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WATER REQUIREMENT FOR DIFFERENT CROPS IN NORTH EASTERN GHAT ZONE OF ODISHA

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ABSTRACT

Water plays a vital role in every living being, and would become a scarce natural resource in the near future. India, with a large population is now facing unique challenges of water scarcity due to its diverse geographical, climatic and geo-environmental conditions apart from unequal distribution of freshwater resources. Therefore, efficient and effective water management strategies are needed for meeting the increasing water demand in agricultural, domestic, industrial and environmental sectors. Agriculture is the one of the most important sectors, which consumes highest percentage of fresh water resource. So, proper water management strategies are highly essential in agriculture sector to mitigate the water shortage in near future. Keeping the above in view, a small 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 North Eastern Ghat zones of Odisha, India. The reference evapotranspiration of the study zone is estimated by using ten different empirical methods. Screening of methods is done to estimate reference crop evapotranspiration close to FAO – 56 Penman-Monteith method. The crop water requirement for major crops grown in this zone is assessed for all the seasons. Among all the methods, the Penman-Monteith and 1982 Kimberly-Penman methods approach to FAO-56 Penman-Monteith method for the zone. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. Knowing the proper water requirement for the crops may encourage managing the agricultural water, effectively.

KEYWORDS: *Water Requirement, Crops in North Eastern Ghat, Zone of Odisha*

INTRODUCTION

Water plays an important role for every living being. Water is and will become scarce natural resource in the near future. 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. India with a huge 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. Odisha is situated in the south eastern coastline of India and receives about 1500mm of rainfall annually, which is uneven, erratic and uncertain in nature. Due to poor water management strategies and storage structures, a heavy amount of rain water drained out to the Bay of Bengal. But, as it is an agrarian economy, it utilizes around 60% of fresh water resource. And also, the demand of water in other sectors such as domestic, industrial and environmental sectors are increasing due to urbanization and globalization. Therefore, efficient and effective water management strategies are essential for meeting the increasing water demand of agricultural, domestic, industrial and environmental sectors.

In agriculture, most of the water is usually lost due to evapotranspiration by the canopy cover of the plant and surface evaporation. Evapotranspiration is the combination of soil evaporation and crop transpiration. Nearly,70% of the water loss is from the earth's surface due to evaporation. Thus, accurate estimation of evapotranspiration is very important for different studies, such as hydrologic water balance, irrigation system design and management, water resources planning and management, etc. The reference evapotranspiration may be defined 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 (Allen*et. al.*, 1998). The evapotranspiration rate is generally expressed in millimeters per unit time (mm/day). 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.

Direct measurement of evapotranspiration by using the lysimeter is found to be the most accurate. But, it is a time consuming method and needs precisely and carefully planned experiments. Thus, empirical equations have been used to estimate the reference evapotranspiration, 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 F AO-56 Penman-Monteith method. Radiation based methods include 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 by using different equations requires number of climatic parameters, so it is very difficult to estimate it accurately due to shortage of data. Therefore, it becomes difficult for many users to select the best reference evapotranspiration (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_0estimation methods. The DSS_ ET model can be used to identify the best ET_0 method for different climatic conditions. It consists of a model base for estimating $ET_0$by twenty two different methods and ranking them and a user-friendly graphical interface (Bandopadhyay *et al.*,2008).

In the present study, the reference evapotranspiration has been estimated by using the available methods using available local weather data and ranked them against FAO-56 Penman-Monteith method to find the best suited method for the locality. These ET_0 values can later be used to find out the water requirement of the various crops grown in the zone.

MATERIALS AND METHODS

This segment deals with the description of the study area, data and methods used for determination of reference crop evaporation using different methods, statistical analysis and calculation of crop water requirement for major crops of the study zone.

Study Area

The study area is North Eastern Ghat Agroclimatic zone of Odisha, situated in south eastern region of Odisha. The zone has a research station at G.Udayagiri, Kandhamal of latitude 20.1300 N and longitude 84.3800 E. On an average the state receives a rainfall of 1597 mm. The climate of the study area is hot and moist sub-humid. The soil type is laterite and brown forest. In this zone, crops are grown in three different seasons i.e. summer, kharif and rabi. Paddy is grown in all the three seasons and groundnut, green gram and black gram are grown in rabi season.

Estimation of Reference Evapotranspiration

Thirty three years (1981-2013) daily climatic data of minimum and maximum air temperature, mean relative humidity, average wind speed, solar radiation, and rainfall were collected and by using eleven different empirical equations such as standardized form of FAO-56 Penman-Monteith by ASCE2005, 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 (ET_0)method, reference evapotranspiration was estimated.

Statistical Analysis

The reference evapotranspiration (ET_0) estimates from ten different methods i.e. 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 (ET_0) method were compared with the reference evapotranspiration (ET_0) estimates of the standardized form of FAO-56 Penman-Monteith method by using different statistical parameters such as 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) and 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%.

Estimation of Crop Water Requirement of Major Crops

In the study zone, paddy is major crop grown in all the three seasons. Three different duration paddy varieties i.e., long (Paddy-III), short (Paddy-I) and medium (Paddy-II) duration are considered in the Kharif season. During summer and rabi season, short duration and medium duration paddy are cultivated respectively. And also in rabi season, apart from paddy, groundnut, green gram and black are cultivated. Crop water requirement for these crops such as paddy, groundnut, black gram and green gram has been calculated by considering the reference evapotranspiration estimates of the FAO-56 PM method and the respective crop coefficient (Kc), presented in Table 1. 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}].

Table 1: Crop Coefficient for Different Crops at Different Stages (Allen Et. Al.,1998)

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
Black gram	70	10	25	25	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 DISCUSSIONS

Estimation of Reference Evapotranspiration (ET_0)

The reference evapotranspiration were estimated by eleven applicable methods 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. 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 estimates obtained from this method. All the methods follow a same pattern of estimates all over the year. The value increases in the month of May and then decreases. The highest value is obtained in the month of May as the mean temperature is maximum and the lowest value is obtained in December. The highest ET_0 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 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) (Figure 1).

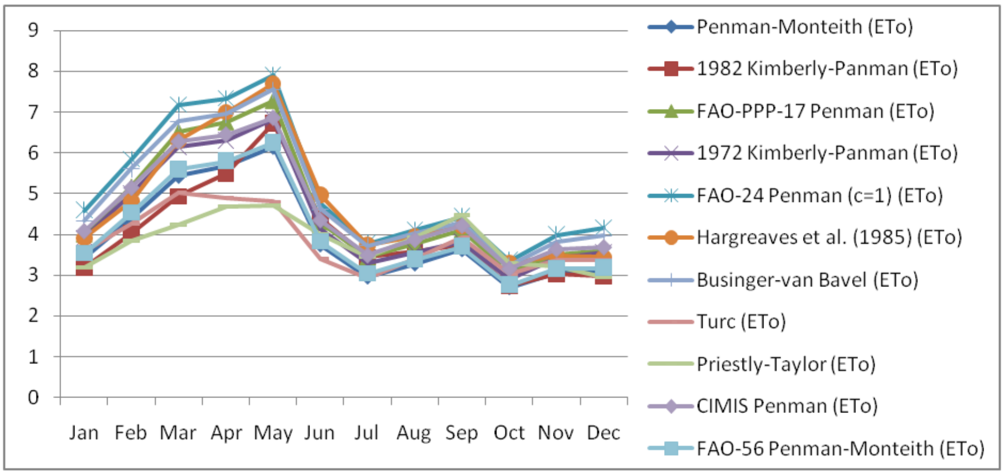

Figure 1: Mean Monthly ET0 By all 11 Methods for North Eastern Ghat Zone.

Statistical Analysis

From the analysis, it is obtained that, 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 (Table2). The rank for different methods with respect to the FAO-56 Penman-Monteith obtained for the study zone. Penman-Monteith performs best, followed by 1972 Kimberly-Penman and CIMIS-Penman method, whereas, Priestley-Taylor method performs worst in the zone (Table 3).

Table 2: Statistical Summary of Monthly ET0 Estimates for North Eastern Ghat Zone

	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**
Mean (mm/d)	4.510	4.582	5.029	5.243	5.834	5.141	5.647	4.152	4.078	5.167
R^2	0.993	0.908	0.985	0.983	0.985	0.747	0.971	0.749	0.557	0.993
SEE (mm/d)	0.186	0.538	0.495	0.720	1.309	1.049	1.170	0.983	1.271	0.569
b	0.975	0.990	1.089	1.137	1.260	1.085	1.225	0.878	0.841	1.108
PE	2.33	0.76	8.91	13.53	26.32	11.33	22.29	10.10	11.68	11.88
MBE	-0.108	-0.036	0.411	0.625	1.216	0.523	1.029	-0.467	-0.539	0.549
RMSE (mm/d)	0.185	0.538	0.495	0.719	1.309	1.049	1.170	0.983	1.271	0.569

Table 3: Ranking of Different Methods with Respect to FAO-56 PM Method

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

In this study, a correction factor developed in which 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 (Figure 2).

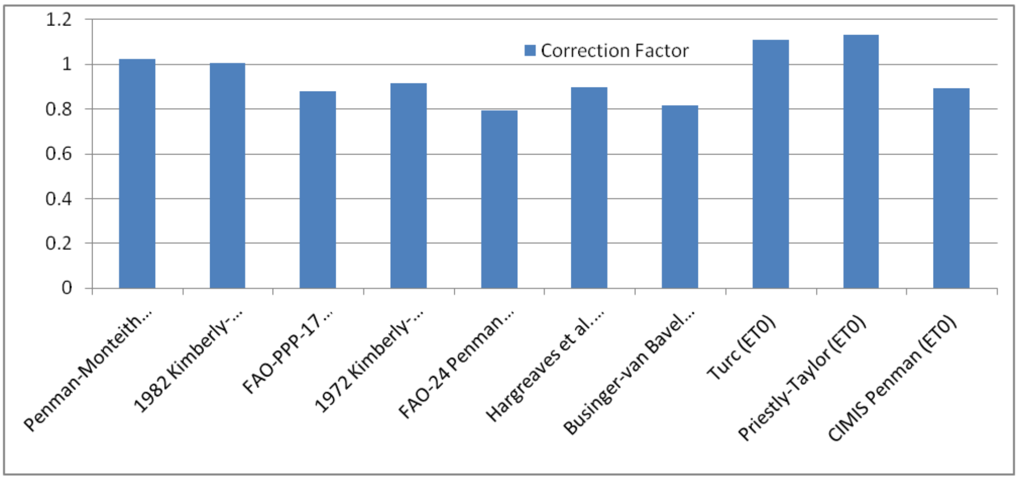

Figure 2: Correction Factor For The Study Zone.

Crop Water Requirements (CWR) for Major Crops

The crop water requirement for different crops such as paddy, groundnut, green gram and black gram was calculated by using reference evapotranspiration and crop coefficient of the respective crops. Paddy consumes more water, as compared to the other major crops and oilseeds like groundnut consumes less water. As the duration of the crop increases, the crop water requirement of the crop increases with increase in reference evapotranspiration (Figure 3).

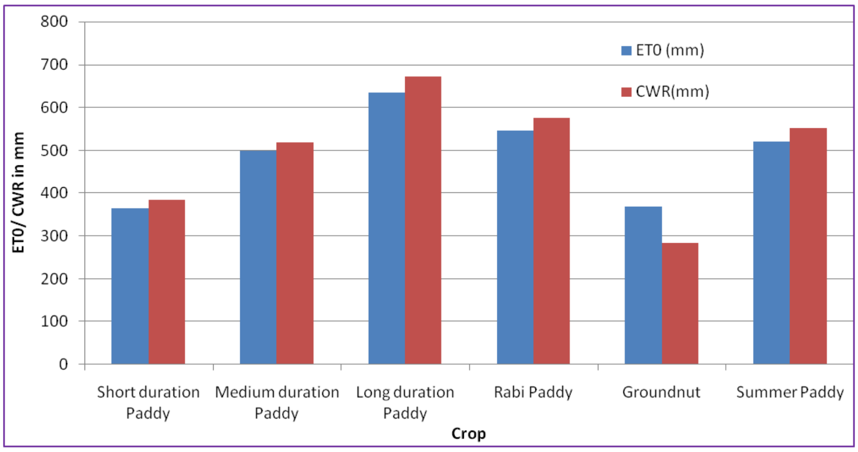

Figure 3: Graphical Representation of Reference Evapotranspiration to Crop Water Requirement.

CONCLUSIONS

Among all the methods, correction factor for Penman-Monteith and 1982 Kimberly- Penman methods approaches to one. The FAO-24 Penman (c=1), Turc and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. Water requirement for short duration paddy was found less as compared to medium and long duration paddy in *Kharif* season. Water requirement for rabi season, paddy varies from 402mm to 659mm, groundnut ranges from 270mm to 330mm.The water requirement is found to be less as compared to the amount of water applied to the crop field. By knowing the actual need of water for a specified crop may help the farmers and stakeholders to reduce the water loss in the agricultural field.

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