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Comparative study of water requirement with seasonal rainfall for Cereals, pulses and oil seed of Khurda district of Odisha

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Abstract
Water requirement of different crops like cereals and pulses was calculated by considering the data available at Bhubaneswar climatic station and DSS_ET version 4.1 software. 30 years long term daily mean climatic data of minimum and maximum air temperature, mean relative humidity, average wind speed, solar radiation, and rainfall were obtained from the OUAT observatory during 2013-14. The latitude of the study area is from $18^0$46’ to 20^0 95’ N and longitude of the area is 83^0 48' to 87^0 46' E and elevation is 42m. Mean annual rainfall is 1408.4 mm and geographical area of the district is 289000 ha. The DSS _ET developed for ET_0 estimation includes a model base with decision-making capabilities, a graphical user interface and a database management system. The model base consists of twenty two most commonly used and internationally accepted ET_0 estimation methods based on combination theory, radiation, temperature and pan evaporation along with an algorithm based decision-making model. In this study, a trial has been made to determine the water requirement of six major crops of Khurda district. Thirteen well established methods are used to estimate the daily reference evapotranspiration for 30 year period. For each crop, reference evapotranspiration was determined by taking 30 years daily average of ET_0 for the crop period. Daily crop water requirement was then calculated by multiplying crop coefficient (K_c), value to the estimated ET_0 from FAO 56, PM method. Crop water requirement was estimated for each crop using the result of reference ET_0 for the crop period. It was found out that that there was sufficient surplus water available during Kharif but in Rabi crop needed irrigation because rainfall was not regular. For Kharif long duration rice crop, water requirement was highest and for Green gram water requirement was lowest.

Keywords: combination theory, decision making capabilities, DSS_ET, ET_0 estimation methods, water requirement

Introduction
India with its large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal spatio-temporal distribution of fresh water resources. Therefore efficient and effective water management strategies are essential for meeting the increasing water needs of agricultural, domestic, industrial and environmental sectors. Considering the current water resources problems and rapid increase in its demand, the importance of effective utilization of water resources cannot be underestimated if India has to remain self-reliant in food production. Evapotranspiration (ET) is the largest and one of the most basic components of the hydrologic cycle. It plays a very important role in the water and energy balance on earth's surface and also has a major role in agricultural and irrigation practices. The question in front of us today is how to increase the production with such limited water resources. Solution may be in different ways but their ultimate aim is to increase the productivity. That is to grow more crop per ha of land and also with per drop of water. Accurate estimation of ET is of vital importance for many studies, such as hydrologic water balance, irrigation system design and management, water resources planning and management, etc. The concept of the reference evapotranspiration is used to study tile evaporative demand of the atmosphere independently of crop type, crop development and management practices. For effective planning and implementation of policies on irrigation projects, it is necessary to determine reference evapotranspiration which is further used in computing crop water use. It is essential for the development of modern irrigation management methodologies, optimum allocation of water and energy resources, and improved irrigation planning and management practices.

The aim of present study is to estimate the reference evapotranspiration by using the available methods using DSS_ET. These ET_0 values can later be used for different purposes such as to derive crop water requirement. The specific the specific objectives of the present study is to estimate water requirement of different major crops in Khurda district by FAO 56 Penman-Monteith Method.

Chattopadhyay and Hulme (1997) [3] analysed the evaporation time series data for different stations in India. They have considered 15 year time period for pan evaporation and 30 year time period for potential evapotranspiration for different seasons. Results indicate that both pan evaporation and potential evapotranspiration have decreased during recent years in India. Martin Smith (2000) [6] developed strategies to optimize the use of water for crop production and to introduce effective water management practices. George *et al* (2002) [4] developed a user friendly decision support system (DSS_ET) for estimation of reference evapotranspiration. Alexandris and Kerkides (2003) [1] used a new empirical equation for estimating hourly reference evapotranspiration which requires solar radiation, air temperature and relative humidity data. Benli *et al* (2010) [2] studied the performance of six commonly used reference evapotranspiration estimation methods such as Penman-Monteith, Priestley-Taylor, FAO-24 Radiation, Hargreaves, Blaney-Criddle and Class A pan by using weighing lysimeter data from a semiarid highland environment. Hua *et al* (2012) [5] calculated reference crop evapotranspiration based on the meteorological data of Mengzhi weather station from 1961 to 2010 using FAO Penman-Moteith formula.

Material and Methods

Crop selection

In Khurda district of Odisha, paddy is mostly cultivated during the Kharif season. In different parts of the district all three verities paddy, viz. long, short and medium duration are almost equally cultivated during the Kharif season. During Rabi, six major crops are sown, which information are given in table 1.

Table 1: Major for information of the study area

CROPS	Total area cultivated ($\times 10^3$) ha	Total duration	Stages				K_C value for different stages			
			Initial Stage (I)	Crop Dev. (II)	Mid Season (III)	Late Season (IV)	I	II	III	IV
1. KHARIF										
Paddy-I	38.25	90	15	25	30	20	1.00	1.05	1.20	0.90
Paddy-II	52.28	120	15	50	25	30	1.00	1.05	1.20	0.90
Paddy-III	24.11	150	15	30	60	45	1.00	1.05	1.20	0.90
2. RABI										
Paddy-II	8.41	120	15	25	50	30	1.00	1.05	1.20	0.90
Wheat	0.04	120	15	25	50	30	0.35	0.75	1.15	0.45
Green gram	35.78	60	10	20	20	10	0.35	0.70	1.10	0.90
Black gram	12.09	70	10	25	25	10	0.35	0.70	1.10	0.90
Groundnut	4.55	137	25	30	40	25	0.45	0.75	1.05	0.70
Pea	0.53	90	15	25	35	15	0.45	0.80	1.15	1.05

Crop duration is and crop stages are taken from Agriculture hand book and K_c values of the selected crops are taken from FAO 24, irrigation and drainage paper. Various methods are given below by which we can estimate the ET_0 values.

Fao 56 Penman-Monteith

$$ET_0=\frac{0.408\Delta(R_n-G)+\gamma\frac{900}{(T+273)}u_2(e_s-e_a)}{\Delta+\gamma(1+0.34u_2)}$$

R_n = net radiation at the crop surface,
G = soil heat flux density,
(e_s-e_a) = the vapour pressure deficit of the air,
u_2=wind speed at 2m height,
T=mean daily air temperature at 2m height,
Δ=slope of saturation vapour pressure temperature relationship,
γ=psychrometric constant

Penman-monteith method

$$ET_0=\left(\frac{1}{\lambda}\right)\left[\left(\frac{\Delta}{\Delta+\gamma}\right)(R_n-G)+\left(\frac{\gamma}{\Delta+\gamma}\right)\left(.622\frac{K_1\lambda\rho}{BP}\right)\frac{(e_z^0-e_z)}{r_a}\right]$$

ET_0 = Evapotranspiration for grass reference crop
λ = heat of vaporization
R_n = net radiation
G = soil heat flux
Δ = slope of the vapour pressure curve
γ = psychrometric constant
ρ = density of air
BP = mean barometric pressure
e_z^0 = average saturated vapour pressure
e_z = actual vapour pressure
$\gamma^* = \gamma(1+r_c/r_a)$
r_c = surface resistance to vapour transport
r_a = aerodynamic resistance to sensible heat and vapour transport
K_1 = the dimension coefficient

Estimation of daily evapotranspiration using DSS_ET

DSS_ET is a Decision Support System for estimation of crop evapotranspiration. The DSS_ET model (Reddy, 1999) developed in Microsoft Visual Basic 6.0 is used in the study to estimate reference evapotranspiration. The DSS _ET developed for ET_0 estimation includes a model base with decision-making capabilities, a graphical user interface and a database management system. The model base consists of twenty two most commonly used and internationally accepted ET_0 estimation methods based on combination theory, radiation, temperature and pan evaporation along with an algorithm based decision-making model. This model is used to identify the best ET_0 estimation method for a given climatic condition. It identifies the data requirement of a method and if the available method satisfies the data requirement of the first-rank method (Penman-Monteith) as given in ASCE ranking. The system estimates the ET with that method: otherwise it searches for the next suitable method. Same procedure is repeated until a suitable method is identified for given location and data conditions. By using the available daily climatological data, the daily reference evapotranspiration (ET_0) values were estimated for 30 years duration, using 13 available methods.

Estimation of correction factor

Different evapotranspiration methods need various data for ET estimation.

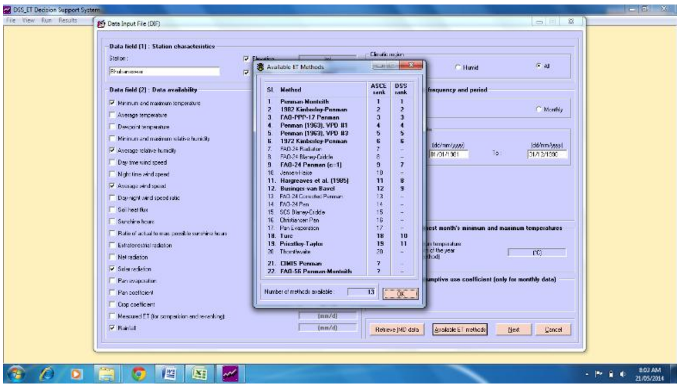

Fig 1: DSS_ET Input Window

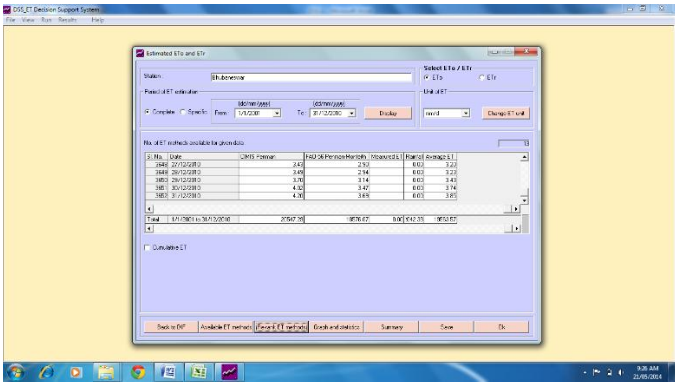

Fig 2: DSS_ET Output Window

Among all these methods FAO 56, PM method is considered as the best methods but data requirement is relatively high for this method. In case of limited data availability one has to choose a method other than FAO 56, PM method, hence, accuracy of estimated ET decreases. In study an effort has been made to develop correction factors for different methods other than FAO 56, PM method. When the correction factor is multiplied with the estimated ET from any method we can get an equivalent result as that of FAO 56, Penman- monteith method. The factor has been developed by considering 30 years daily ET_0 data, and then average of the daily factors is taken as the correction factor for any particular method.

$$\text{Correction factor} = \frac{1}{n} \times \left(\frac{ET_{0p}}{ET_{oa}}\right)$$

Where, ET_{op}=reference evapotranspiration from FAO 56, Penman Monteith method

ET_{oa}=reference evapotranspiration from any method.

Estimation of crop water requirement of major crops

Six Rabi crops and three types of Kharif paddy are considered in this study as the major crops of Khurda district. Thirty years reference crop evapotranspiration for all crops has been calculated by using FAO 56, PM method. Then 30 years daily average is taken to determine ET_0 for any day during the crop period of any crops. Daily crop water requirement was then calculated by multiplying crop coefficient (Kc), table 1, value to the estimated ET_0 from FAO 56, PM method.

Results and Discussions

Here a trial has been made to determine the water requirement of six major crops of Khurda district. Thirteen well established methods are used to estimate the daily reference evapotranspiration for 30 year period. All methods are then ranked with respect to the FAO 56, Penman-Monteith method. Then correction factors are derived for 12 methods in order to get equivalent result as that of FAO 56 PM method. For each crop, reference evapotranspiration was determined by taking 30 years daily average of ET_0 for the crop period. Crop water requirement and seasonal irrigation requirement were estimated for each crop using the result of reference ET_0 for the crop period.

Different ET_0 Vs. Rainfall graph

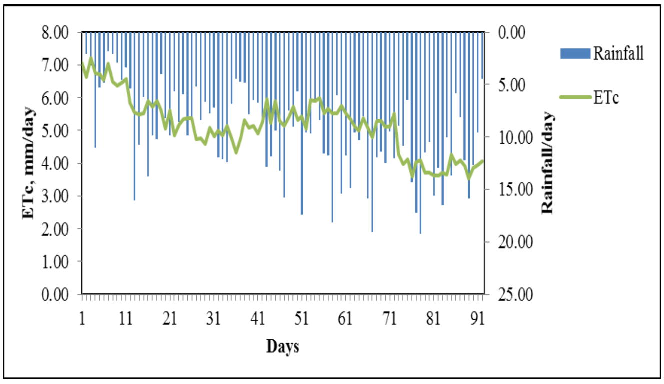

Fig 3: Rainfall and crop evapotranspiration of short variety Kharif paddy

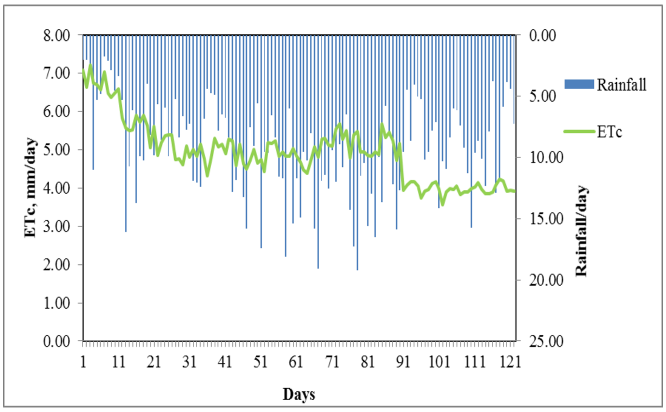

Fig 4: Rainfall and crop evapotranspiration of medium variety Kharif paddy

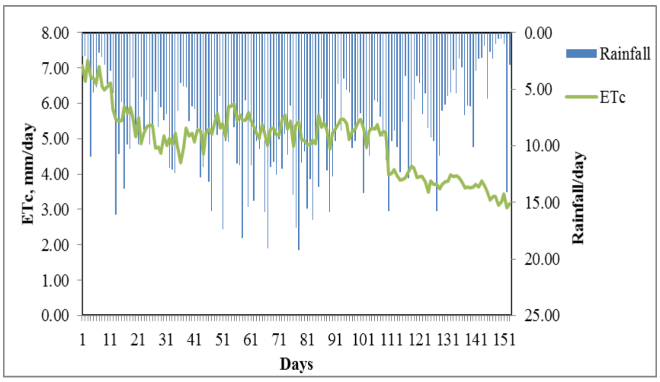

Fig 5: Rainfall and crop evapotranspiration of long variety Kharif paddy

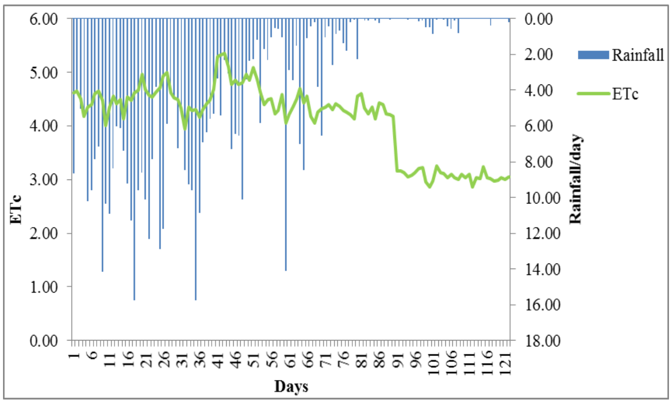

Fig 6: Rainfall and crop evapotranspiration of Rabi paddy.

Rabi Paddy

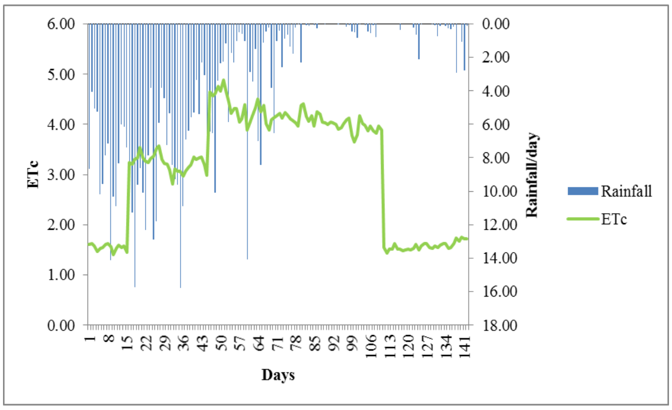

Fig 7: Rainfall and crop evapotranspiration of Wheat in Rabi

Wheat

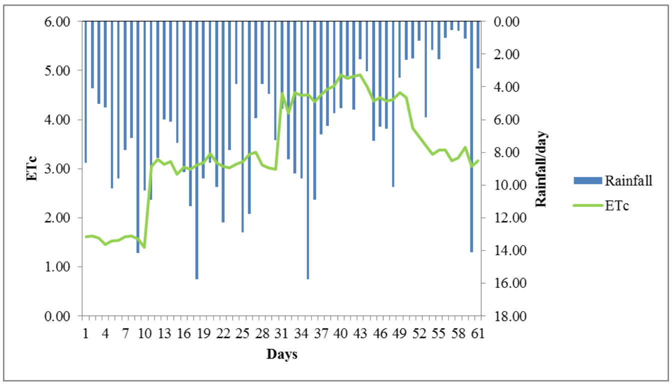

Fig 8: Rainfall and crop evapotranspiration of Green Gram in Rabi

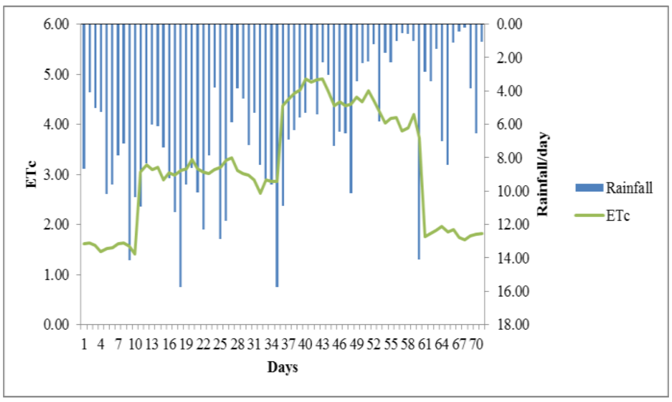

Fig 9: Rainfall and crop evapotranspiration of Black Gram in Rabi

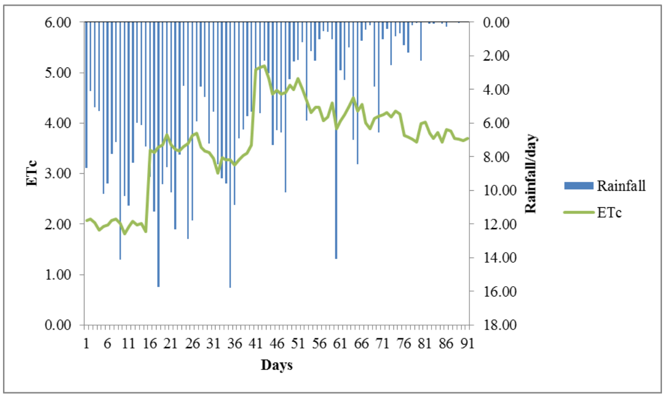

Fig 10: Rainfall and crop evapotranspiration of Pea in Rabi

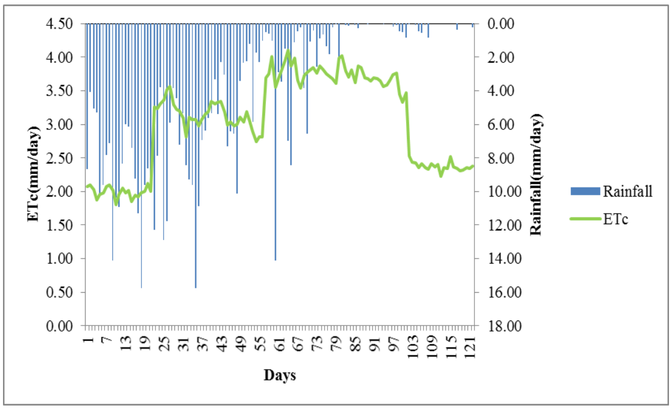

Fig 11: Rainfall and crop evapotranspiration of groundnut in rabi

Crop water requirement Vs. Total seasonal rainfall characteristics

Total seasonal crop water requirement and total seasonal rainfall is shown in the fig.12. The figure indicates that there is sufficient surplus water available during Kharif but in Rabi, crop needs irrigation because rainfall is not regular. For Kharif long duration rice crop, water requirement is highest and for Green gram water requirement is lowest.

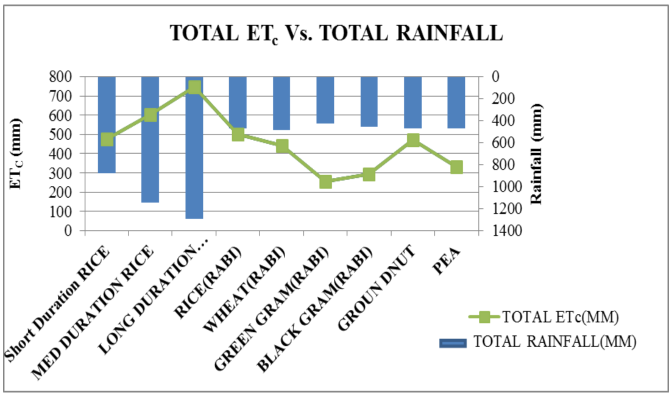

Fig 12: Total rainfall and total crop evapotranspiration of different crops

Conclusion

Daily crop evapotranspiration were determined for major crops of Khurda during Kharif and Rabi season. Crop water requirement was estimated for each crop using the result of reference ET_0 for the crop period. It was found out that that there was sufficient surplus water available during Kharif but in Rabi crop needed irrigation because rainfall was not regular. For Kharif long duration rice crop, water requirement was highest and for Green gram water requirement was lowest.

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