods includes Turc, Jensen-Haise, Priestly-Taylor and FAO-24 estimation methods. Thornthwaite, SCS Blaney-Criddle, FAO-24 Blaney-Criddle, and Hargreaves come under temperature based methods.

Estimation of 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. This decision support system was further modified to include more  $ET_0$  estimation methods (Swarnakar and Raghuwanshi, 2000) and named as DSS\_ET model.

This model was further improved by Bandopadhyay *et al.*, (2008). The DSS\_ET model can be used to identify the best  $ET_0$  method for different climatic conditions. It is developed in Microsoft Visual Basic 6.0. It consists of a model base for estimating  $ET_0$  by twenty two different methods and ranking them and a user-friendly graphical interface. These available methods can be used for estimating daily and monthly  $ET_0$  values for the time interval considered in this study.

The aim of present study is to estimate the reference evapotranspiration by using the available methods and ranked them to find the

best suited method. These  $ET_0$  values can later be used for different purposes such as to derive irrigation water requirement of crops, to obtain  $ET_0$  estimate for locations with no meteorological data and to fill the gaps in available records of  $ET_0$ . The  $ET_0$  was found out for South Eastern Ghat zone of Odisha by Mohanty and Subudhi (2018) Keeping the above in view, the following objectives are selected for this study:

1. Estimation of reference evapotranspiration for agro-climatic zones of Odisha using weather data of the respective localities.
2. Screening of methods to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method.
3. Assessment of crop water requirement for major crops grown in the zone.

## **Materials and Methods**

The South Eastern Ghat zone is situated at Kalimela of latitude 17.98688N and longitude 81.7735 E. Table 1 shows the major crops of this zone.

The methods given below are taken for estimation for ET for present study:

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

- Method
- f) 1972 Kimberly-Penman Method
  - g) 1982 Kimberly-Penman Method
  - h) CIMIS Penman method
  - i) FAO-PPP-17 Penman (ET<sub>0</sub>) method [Frère and Popov (1979)]
  - j) FAO-24 Penman (c=1) (ET<sub>0</sub>) method [Doorenbos and Pruitt (1975, 1977)]

### Statistical analysis

ET<sub>0</sub> estimates from all methods were compared by using simple error analysis and linear regression. For each 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<sup>2</sup>)

Regression Coefficient (b)

Monthly Mean (mm/d)

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

### Estimation of crop water requirement of major crops

Depending upon the cropping season 3 major growing seasons are noticed like *kharif*, *rabi* and *summer*. Eight Rabi crops, one summer

paddy and three types of *kharif* paddy are selected for the study as the major crops of ten different agro-climatic zones of Odisha stated in Table 3.2. Reference crop evapotranspiration for thirty three years for all crops were calculated by using FAO-56 PM method. On the basis of average ET<sub>0</sub> for any day during the crop period of any crops daily crop water requirement was estimated by multiplying crop coefficient (K<sub>c</sub>), presented in Table 3.3, value to the estimated ET<sub>0</sub> from FAO-56 PM method.

### Crop selection

In Odisha, paddy is major crop during the *Kharif* season, summer season and also in *rabi* season. In different parts of the state all varieties paddy, i.e., long, short and medium duration are almost equally cultivated during the *Kharif* season. During summer and *rabi* season, short duration and medium duration paddy are cultivated respectively. And also in *rabi* season, different pulses, oilseeds, are grown as major crops given in Table 2.

### Crop coefficient approach

In the crop coefficient approach the crop evapotranspiration, ET<sub>c</sub>, is calculated by multiplying the reference crop evapotranspiration, ET<sub>0</sub>, by a crop coefficient, K<sub>c</sub>

$$ET_c = K_c * ET_0$$

Where

ET<sub>c</sub> = crop evapotranspiration [mm d<sup>-1</sup>], K<sub>c</sub> = crop coefficient,

ET<sub>0</sub> = reference crop evapotranspiration [mm d<sup>-1</sup>]

Table 2 shows crop coefficient used to calculate the crop water requirement of this zone.

## **Results and Discussion**

### **Reference Evapotranspiration ( $ET_0$ ) estimation**

For each agro-climatologic zone, climatic data were imported to DSS\_ET. The DSS\_ET selected the methods applicable for that data availability condition and estimated  $ET_0$  values for all the ten agro-climatic zones of Odisha. Out of 22 widely used available methods, 11 methods were taken for 10 stations in this study.

The  $ET_0$  values were estimated by 11 applicable methods for 10 climatic zones using mean daily climatic data of minimum and maximum air temperature, mean relative humidity, wind speed and solar radiation with the help of DSS\_ET. Due to the unavailability of pan evaporation data, pan evaporation based methods were not used for the calculation. All the calculations were done on a daily basis from 1981-2013 for each zone by using DSS\_ET. The FAO-56 PM method was used as the standard method to estimate  $ET_0$  and the obtained  $ET_0$  values from the other methods were compared with this method.

Comparing the estimated  $ET_0$  values for all different climatic stations, it was found that the performance of different methods varies differently in different stations according to their climatic conditions.

### **$ET_0$ method comparison**

The  $ET_0$  values obtained by different methods were compared with the FAO-56 Penman-Monteith  $ET_0$  estimate due to the non availability of reliable lysimeter data in ten different agro-climatic zones of Odisha. Comparison studies for different zones are as follows:

### **$ET_0$ comparison for north western plateau**

The mean monthly  $ET_0$  was estimated using all the methods and compared with the FAO-56 Penman-Monteith estimates. Out of all the 10 methods, the FAO-24 Penman(c=1) method yielded the highest mean  $ET_0$  (6.642 mm/day). The Priestley-Taylor methods estimated the lowest mean  $ET_0$  of 4.216 mm/day. The Penman-Monteith and Priestley-Taylor methods resulted in the minimum and maximum SEE and RMSE values respectively. Similarly, the percentage error (PE) was found minimum and maximum for 1982 Kimberly-Penman method and FAO-24 Penman(c=1) method respectively. Priestley-Taylor and FAO-24 Penman(c=1) methods resulted the minimum and maximum Mean Bias Error (MBE) values respectively (Table 3).

For this zone, the highest  $ET_0$  values was found to be 10.32 mm/d for FAO-24 Penman(c=1) method followed by Busingervan Bavel (9.73 mm/d) and FAO-PPP-17-Penman (9.68 mm/d) in the month of May, whereas, lowest  $ET_0$  value was found in the month of December (2.54 mm/d) for the Priestly-Taylor method followed by 1982 Kimberly-Penman method (3.07 mm/d) (Fig. 1).

### **Correction factor for north western plateau**

For this zone, correction factor for Penman-Monteith and 1982 Kimberly-Penman approaches to one. The FAO-24 Penman (c=1) and Busingervan Bavel give more diversion from FAO-56 Penman-Monteith method. PM method have got highest ranking (Table 4) compared to other methods. The correction factor for north western plateau is shown in fig 2. And Table 5.  $ET_0$  and CWR of different crops were shown in Fig 3.

**Table.1** Major crops information of the study area

Sl. No.	Name of zones	Research Station	Soil type	Kharif	Rabi season
1.	South Eastern Ghat	Kalimela	Red, mixed red & black	Paddy	Paddy, Millet, Sesamum

**Table.2** Crop coefficient for different crops at different stages

CROPS	Total duration	Stages (in duration)				K <sub>c</sub> value for different stages			
		Initial Stage(I)	Crop Dev. (II)	Mid Season (III)	Late Season (IV)	Initial Stage (I)	Crop Dev. (II)	Mid Season (III)	Late Season (IV)
Paddy-I	90	15	25	30	20	1.00	1.05	1.20	0.90
Paddy-II	120	15	50	25	30	1.00	1.05	1.20	0.90
Paddy-III	150	15	30	60	45	1.00	1.05	1.20	0.90
Sesamum	90	15	25	35	15	0.35	0.7	1.15	0.25
Millet	100	15	25	40	20	0.35	0.6	1.0	0.3

**Table.3** Statistical summary of monthly ET<sub>0</sub> estimates for South Eastern Ghat

Statistical Parameters	ET <sub>0</sub> Methods									
	PM	KP-82	KP-72	FAO-PPP-17-P	FAO-24-P(c=1)	HG	BvB	Turc	PT	CIMIS-Penman
Mean (mm/d)	4.382	4.444	4.959	5.119	<b>5.721</b>	4.628	5.684	3.997	<b>3.883</b>	5.005
R <sup>2</sup>	<b>0.994</b>	0.917	0.986	0.982	0.988	0.735	0.971	0.760	<b>0.518</b>	0.991
SEE(mm/d)	<b>0.198</b>	0.528	0.531	0.699	1.307	0.944	1.339	1.028	<b>1.413</b>	0.525
b	0.970	0.978	1.098	1.132	<b>1.264</b>	0.986	1.262	0.868	<b>0.809</b>	1.096
PE	2.86	<b>1.47</b>	9.96	13.49	<b>26.84</b>	2.59	26.01	11.37	13.91	10.97
MBE	-0.129	-0.066	0.449	0.609	<b>1.211</b>	0.117	1.173	-0.513	<b>-0.628</b>	0.495
RMSE	<b>0.198</b>	0.528	0.531	0.698	1.307	0.944	1.338	1.028	<b>1.412</b>	0.525

**Table.4** Ranking of different methods for different stations with respect to FAO-56 PM method

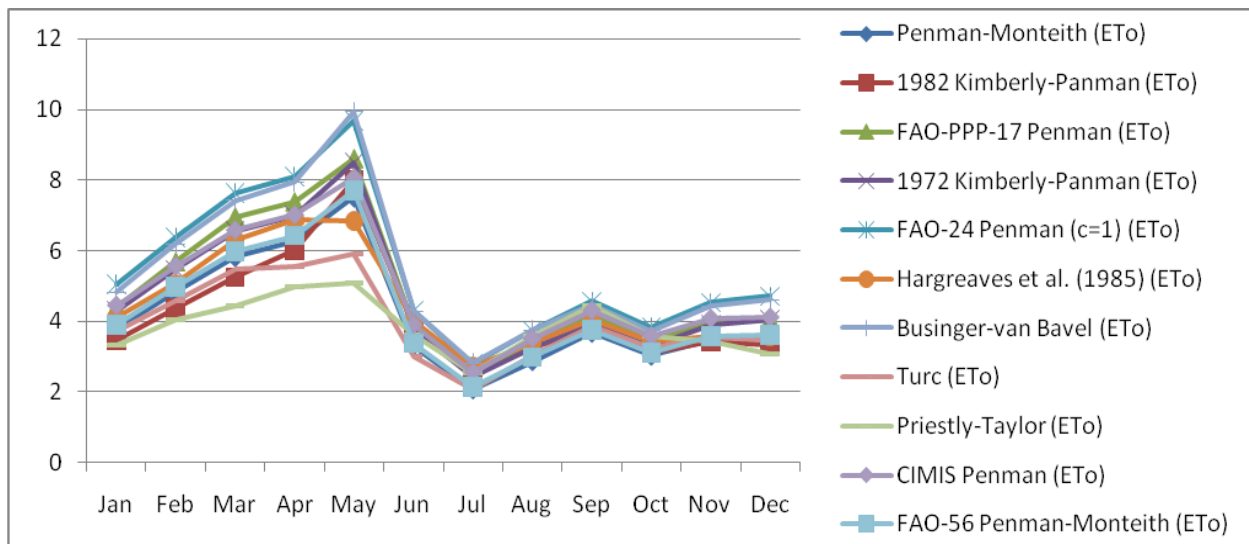
Station Name	PM	KP-82	KP-72	FAO-PPP-17-P	FAO-24 P (c=1)	HG	BvB	Turc	PT	CIMIS-Penman
AZ-7	1	4	2	5	9	7	8	6	10	3



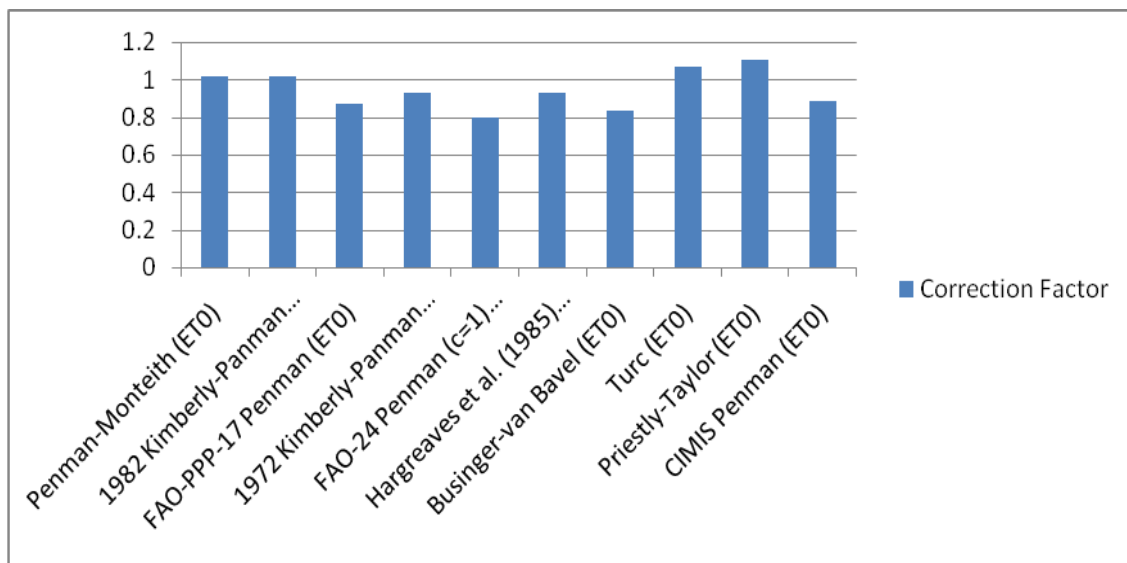
**Table.5** Correction factor with respect to FAO-56 method for South Eastern Ghat zone of Odisha

Station Name	PM	KP-82	FAO-PPP-17-P	KP-72	FAO-24 P (c=1)	HG	BVB	Turc	PT	CIMIS-Penman
AZ-7	1.019	1.015	0.874	0.926	0.795	0.931	0.834	1.071	1.104	0.889

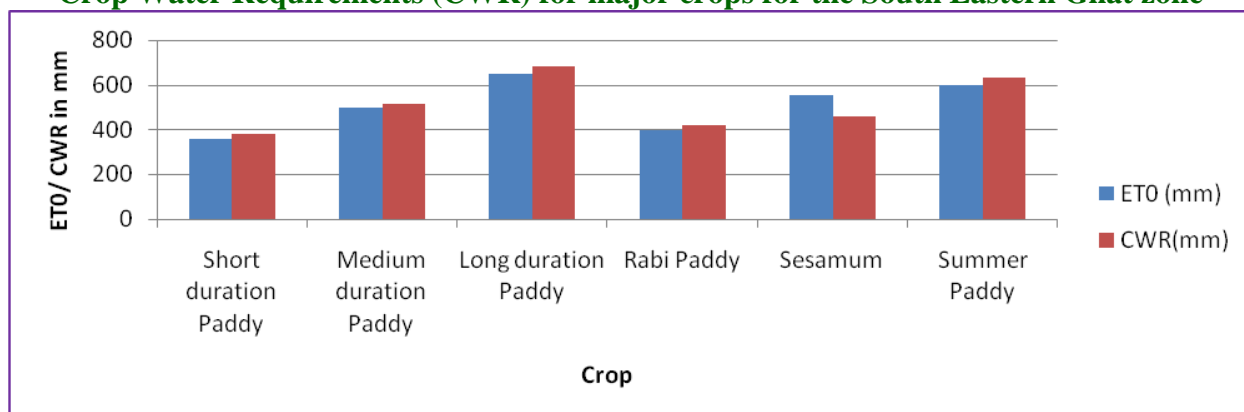
**Fig.1** Mean monthly ET<sub>0</sub> by all 11 methods for South Eastern Ghat



**Fig.2** Correction factor for South Eastern Ghat zone



**Fig.3 ET<sub>0</sub> Vs CWR for South Eastern Ghat zone**  
**Crop Water Requirements (CWR) for major crops for the South Eastern Ghat zone**



Conclusions of the study are as follows:

Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches to one in most of the zones. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method.

Water requirement for *Kharif* season, short duration paddy crop ranges from 333 mm to 480 mm, medium duration paddy ranges from 470 mm to 629 mm, long duration paddy 600 mm to 821 mm for this zone.

Water requirement for *rabi* season, paddy varies from 402mm to 659mm, sesamum ranges from 420 to 430 mm

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