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Water Requirement for Different Crops in North Eastern Coastal Plain Zone of Odisha

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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 North Eastern Coastal Plain zones of Odisha. Water plays a vital role for every living being. Water is and will become a 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 North Eastern Coastal Plain of Odisha receives about 1568 mm 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 resources. 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, Estimation of reference evapotranspiration for North Eastern Coastal Plain of Odisha using weather data of the respective localities [1]. Screening of methods to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method[2]. Assessment of crop water requirement for major crops grown in agro-climatic zones of Odisha[3]. Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approach 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.

Key words: Water Requirement, Crops in North Eastern Coastal Plane, Zone of Odisha

Introduction

Water plays a vital role for every living being. Water is and will become a 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 resources. 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 ET0 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 the 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 a 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 (ET0) from a standard surface is estimated and then an appropriate empirical crop coefficient for a particular crop is multiplied to determine the crop evapotranspiration (ETc). Numbers of empirical equations have been used for ET0 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 KimberlyPenman, 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 a number of parameters, so it is very difficult to estimate it accurately. Therefore, it becomes impractical for many users to select the best ET0 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 ET0 estimation methods[4]. This decision support system was further modified to include more ET0 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 ET0 method for different climatic conditions. It is developed in Microsoft Visual Basic 6.0. It consists of a model base for estimating ET0 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 ET0 values of 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 ET0 values can later be used for different purposes such as to derive irrigation water requirements of crops, to obtain ET0 estimate for locations with no meteorological data and to fill the gaps in the available records of ET0. The ET0 was found out for North Eastern Coastal Plain of Odisha by Mohanty and Subudhi (2018) Keeping the above in view, the following objectives are selected for this study:

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

Materials and Methods

The North Eastern Coastal Plane zone is situated at Ranital of latitude 21.06000 N and longitude 86.50000 E. Table 1 shows the major crops of this zone.

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

1) Standardized form of FAO-56 Penman-Monteith by ASCE 2005
2) Penman Monteith Method (Monteith (1965), Allen (1986), Allen et al. 1989)
3) Hargreaves Temperature Method
4) Priestly-Taylor Radiation & Temperature Method
5) Turc Radiation and Temperature Method
6) 1972 Kimberly-Penman Method
7) 1982 Kimberly-Penman Method
8) CIMIS Penman method
9) FAO-PPP-17 Penman (ET0) method [Frére and Popov (1979)]
10) FAO-24 Penman (c=1) (ET0) method [Doorenbos and Pruitt (1975, 1977)]
11) Businger-van Bavel (ET0) method

Statistical Analysis

ET0 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 (R2)
- Regression Coefficient (b)
- Monthly Mean (mm/d)

The performance of a model is good when regression coefficient (b) is close to 1.0, R2 > 0.6, RMSE < 0.6 mm d-1 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. Reference crop evapotranspiration for thirty three years for all crops were calculated by using the FAO-56 PM method. On the basis of average ET0 for any day during the crop period of any crops daily crop water requirement was estimated by multiplying the crop coefficient (Kc), presented in Table 3, value to the estimated ET0 from FAO-56 PM method.

Crop selection

In Odisha, paddy is the major crop during the Kharif season, summer season and also in rabi season. In different parts of the state all verities 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

Table 1. Major Crops and Soil Type Information of the Study Area

Sl. No.	Name of zones	Research Station	Soil type	Major Crops		
				Summer	Kharif season	Rabi season
1	North Eastern Coastal Plain	Ranital (Bhadrak)	Alluvial	Paddy	Paddy	Paddy, Green gram, Black gram, Groundnut

Table 2. Crop Coefficient for Different Crops at Different Stages

Crops	Total Duration	Stages (In Duration)				Kc Value for Different Stages			
		Initial Stages(I)	Crop Dev.(II)	Mid Season(III)	Late Season(IV)	Initial Stages(I)	Crop Dev.(II)	Mid Season(III)	Late Season(IV)
Paddy-I	90	15	25	30	20	1	1.05	1.2	0.9
Paddy-II	120	15	50	25	30	1	1.05	1.2	0.9
Paddy-III	150	15	30	60	45	1	1.05	1.2	0.9
Wheat	120	15	25	50	30	0.35	0.75	1.15	0.45
Green Gram	60	10	20	20	10	0.35	0.7	1.1	0.9
Black Gram	70	10	25	25	10	0.35	0.7	1.1	0.9
GroundNut	137	25	30	40	25	0.45	0.75	1.05	0.7
Maize	125	20	35	40	30	0.3	0.6	1.2	0.35
Sesamum	90	15	25	35	15	0.35	0.7	1.15	0.25

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, ETc, is calculated by multiplying the reference crop evapotranspiration, ET0, by a crop coefficient, Kc

ETc = Kc * ET0

Where

ETc = crop evapotranspiration [mm d-1],

Kc = crop coefficient,

ET0 = reference crop evapotranspiration [mm d-1] Table 2 shows crop coefficient used to calculate the crop water requirement of this zone.

Results and Discussion

Reference Evapotranspiration (ET0) 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 ET0 values for all the ten agro-climatic zones of Odisha. Out of 22 widely used available methods, 11 methods were taken from 10 stations in this study. The ET0 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 ET0 and the obtained ET0 values from the other methods were compared with this method.

Comparing the estimated ET0 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.

ET0 Method Comparison

The ET0 values obtained by different methods were compared with the FAO-56 Penman- Monteith ET0 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:

ET0 Comparison for North Western Plateau

The mean monthly ET0 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 ET0 (6.642 mm/day). The Priestley-Taylor methods estimated the lowest mean ET0 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 ET0 values was found to be 10.32 mm/d for FAO-24 Penman(c=1) method followed by Businger-van Bavel (9.73 mm/d) and FAO-PPP-17-Penman (9.68 mm/d) in the month of May, whereas, lowest ET0 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) (Figure 1).

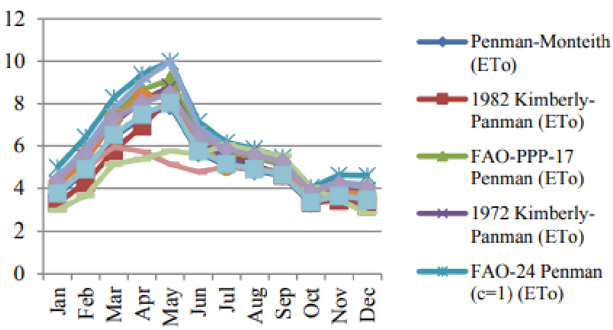

Figure 1. Mean Monthly ETo by all 11 Methods for North Eastern Coastal Plain

Correction Factor for North Eastern Coastal Plain Zone

For this zone, correction factor for Penman-Monteith and 1982 Kimberly-Penman approaches to one. The FAO-24 Penman (c=1) and Businger van 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

Table 3. Statistical Summary of Monthly ET0 Estimates for North Eastern Coastal Plain Zone

	ETo Methods									
Statistical Parameters	PM	KP-82	KP-72	FAO-PPP-17-P	FAO-24-P(c=1)	HG	BvB	Turc	PT	CIMIS-Penman
Mean(mm/d)	5.098	5.129	5.665	5.884	6.533	5.109	6.406	4.484	4.684	5.789
R2	0.994	0.913	0.982	0.983	0.984	0.754	0.968	0.65	0.536	0.992
SEE(mm/d)	0.183	0.545	0.538	0.748	1.398	0.904	1.35	1.305	1.334	0.595
b	0.977	0.984	1.086	1.128	1.249	0.965	1.233	0.826	0.869	1.1
PE	2.22	1.63	8.66	12.86	25.3	2.02	22.85	14	10.16	11.02
MBE	-0.116	-0.085	0.452	0.67	1.319	-0.105	1.192	-0.73	-0.529	0.575
RMSE(mm/d)	0.185	0.545	0.538	0.748	1.398	0.904	1.349	1.305	1.334	0.595

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-3	1	4	3	5	7	6	8	10	9	2

Table 5. Correction Factor with Respect to FAO-56 Method For North Eastern Coastal Plain Zone of Odisha

Station Name	PM	KP-82	KP-72	FAO-PPP-17-P	FAO-24 P (c=1)	HG	BvB	Turc	PT	CIMIS-Penman
AZ-3	1.023	1.016	0.92	0.886	0.798	1.021	0.814	1.163	1.113	0.901

plateau is shown in Figure 2. and Table 5. ETo and CWR of different crops were shown in Figure 3.

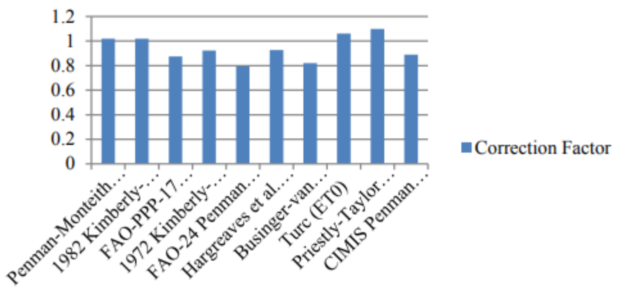

Figure 2. Correction Factor for North Eastern Coastal Plain Zone Crop Water Requirements (CWR) for Major Crops for the North Eastern Coastal Plain Zone

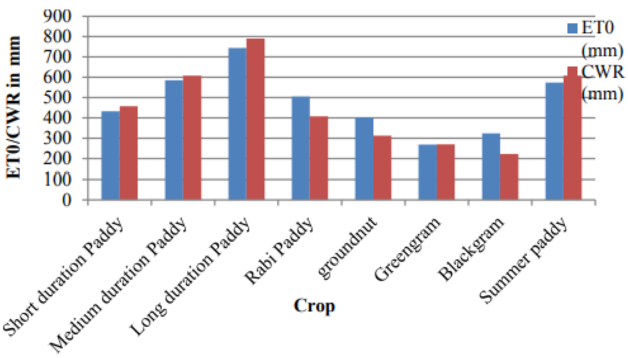

Figure 3. ETo Vs CWR for North Eastern Coastal Plain Zone

Conclusion

- Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly- Penman methods approaches to one in this zone. 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 402 mm to 659 mm, groundnut ranges from 270 mm to 330 mm, green gram ranges from 201 mm to 317 mm, black gram ranges from 242 mm to 270 mm
- In summer season, short duration paddy is cultivated in some areas of this zone. The water requirement varies from 540 mm to 658 mm.

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