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Estimation of Actual Evapotranspiration (ET_a) of Major Crops of a Distributary of Mahanadi Canal Command Using CROPWAT 8.0 Model by Penman: Montieth Method

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This paper aims to estimate Actual Evapotranspiration of major crops by using CROPWAT 8.0 software in 2A canal command of Mahanadi of Dhamtari district. Actual evapotranspiration is a key process of hydrological cycle and a sole term that links land surface water balance and land surface energy balance. Irrigation is an essential part of different crops because rainfall is not enough for irrigated farmland. Long term daily meteorological data including rainfall, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours of IMD

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station data was used as input data in modified Penman method and CROPWAT 8.0 model. The crop stage data, including the value of Kc in, Kc mid, Kc end for the selected crop was obtained from Department of Irrigation the rooting depth, critical depletion and crop height of different crops are taken from FAO Irrigation and Drainage Paper 56. The Penman Monteith method was used to estimate ET_o and ET_c respectively. The major crops in 2A canal command area are Paddy, Wheat, Chickpea , Summer Paddy. Based on the intensive study of this paper, daily basis meteorological weather data was recorded from 2007 to 2021 were used to obtain the result. The study detects that Penman–Montieth method is the best method to estimate Actual Evapotranspiration of all crops.

Keywords: Reference evapotranspiration; crop coefficient; modified penman method; CROPWAT 8.0; crop water requirement; actual evapotranspiration.

1. INTRODUCTION

"Evapotranspiration is a process by which water is lost by evaporation and transpiration. In real world conditions, the evaporation and transpiration can occur at the same time and it is very difficult to differentiate between .When the crop is small, soil evaporation is the primary source of evapotranspiration however, once the crop has matured and fully covers the soil, transpiration becomes the primary source of water loss. Temperature, Relative humidity, movement of wind and movement of air, availability of Soil moisture, different type of crops available are parameters affecting evapotranspiration" [1]. "Evapotranspiration calculation is critical not only for the analysis of climate emergency and the assessment of water supplies, and include for crop water demand, drought forecast and tracking effective water

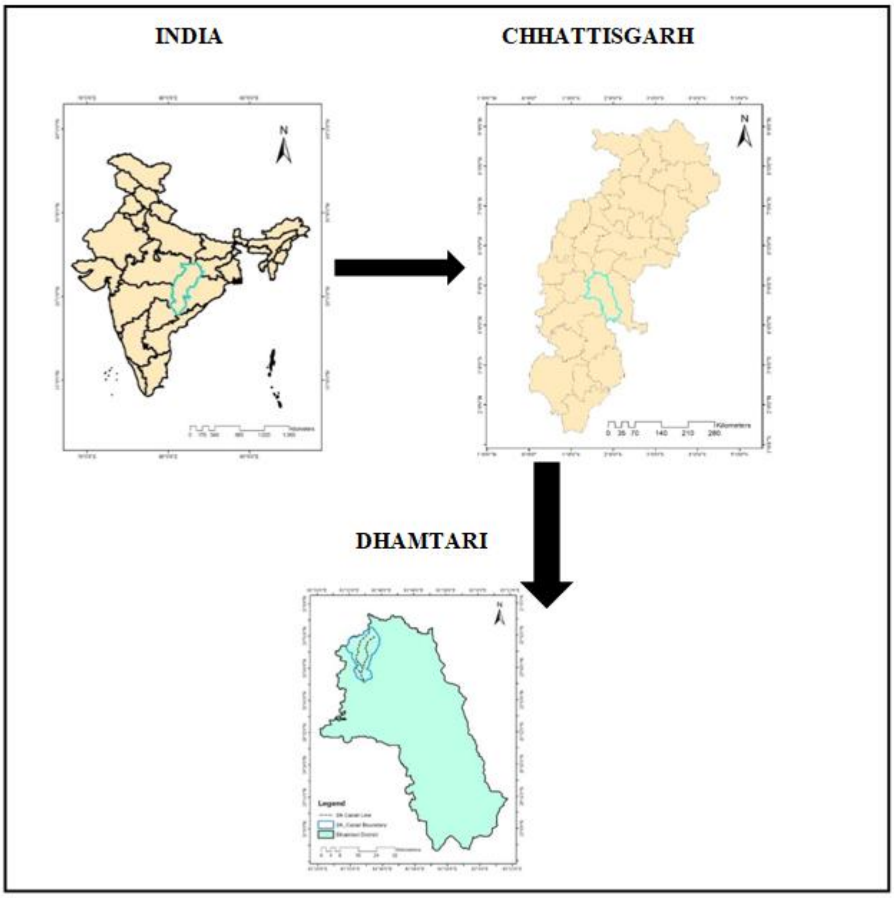

Fig. 1. Location map of the study area

resource output and use" [2-4]. "ET, from an agricultural perspective, decides the volume of water to be supplied artificially. ET estimation is essential since it defines the size of irrigation channels and other irrigation. Evapotranspiration can be measured directly or indirectly and depend on weather data and soil water balance" [5,6]. These methods are broadly known as empirical (e.g., Thornthwaite method, Blaney and Criddle) or physical methods (e.g., Penman - Montheith, and FAO Penman Montheith method [1]. To better estimate crop water requirements, Food and Agriculture Organization recommends the use of CROPWAT software, CROPWAT is frequently used for crop evapotranspiration, reference crop evapotranspiration, irrigation scheduling, and cropping patterns prediction. The study help on using CROPWAT model for estimating actual evapotranspiration [7-11].

1.1 Study Area

The present study carried out in Mahanadi Command area Dhamtari and Kurud Block of Northern part of Dhamtari district of Chhattisgarh State. The area lies between 20.7404 and 21.0829 N latitudes and 81.4750 and 81.8530 E longitudes. The geographical extension of the study area is 975 sq km representing around 29% of the district's geographical area. One of the major rivers of North India is Mahanadi, which originates from the Sihawa hill, located on the east of Nagri tehsil. Mahanadi is the principal river of the Dhamtari district along with its tributaries and Kharun on western boundary of block respectively. Dhamtari district is agriculturally intensive due to the establishment of good network of irrigation canals from New Rudri Barrage, which was constructed on the Mahanadi River. The major crop of this district and kurud block is paddy in kharif season and in Rabi season mostly summer paddy whereas paddy is grown in command areas of tank, and wheat, chickpea, pulses (mainly gram and millets) and oil seeds are taken. The length of 2A Canal is 22200 M and Cultural command area is 12461.58 and Discharge (Q) =11.40 CUMEC.

2. MATERIALS AND METHODS

Following are data used in CROPWAT8.0 software to estimate Actual Evapotranspiration for each crop:

All the input data are required for model to calculate actual evapotranspiration (ETa). All the daily climate data are taken from IMD (India Meteorological Department) of 15 years and rainfall data is also taken daily basis of 15 years as well as crop data is of 15 years daily basis.

List 1. Model Input data for CROPWAT 8.0

Climate Data	Minimum Temperature Maximum Temperature Relative Humidity Wind Speed Sunshine Hours
Rainfall Data in mm	Daily
Crop Data	K_c value for paddy,wheat, chickpea, summer paddy

2.1 Methodology

Data: The input for the computation of ET_a requires meteorological variables such a maximum temperature, minimum temperature, relative humidity, wind speed, sunshine hours and rainfall. The meteorological database has been generated for 15 years from (2007- 2021) on daily basis. Using the CROPWAT software reference evapotranspiration was calculated for the entire study area which uses FAO56 Penman Monteith method. Soil data have been collected from Department of Soil Science and Agricultural Chemistry, IGKV, Raipur. Crop data have been collected from Agriculture Department of dhamtari block.

CROPWAT:

CROPWAT 8.0 developed by FAO, based on FAO Irrigation and Drainage Paper 56 named FAO56. FAO56 adopted the P - M (Penman - Monteith) method as a global standard to estimate ETo from meteorological data. The Penman–Monteith equation is used for computation of daily reference evapotranspiration. Penman-Monteith equation is mathematically expressed as shown in equation (1).

$$ET_0 = \frac{0.408\Delta\,(Rn\text{-}G) + \gamma = \frac{900}{T+273}\,U(es\text{-}ea)}{\Delta + \gamma(1+0.34U)}$$

Where,

ET_0 : reference crop evapotranspiration [mm/day]

R_n : net radiation at the crop surface [MJ/ m^2 /day]

G: soil heat flux [MJ/(m2 .d]

T: average air temperature [º C]
U: wind speed measured at 2 m height [m/s]
es :saturation vapour pressure [kPa]
ea: actual vapour pressure [kPa]
(es- ea): saturation vapour pressure deficit [kPa]
Δ: slope of the vapor pressure curve, [kPa/ º C]
γ: psychrometric constant, [kPa/ ºC]
900: conversion factor.

The FAO CROPWAT program incorporates procedures for reference crop evapotranspiration and crop water requirements and allow the simulation of crop water use under various climates, crop and soil conditions.

Crop data:

The major cultivated crops in the study area are paddy, wheat, chickpea ,summer paddy. Crop coefficient values (K_c) are taken from available published data. K_c values for initial, development, mid-season and late-season growth stages of different crops are used.

Actual Evapotranspiration:

Actual evapotranspiration is mathematically a product of reference evapotranspiration and crop coefficient, which is given in the equation below:-

$$ET_a = ET_O \times K_C$$

where,

ET_a = *Actual evapotranspiration*
ET_O = *Reference evapotranspiration*
K_C = *Crop Coeffcient*

The crop coefficient changes with the growing stages of the crop. The value of Kc for any crop is most likely to be less in planting stage and reaches a maximum at mid season. In the present study wheat, paddy, chickpea, summer paddy crop is chosen for determination of evapotranspiration. The K_c values for different growth stages as per FAO 56 are shown in Table 1.

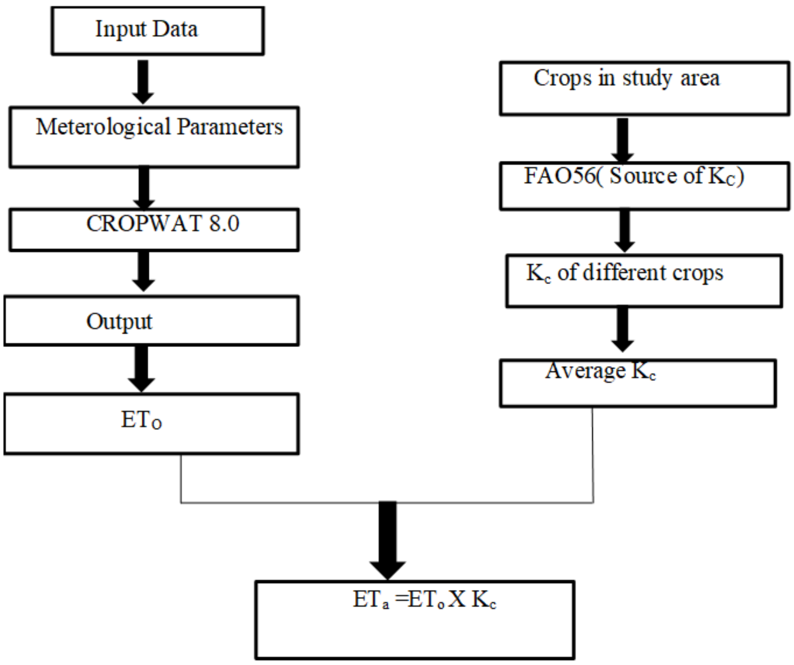

Table 1. Crop coefficient of growing stages of different crop

Sl. No.	Crops	Growing stages of crops			
		Initial	Development	Mid season	Late season
1.	Paddy	1.10	1.20	1.20	1.05
2.	Wheat	0.30	1.15	1.15	0.30
3.	Chickpea	0.40	1.0	1.0	0.35
4.	Summer paddy	1.05	1.20	1.20	0.70

3. RESULTS AND DISCUSSION

The CROPWAT 8.0 Model was used to calculate the reference evapotranspiration, and the crop coefficient was used to multiply the reference evapotranspiration to determine the real evapotranspiration. The input data provided for CROPWAT model includes minimum temperature, maximum temperature, latitude, longitude, altitude, sunshine hours and wind velocity. The input data was collected and analysed for a decade starting from 2007 to 2021 in the Dhamtari region. The daily potential evapotranspiration was obtained and tabulated using the CROPWAT 8.0 model as shown in Tables.

Table 2. Reference evapotranspiration of the study area by CROPWAT model for Rice Crop

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	2.18	2.88	3.46	3.89	4.11	3.77	2.92	2.98	3.06	1.84	2.55	2.18
2008	2.12	2.55	3.26	4.07	3.95	3.04	3	2.92	3.47	3.23	2.4	2.04
2009	2.23	2.76	3.06	3.8	4.37	4.18	2.91	3.26	3.54	3.02	2.33	2.08
2010	2.07	2.81	3.47	4.26	4.55	4.04	3.22	3.38	3.38	3.24	2.58	2.03
2011	2.29	2.79	3.64	4.33	4.78	3.8	3.44	2.99	2.97	3.38	2.6	2.08
2012	1.85	2.78	3.15	4.2	4.29	3.8	2.81	2.83	3.18	3.24	2.41	2.15
2013	2.12	2.81	3.34	4.17	4.54	3.67	2.97	2.8	3.25	2.72	2.57	2.12
2014	2.12	2.81	3.34	4.13	4.41	3.84	3.04	3.18	2.93	3.07	2.5	1.96
2015	2.56	2.94	3.27	3.69	3.64	3.21	3.09	3.24	3.61	3.5	2.82	1.75
2016	1.94	2.19	3.15	4.22	4.59	4.28	3.07	3.01	2.89	3.05	2.52	2.06
2017	2.29	2.86	3.34	3.85	4.4	4.07	3.04	3.37	3.58	3.32	2.75	2.4
2018	2.21	2.66	3.2	4	4.5	4.13	2.66	2.61	3.33	3.39	2.65	1.72
2019	1.69	2.57	2.95	3.35	3.62	3.43	3.18	2.96	3.05	3.04	2.39	1.65
2020	2.04	2.54	3.02	3.49	3.93	3.38	3.18	2.78	2.55	2.66	2.5	1.6
2021	1.68	2.01	2.72	2.69	3.47	3.37	3.05	2.85	2.57	3.23	2.38	2.17

Table 3. Reference Evapotranspiration of the study area by CROPWAT model for Chickpea Crop

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	2.18	2.88	3.46	3.89	4.11	3.77	2.92	2.98	3.06	1.84	2.55	2.18
2008	2.12	2.55	3.26	4.07	3.95	3.04	3	2.92	3.47	3.23	2.4	2.04
2009	2.23	2.76	3.06	3.8	4.37	4.18	2.91	3.26	3.54	3.02	2.33	2.08
2010	2.07	2.81	3.47	4.26	4.55	4.04	3.22	3.38	3.38	3.24	2.58	2.03
2011	2.29	2.79	3.64	4.33	4.78	3.8	3.44	2.99	2.97	3.38	2.6	2.08
2012	1.85	2.78	3.15	4.2	4.29	3.8	2.81	2.83	3.18	3.24	2.41	2.15
2013	2.12	2.81	3.34	4.17	4.54	3.67	2.97	2.8	3.25	2.72	2.57	2.12
2014	2.12	2.81	3.34	4.13	4.41	3.84	3.04	3.18	2.93	3.07	2.5	1.96
2015	2.56	2.94	3.27	3.69	3.64	3.21	3.09	3.24	3.61	3.5	2.82	1.75
2016	1.94	2.19	3.15	4.22	4.59	4.28	3.07	3.01	2.89	3.05	2.52	2.06
2017	2.29	2.86	3.34	3.85	4.4	4.07	3.04	3.37	3.58	3.32	2.75	2.4
2018	2.21	2.66	3.2	4	4.5	4.13	2.66	2.61	3.33	3.39	2.65	1.72
2019	1.69	2.57	2.95	3.35	3.62	3.43	3.18	2.96	3.05	3.04	2.39	1.65
2020	2.04	2.54	3.02	3.49	3.93	3.38	3.18	2.78	2.55	2.66	2.5	1.6
2021	1.68	2.01	2.72	2.69	3.47	3.37	3.05	2.85	2.57	3.23	2.38	2.17

Table 4. Reference Evapotranspiration of the study area by CROPWAT model for Wheat Crop

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	2.18	2.88	3.46	3.89	4.11	3.77	2.92	2.98	3.06	18.4	2.55	2.18
2008	2.12	2.55	3.26	4.07	3.95	3.04	3	2.92	3.47	3.23	2.4	2.04
2009	2.23	2.76	3.06	3.8	4.37	4.18	2.91	3.26	3.54	3.02	2.33	2.08
2010	2.07	2.81	3.47	4.26	4.55	4.04	3.22	3.38	3.38	3.24	2.58	2.03

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	2.29	2.79	3.64	4.33	4.78	3.8	3.44	2.99	2.97	3.38	2.6	2.08
2012	1.85	2.78	3.15	4.2	4.29	3.8	2.81	2.83	3.18	3.24	2.41	2.15
2013	2.12	2.81	3.34	4.17	4.54	3.67	2.97	2.8	3.25	2.72	2.57	2.12
2014	2.12	2.81	3.34	4.13	4.41	3.84	3.04	3.18	2.93	3.07	2.5	1.96
2015	2.56	2.94	3.27	3.69	3.64	3.21	3.09	3.24	3.61	3.5	2.82	1.75
2016	1.94	2.19	3.15	4.22	4.59	4.28	3.07	3.01	2.89	3.05	2.52	2.06
2017	2.29	2.86	3.34	3.85	4.4	4.07	3.04	3.37	3.58	3.32	2.75	2.4
2018	2.21	2.66	3.2	4	4.5	4.13	2.66	2.61	3.33	3.39	2.65	1.72
2019	1.69	2.57	2.95	3.35	3.62	3.43	3.18	2.96	3.05	3.04	2.39	1.65
2020	2.04	2.54	3.02	3.49	3.93	3.38	3.18	2.78	2.55	2.66	2.5	1.6
2021	1.68	2.01	2.72	2.69	3.47	3.37	3.05	2.85	2.57	3.23	2.38	2.17

Table 5. Reference Evapotranspiration of the study area by CROPWAT model for Summer Rice Crop

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	2.18	2.88	3.46	3.89	4.11	3.77	2.92	2.98	3.06	1.84	2.55	2.18
2008	2.12	2.55	3.26	4.07	3.95	3.04	3	2.92	3.47	3.23	2.4	2.04
2009	2.23	2.76	3.06	3.8	4.37	4.18	2.91	3.26	3.54	3.02	2.33	2.08
2010	2.07	2.81	3.47	4.26	4.55	4.04	3.22	3.38	3.38	3.24	2.58	2.03
2011	2.29	2.79	3.64	4.33	4.78	3.8	3.44	2.99	2.97	3.38	2.6	2.08
2012	1.85	2.78	3.15	4.2	4.29	3.8	2.81	2.83	3.18	3.24	2.41	2.15
2013	2.12	2.81	3.34	4.17	4.54	3.67	2.97	2.8	3.25	2.72	2.57	2.12
2014	2.12	2.81	3.34	4.13	4.41	3.84	3.04	3.18	2.93	3.07	2.5	1.96
2015	2.56	2.94	3.27	3.69	3.64	3.21	3.09	3.24	3.61	3.5	2.82	1.75
2016	1.94	2.19	3.15	4.22	4.59	4.28	3.07	3.01	2.89	3.05	2.52	2.06
2017	2.29	2.86	3.34	3.85	4.4	4.07	3.04	3.37	3.58	3.32	2.75	2.4
2018	2.21	2.66	3.2	4	4.5	4.13	2.66	2.61	3.33	3.39	2.65	1.72
2019	1.69	2.57	2.95	3.35	3.62	3.43	3.18	2.96	3.05	3.04	2.39	1.65
2020	2.04	2.54	3.02	3.49	3.93	3.38	3.18	2.78	2.55	2.66	2.5	1.6
2021	1.68	2.01	2.72	2.69	3.47	3.37	3.05	2.85	2.57	3.23	2.38	2.17

Table 6. Weightage Crop coefficient for major crops of the study area

Sl. NO.	Crops	Weightage K_c
1	Rice	1.030
2	Chickpea	0.782
3	Wheat	0.831
4	Summer Rice	1.030

Table 7. Actual Evapotranspiration (ET_a mm/day) values obtained from CROPWAT model of all major Crops

Year	RICE	WHEAT	CHICKPEA	SUMMER
2007	3.4834	2.4453	2.0691	3.4031
2008	3.2259	2.3572	1.9815	3.2857
2009	3.4834	2.3090	1.9549	3.3413
2010	3.5555	2.4420	1.9971	3.5349
2011	3.4154	2.5068	2.0864	3.6729
2012	3.2609	2.3373	1.9502	3.3516
2013	3.1744	2.4254	2.0081	3.4978
2014	3.3083	2.4138	2.0284	3.4628
2015	3.4299	2.3971	2.0707	3.3166
2016	3.3578	2.2026	1.8547	3.3145
2017	3.5802	2.3938	2.0457	3.4484

Year	RICE	WHEAT	CHICKPEA	SUMMER
2018	3.3207	2.4054	2.0691	3.4134
2019	3.2259	2.0414	1.8125	2.9210
2020	2.9973	2.1178	1.8218	3.0941
2021	3.1044	1.7787	1.6450	2.5441

4. CONCLUSION

Water requirements of crops vary depending on climate, soil type, and crop variety. Because of its various input factors, the CROPWAT 8.0 model is an excellent tool for irrigation planning and control. Evapotranspiration offers the critical knowledge about water requirements for producing different crops in different seasons. The results show that the crop water requirement of different crops will consequently help improving the management of water resources and productivity. The CROPWAT 8.0 model gives sufficiently accurate results and reduces the calculation and also consumes less time. The major crops in 2A canal command area are Paddy, Wheat, Chickpea, Summer Paddy. Based on the intensive study of this paper, daily basis meteorological weather data recorded from 2007 to 2021 were used to obtain the result. The study detects that Penman–Montieth method is the best method to estimate ETa because of its inclusion of parameters in calculation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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