International Journal of Applied
and Natural Sciences (IJANS)
ISSN (P): 2319–4014; ISSN (E): 2319–4022
Vol. 9, Issue 3, Apr–May 2020; 39–46

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

WATER REQUIREMENT FOR DIFFERENT CROPS IN EAST & SOUTH EASTERN COASTAL PLAIN ZONE OF ODISHA

Mohanty Anita[1], Subudhi C.R[2] & R.Subudhi[3]

[1]Research Scholar, Ex M.Tech student, CAET, OUAT, Bhubaneswar, India

[2]Professor, Department of SWCE, CAET, OUAT, Bhubaneswar, Odisha, India

[3]Research Scholar, Ex Student, CAET, OUAT, Bhubaneswar, Odisha, India

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 different crops grown in East & South Eastern Coastal Plain zone of Odisha, India. In India, a large population is facing challenges of water scarcity due to its huge population, diverse geographical, climatic and geo-environmental conditions along with an unequal distribution of freshwater resources. Therefore, efficient water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. Agriculture is the backbone of India and it consumes around 60% of fresh water resource. So, it is essential to manage the water in the field of agriculture efficiently. Odisha is south eastern state of India having 480 km of coast to Bay of Bengal. Although, it receives a good amount of annual rainfall, the management of agriculture water in field is very poor due to insufficient knowledge of farmer about the water requirement of crops. In the present study, a small attempt was taken to estimate the crop water requirement for different major crops in east and south eastern coastal plain agro-climatic zone of Odisha by using local climate data and crop coefficients. The reference evapotranspiration of the study zone is estimated by using ten different empirical methods and screening of methods is done to estimate the reference crop evapotranspiration, close to FAO – 56 Penman-Monteith methods. Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches in similar path. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method.

***KEYWORDS**: Reference Evapotranspiration, Water Requirement, East & South Eastern Coastal Plain*

Article History

***Received:** 13 Feb 2020 | **Revised:** 09 Mar 2020 | **Accepted:** 24 Apr 2020*

INTRODUCTION

Water plays a very crucial role for every living being. Due to urbanization, industrialization and economic and environmental constraints on new water resources developments, agriculture's share of water use is likely to go down day by day. In India, a large population is facing challenges of water scarcity due to its diverse geographical, climatic and geo-environmental conditions along with unequal distribution of fresh water resources. On an average East and South Eastern Coastal Plain zone of Odisha receives about 1449 mm of rainfall, which is uneven, erratic and uncertain in nature. The patterns of rainfall become more and more erratic due to climate change. Therefore, efficient water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors. India is an agrarian country and agriculture is the one of the most important sector that utilises around 60% of fresh water. 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 water resources planning and management. Allen et al., (1998) defined the reference evapotranspiration (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 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, generally expressed in terms of days. Evapotranspiration 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.

Evapotranspiration can be directly measured by using the lysimeter and it seems to be the most accurate. But, it is a time consuming method and needs precisely and carefully planned experiments. Apart from lysimeter, evapotranspiration may be estimated by using some empirical methods developed in different places on the basis of climatelogical parameters. The empirical equations 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 F AO-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 large number of weather 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. 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 (22) different methods and ranking them and represented in a user-friendly graphical interface. These available methods can be used for estimating daily and monthly ET0 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 rank them to find the best suited method. These reference evapotranspiration values can later be used for different purposes such as to derive irrigation water requirement of crops, to obtain ET0 estimate for locations with no meteorological data and to fill the gaps in available records of ET0. The ET0 was found out for East & South Eastern Coastal Plain zone of Odisha by

Mohanty and Subudhi (2018). The reference evapotranspiration by ten (10) different empirical methods using local weather data has been estimated and screened to estimate the reference crop evapotranspiration close to FAO – 56 Penman-Monteith methods. Then the crop water requirement for major crops grown in the zone has been assessed.

MATERIALS AND METHODS

This chapter deals with the description of the study area, data and methods used for determination of reference crop evaporation, statistical analysis for ranking and conversion factors of used methods, and estimation of crop water requirement for major crops grown in the study area.

Study Area

The study area is East & South Eastern Coastal Plain Agro-climatic zone of Odisha, situated in east and south eastern region of Odisha. The zone has a research station at Bhubaneswar situated between latitude 20.2645 N and longitude 85.8120 E. On an average, the zone receives a rainfall of 1449 mm and having a coastal region that drains to Bay of Bengal. The climate of the study area is sub-humid. The soil type is coastal alluvial saline (Table 1). Thirty three years (1981-2013) of daily climatic data of minimum and maximum air temperature, mean relative humidity, average wind speed, solar radiation, and rainfall were collected and analysed.

Table 1: Major Information of the Study Area

Name of Study Area	Research Station	Soil Type	Major Crops		
			Summer	Kharif Season	Rabi Season
East & South Eastern Coastal Plain	Bhubaneswar	Coastal alluvial saline (near the coast line)	Paddy	Paddy	Paddy, Groundnut, Green gram

Estimation of Reference Evapotranspiration

The reference evapotranspiration is estimated by using eleven (11) different empirical equations. These methods include standardized form of FAO-56 Penman-Monteith by ASCE 2005, Penman Monteith Method (Monteith (1965), Allen et al. 1998), 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 [Frére and Popov (1979)], FAO-24 Penman (c=1) (ET_0) method [Doorenbos and Pruitt (1975, 1977)] and Businger-van Bavel (ET_0) method

Statistical Analysis

The reference evapotranspiration (ET_0) estimates obtained from ten different methods like Penman Monteith Method, 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 and Businger-van Bavel methods were compared with the ET_0 estimates of standardized form of FAO-56 Penman-Monteith by ASCE 2005, by using simple error analysis and linear regression. The statistical analysis has been done by using the statistical parameters of Standard Error Estimate (SEE), Root Mean Square Error (RMSE), Percentage Error Estimate (PE), Mean Bias Error (MBE), Coefficient of Determination (R^2), and Regression Coefficient (b). The performance of a method is supposed to be good when regression coefficient (b) is close to 1.0, $R^2 > 0.6$, RMSE < 0.6 mm d^{-1} and PE < 20%.

Estimation of Crop Water Requirement of Major Crops

Three major growing seasons like kharif, rabi and summer has been considered for calculation of crop water requirement. The reference evapotranspiration were calculated by using FAO-56 Penman Monteith method. Again, reference crop evapotranspiration has been calculated by considering the reference evapotranspiration and crop coefficient presented in Table 2.

Crop Selection

In the study zone, paddy is a major crop grown during the *Kharif* season, summer season and also in *rabi* season. Three types of paddy crops based on growing duration have been considered, i.e., long, short and medium duration during the *Kharif* season. During summer and *rabi* season, short duration and medium duration paddy are cultivated, respectively. Again in *rabi* season, apart from paddy, groundnut and green gram are grown as major crops (Table 1).

Crop Coefficient Approach

In the crop coefficient approach the crop evapotranspiration, ET_c, is calculated by multiplying the reference crop evapotranspiration, ET_0, by a crop coefficient, K_c

$$ET_c = K_c * ET_0$$

Where, ET_c is the crop evapotranspiration [mm d^{-1}], K_c is the crop coefficient given in Table 2, and ET_0 is the reference crop evapotranspiration [mm d^{-1}] estimated by empirical methods.

Table 2: Crop Coefficient for Different Crops at Different Stages

Crops	Total Duration	Stages (in Duration)				K_C 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
Green gram	60	10	20	20	10	0.35	0.70	1.10	0.90
Groundnut	137	25	30	40	25	0.45	0.75	1.05	0.70

RESULTS AND DISCUSSION

Estimation of Reference Evapotranspiration (ET_0)

Based on the available local weather data such as mean daily minimum and maximum air temperature, mean relative humidity, wind speed and solar radiation, with the help of DSS_ET, the reference evapotranspiration (ET_0) values were estimated by eleven (11) applicable methods. All the calculations were done on a daily basis from 1981-2013. The estimates of reference evapotranspiration follow a same pattern for all the methods. It increased from January to May and decreased thereon. It might be because of increase and decrease in atmospheric temperature over the study region. The highest ET_0 values was found to be 12.40 mm/d for Businger-van Bavel method followed by FAO-24 Penman(c=1) (11.40 mm/d) and 1972 Kimberly-Penman (10.23 mm/d) in the month of May, whereas, lowest ET_0 value was found in the month of December for the Priestly-Taylor method (2.91 mm/d) followed by Hargreaves method (3.41 mm/d) (Fig 1).

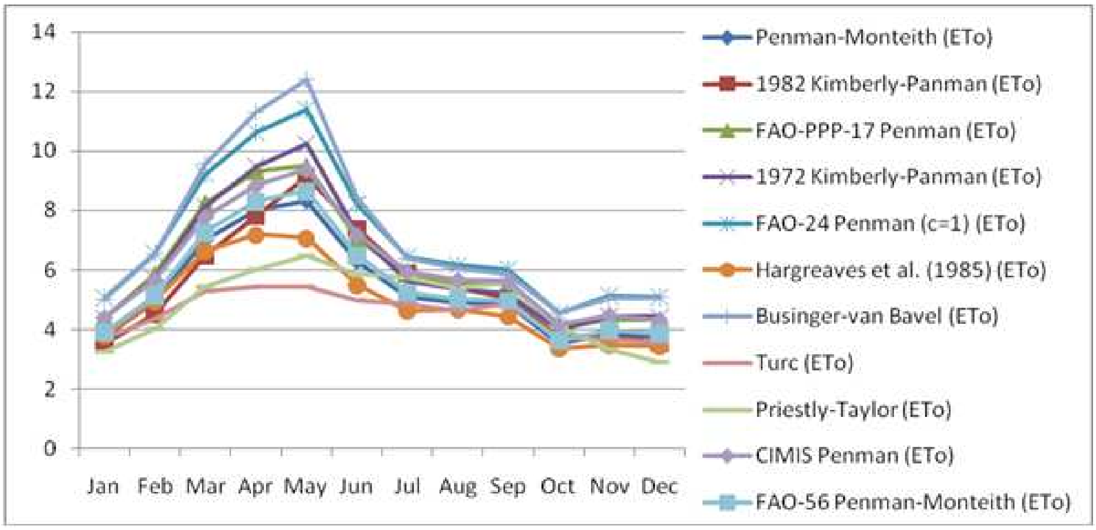

Figure 1: Mean Monthly Reference Evapotranspiration Obtained from Eleven Empirical Methods.

Statistical Analysis

The mean monthly ET_0 estimates obtained from ten (10) different empirical methods has been compared with the estimate of FAO-56 Penman-Monteith. Out of all the ten (10) methods, Penman Monteith method is found to be most suitable, as the value of coefficient of determination and regression coefficient (b) approached in similar path, as shown in Table 3. And the square error estimate and root mean square error also found minimum as compared to other methods. So, it ranked as one, as shown in Table 4. Businger-van Bavel method deviates much more as the standard method which denotes the last position in the series.

Table 3: Statistical Summary of Monthly ET_0 Estimates with Respect to FAO-56 Penman Monteith

	ET_0 Methods									
Statistical Parameters	**PM**	**KP-82**	**KP-72**	**FAO-PPP-17-P**	**FAO-24-P (c=1)**	**HG**	**BvB**	**Turc**	**PT**	**CIMIS-Penman**
R^2	0.996	0.927	0.981	0.982	0.986	0.773	0.963	0.652	0.621	0.992
SEE (mm/d)	0.252	0.562	0.880	0.696	1.718	1.284	2.157	1.697	1.460	0.624
b	0.963	1.005	1.138	1.107	1.287	0.831	1.349	0.759	0.829	1.098
PE	3.43	0.54	13.18	11.01	28.52	14.62	33.39	20.22	14.08	10.65
MBE	-0.190	0.027	0.730	0.608	1.582	-0.816	1.844	-1.122	-0.784	0.589
RMSE (mm/d)	0.251	0.562	0.879	0.695	1.716	1.288	2.156	1.694	1.463	0.622

Table 4: Ranking of Different Methods with Respect to FAO-56 PM Method

ET_0 Method	**PM**	**KP-82**	**KP-72**	**FAO-PPP -17-P**	**FAO-24 P (c=1)**	**HG**	**BvB**	**Turc**	**PT**	**CIMIS-Penman**
Ranking	1	3	5	4	7	6	10	9	8	2

Correction Factor for East & South Eastern Coastal Plain Zone

The correction factor as compared to standard FAO-56 Penman Monteith method has been observed. The correction factor for Penman-Monteith and 1982 Kimberly-Penman methods approaches in similar path. The FAO-24 Penman (c=1), Businger-van Bavel and Turc methods were found to have diverted from FAO-56 Penman-Monteith method (Fig 2)

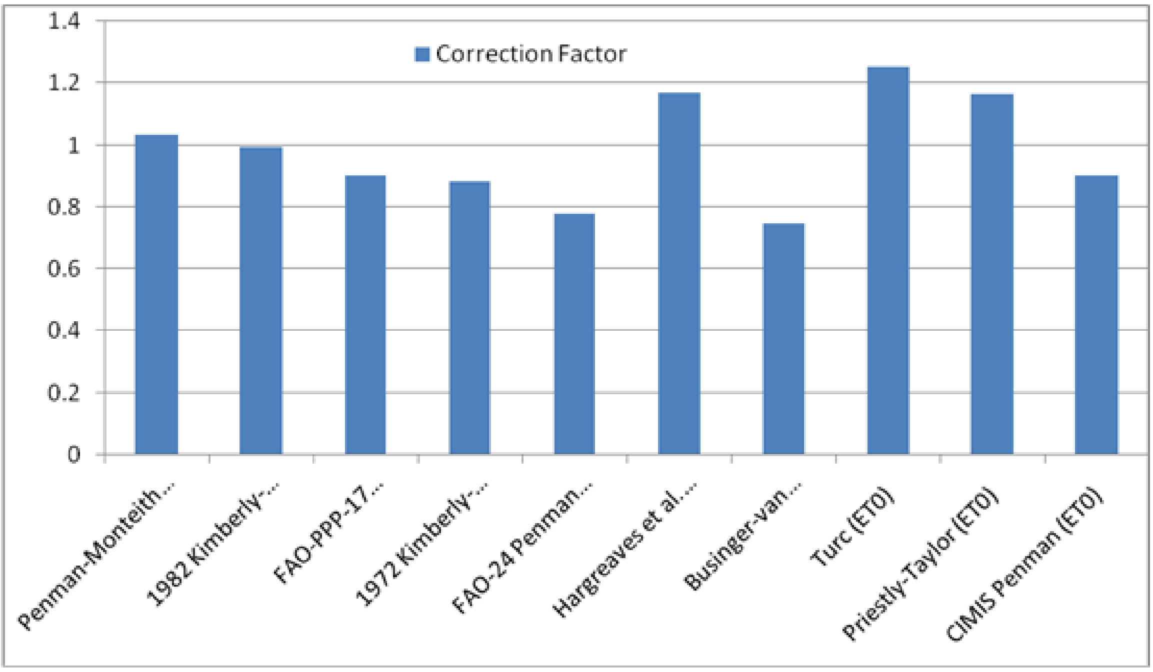

Figure 2: Correction Factor for East & South Eastern Coastal Plain Zone.

Crop Water Requirements (CWR) for Major Crops

The crop water requirement for different crops such as paddy for different seasons, groundnut and green gram for rabi season has been calculated by using reference evapotranspiration and crop coefficient of respective crops. Paddy consumes more water as compared to the other major crops and oilseeds like groundnut consumes less water. A graphical presentation between reference evapotranspiration and crop water requirement is presented in Fig. 3. As the reference evapotranspiration increased, the water requirement also increased for the crops due to its increase in metabolic activities.

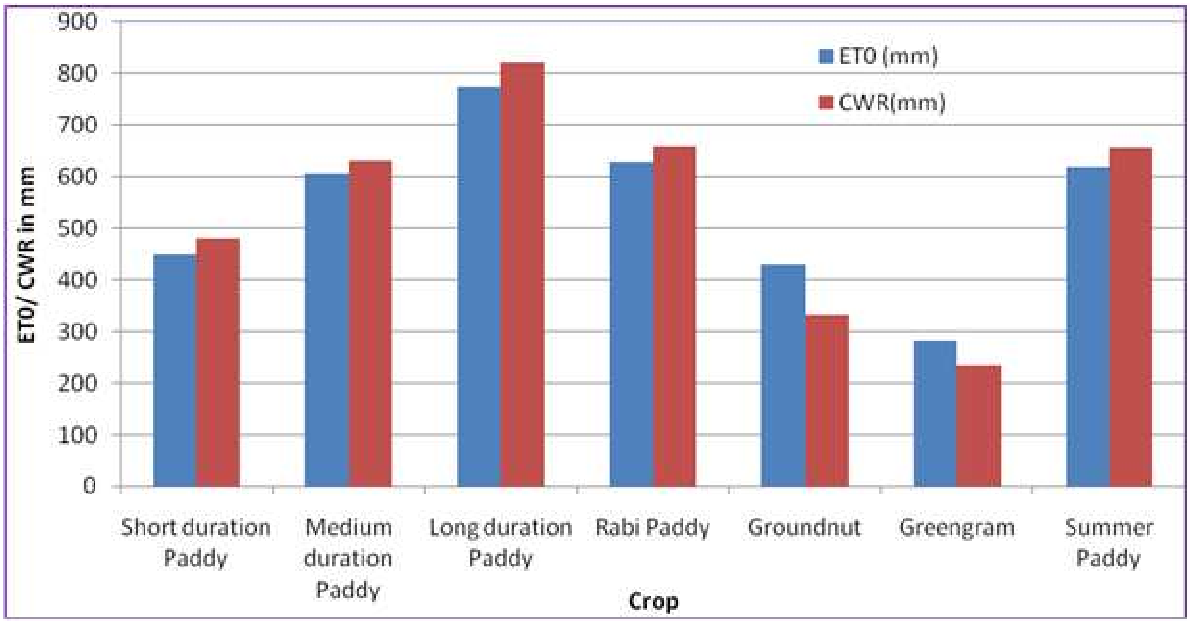

Figure 3: ET_0 Vs CWR for East & South Eastern Coastal Plain Zone

CONCLUSIONS

The Penman-Monteith method approaches similar to the standard FAO-56 Penman Monteith method. It may be concluded that, for the study region, if sufficient weather data is not available, one may go for Penman-Montheith method to calculate the reference evapotranspiration and also water requirement of different crops in study area. Water requirement for short duration paddy was found to be less as compared to medium and long duration paddy in *Kharif* season. The water requirement for different crops is found to be less as compared to the amount of water actually applied to the crop field. This may help the farmers to know the exact quantity of water requirement for the crops. This leads to reduction of the losses of water in the crop field and encourage the efficient management of water.

REFERENCES

1. *Allen RG, Pereira LS, Raes D, Smith M. 1998. Crop evapotranspiration: guidelines for computing crop water requirements – FAO irrigation and drainage paper 56. FAO, Rome, Italy: 300.*
2. *Bandyopadhyay A, Bhadra A, Raghuwanshi NS and Singh R. (2008). Estimation of monthly solar radiation from measured air temperature extremes, Agricultural and forest Meteorology, 148: 1707-1718.*
3. *Mohanty, A and Subudhi,C.R. 2018 Water requirement for different crops in North western platue zone of Odisha. International Journal of Pharmacy and Pharmaceutical Research.12 (4):221-234.*
4. *Reddy BRS. 1999. Development of a decision support system for estimating evapotranspiartion, M.Tech Thesis, Dept. Agri. Food Engg., Indian Institute of Technology Kharagpur, India.*