Estimation of Monthly Irrigation Water Requirement of Crops Using CROPWAT

Abstract

Water is increasingly becoming a limited resource due to rising demands for various uses, including hydropower generation, irrigation, and domestic supply. As the population continues to grow, the need for water across different sectors is constantly increasing. However, the availability of water resources is restricted both spatially and temporally. Therefore, there is an urgent need for systematic and scientific planning to ensure its optimal use.Agriculture sector being the major consumer of water resources, the adoption of modern irrigation techniques can significantly reduce water consumption and promote water conservation. This advancement will expand the irrigated areas and ultimately lead to increased agricultural productivity.Irrigation water requirements of major crops, namely, Paddy, maize, sugarcane etc. are determined using the CROPWAT model. The present study aimed to find out the irrigation water requirement for the major crops grown in Krishna Central Delta, Andhra Pradesh. Results revealed that irrigation water requirement for kharif season rangesfrom 89-475 mm and in rabi season the irrigation water requirement for different crops varied from 320-821 mm. For sugarcane irrigation water requirement was found to be 927 mm.

Keywords: CROPWAT, irrigation water requirement, CLIMWAT, effective rainfall

1. Introduction

Water is a vital natural resource essential for daily life and meeting various demands. Economic and national development requires increased water resources to satisfy growing municipal and industrial needs, which consequently reduces the availability of water for agricultural purposes. Efficient management of water resources at all usage levels is critical to address the rising demands of an expanding population, particularly in India. Agriculture, which is the backbone of the Indian economy, accounts for approximately 60% of the country's freshwater usage. Therefore, it is crucial to plan and implement effective water management strategies to meet the increasing demands across all sectors, especially in agriculture, as it is the largest consumer of water resources.The primary objective of irrigation is to apply water to maintain crop Evapotranspiration (ET_c) when precipitation is insufficient.Precise information is required for crop water requirements, irrigation withdrawal as a function of crop, soil type and weather conditions to achieve effective planning. CROPWAT software is employed for estimating the irrigation water requirements of different crops grown in study area.

Roja *et al.* (2020) conducted a study to determine crop water requirements and develop irrigation schedules for groundnut crops using 10 years of climatic data (2009-2019) from the Naira meteorological station, Andhra Pradesh. The study utilized the CROPWAT 8.0 model to calculate crop evapotranspiration (ET_c) and reference crop evapotranspiration (ET_o). Results indicated that the irrigation requirements for groundnut were estimated at 184.3 mm per decade. The study concluded that the CROPWAT 8.0 model is effective for proper irrigation scheduling, ensuring optimal water use for groundnut cultivation. Ewaid*et al*., (2019) estimate the crop water requirements (CWRs) and irrigation schedules for some major crops in Dhi-Qar Province in southern Iraq,using the Food and Agriculture Organization (FAO) CROPWAT 8.0 simulation software and the CLIMWAT 2.0 tool attached to it. The irrigation requirements were1142, 203.2, 844.8, and 1180 mm/dec for wheat, barley, white corn, and tomatoes, respectively. This study proved that the CROPWAT model is useful for calculating the crop irrigation needs for the proper management of water resources.Raju *et al.* (2011) utilized the computer simulation model CROPWAT to estimate crop water requirements for the Appapuram Channel Command in the Krishna Western Delta of Andhra Pradesh, covering the period from 2000 to 2010. The Penman-Monteith method was employed to calculate evapotranspiration within the model. The study estimated that the gross water requirement to irrigate 8,880 hectares of registered and 4,000 hectares of unregistered ayacut during the kharif season, as well as 4,000 hectares of maize during the rabi season, amounted to 82.68 million cubic meters. Keeping the above in view,the objective of this present study is to estimate the crop water requirements for major crops grown in the Krishna Central Delta.

2. Material and Methods

2.1 Description of study area

Krishna Central Delta (KCD) is a part of Krishna Eastern Delta that starts from the left bank of Prakasam Barrage at Vijayawada, Andhra Pradesh, India. KCD constitutes the command area of Bandar Direct canal and has it ayacutmandal's in both Krishna and NTR districts, totally about 1,11,268 ha of command area. KCD has sub humid climate with high temperatures in summer and good seasonal rainfall. Calcareous soil is the predominant type of soil in the study area followed by clay and coastal sandy soils. Paddy is the major crop grown in kharif season and paddy and maize are predominantly grown in the rabi season. Sugarcane also constituted the significant share in the cropped area. The other crops grown in the study area are: groundnut, vegetables and pulses.

2.2 Overview of CROPWAT

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain fed conditions or deficit irrigation (FAO, 1992).

CROPWAT is used for the estimation of monthly irrigation water requirement of selected crops for conjunctive use planning in the study area. CROPWAT is a computer program that uses the FAO Penman-Monteith method to calculate reference evapotranspiration (ET_o), crop water requirements (ET_c) and irrigation scheduling (FAO 1992). The program allows for the development of irrigation schedules under various management and water supply conditions and to evaluate rain-fed production, drought effects and efficiency of irrigation practices (FAO 2002). CROPWAT is helpful to agro scientists, agro researchers and water resources engineers as a practical tool to carryout standard calculations for evapotranspiration and management of irrigation schemes. Plants use water for cooling purposes and the driving force 'of this process is prevailing weather conditions. Under the same climate and atmosphere, different crops have different water use requirements. CROPWAT integrates various data inputs, including soil characteristics, crop types, and climatic conditions, allowing for a holistic view of agricultural water needs. This comprehensive approach supports better irrigation planning and management decisions.The procedure followed for estimation of irrigation water requirement using CROPWAT software is outlined below.

2.3 Climate

Climate data of Machilipatnam station is considered as the representative weather station for the study area. The climatic data which includes minimum and maximum temperatures in ^{0}C, humidity in %, wind speed in km/day, mean sunshine in hours and mean solar radiation in MJ/m^2/day. All these climate variables pertaining to the Machilipatnam station was downloaded from CLIMWAT software.

Table 1. Climate file of Machilipatnam for CROPWAT

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind speed (km/day)	Sunshine (hours)	Solar Radiation (MJ/m²/day)
January	19	28.5	77	147	9.3	19.3
February	20.8	30.2	77	147	9.3	21.1
March	22.6	32.5	75	147	10	23.8
April	25.7	34.6	73	216	9.5	24.2
May	27.5	37.3	65	268	9.3	23.8
June	27	36.7	61	268	8	21.6
July	25.6	33.7	71	216	6.9	19.9
August	25.4	32.6	74	216	6.9	20.0
September	25.3	32.5	78	164	6.9	19.4
October	24	31.6	80	147	7.5	18.9
November	21.6	30.1	77	164	8	17.9
December	19.9	28.8	75	164	8.7	17.9
Average	23.7	32.4	74	189	8.4	20.6

CLIMWAT is a climate database designed to work with the CROPWAT software. It offers meteorological data from over 5,000 climate stations around the globe, enabling CROPWAT to determine crop water needs, irrigation supplies, and scheduling for various crops. CLIMWAT supplies long-term monthly average values (based on 30 years of data i.e., from 1971-2000) for key climate parameters required to calculate potential evapotranspiration using the Penman-Monteith method. Additionally, it includes data on total and effective monthly rainfall. All variables, except for potential evapotranspiration, are either direct measurements or derived from observed data. Input of climate file for Machilipatnam is presented in Table 1.

2.4 Rainfall

Rainfall data for Machilipatnam is also downloaded from the CLIMWAT software and it provides average monthly rainfall in mm. Then utilizing the rainfall data, effective rainfall is calculated by the software using the opted USDA S.C. method. Monthly effective rainfall of Machilipatnam station is given below. (Table 2)

Table 2 :Monthly effective rainfall of Machilipatnam (in mm)

Month	Rainfall, mm	Effective rainfall, mm
January	5	5
February	9	8.9
March	12	11.8
April	9	8.9
May	36	33.9
June	94	79.9
July	186	130.6
August	188	131.4
September	162	120
October	187	131
November	104	86.7
December	24	23.1
Total	1016	771.2

2.5 Crop Data

For the selected crops, the planting dates were given as input and then the harvesting date is automatically displayed. The crop coefficient (K_c) values for different growth stages of various crops were taken from the FAO Irrigation and Drainage paper 56 (Allen *et al.*, 1998) for crop module and presented in Table 3.

Table.3:Crop duration and its corresponding K_C values for different crops at different growth stages.

S. No.	Crop	Crop growing stages (days)				Total crop duration (days)	Crop Coefficient (K_c)		
		Initial	Develo-pment	Mid Season	Late Season		Initial	Mid-season	Late Season
	Kharif								
1	Paddy	50	30	40	30	150	1.18	1.2	1.05
2	Maize	20	35	40	30	125	0.3	1.2	0.35
3	Groundnut	25	35	45	25	130	0.4	1.15	0.6
4	Vegetables	30	30	30	15	95	0.7	1.05	0.95
	Rabi								
5	Paddy	50	30	40	30	150	1.18	1.2	1.05
6	Maize	20	35	40	30	125	0.3	1.2	0.35
7	Groundnut	25	35	45	25	130	0.4	1.15	0.6
8	Vegetables	30	30	30	15	95	0.7	1.05	0.95
9	Pulses	20	30	40	20	110	0.4	1.15	0.35
	Perennial								
10	Sugarcane	30	60	180	95	365	0.4	1.25	0.75

2.6 Soil Data

In Krishna Central Delta, the major portion of command area is under black clay soils. The soil properties related to moisture content were obtained from the FAO, Irrigation and Drainage paper 56 (Allen *et al.*, 1998) and presented in Table 4.

Table 4.Soil data used for CROPWAT

S.No.	General Soil Data	Black Clay Soil
1	Total available soil moisture (mm/meter)	200

2	Maximum infiltration rate (mm/day)	30
3	Maximum rooting depth (cm)	90
4	Initial soil moisture depletion (as %TAM)	50

By providing the input to all the four modules in the CROPWAT software viz., Climate, rainfall, crop and soil module. Then crop water requirement is estimated by CROPWAT for all the crops under consideration of conjunctive use, the irrigation water requirement is calculated.

3. Results and Discussion

The CROPWAT model was run for different crops in Krishna Central Delta utilizing the Machilipatnam climatic data and FAO 56 paper. The results obtained were discussed in the following sub sections.

3.1 Estimation of potential evapotranspiration (ET_o):

Using the CROPWAT software, the ET_o was estimated for Machilipatnam climatic data using Penman Monteith formula. ET_o was found to range from 3.44 mm/day in January to 7.28 mm/day in the month of June. On an average 4.89 mm/day is the potential evapotranspiration for the Krishna Central Delta. Monthly ET_o values were shown in the Fig.1 below

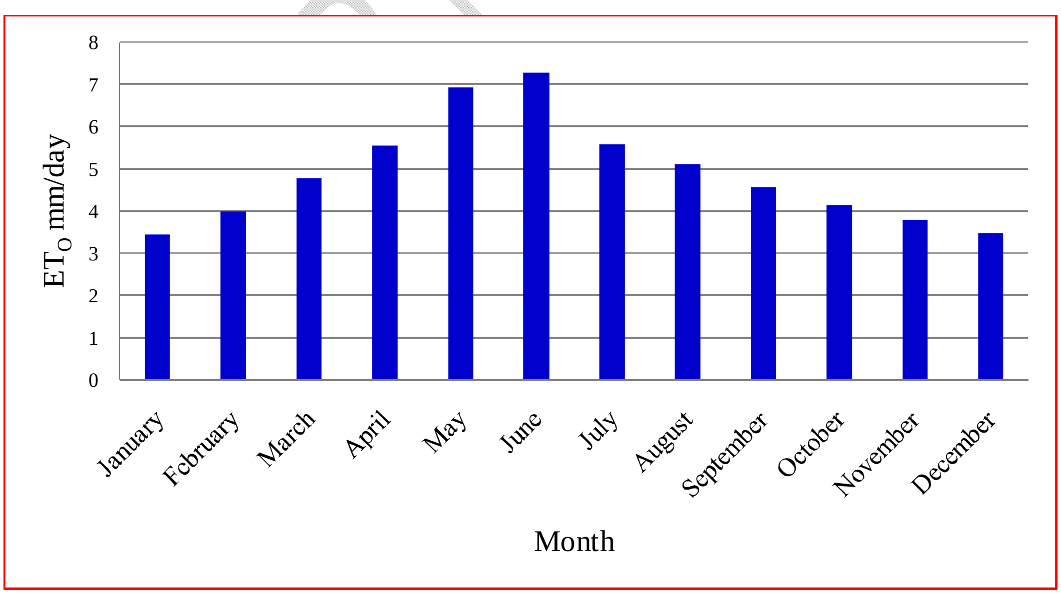

Fig. 1. Monthly ET_o values of Krishna Central Delta

3.2.Estimation of irrigation water requirement for different crops

Utilizing the crop coefficients values provided in the crop data file and the potential Evapotranspiration data from the climate data file, CROPWAT calculates the irrigation requirement of crops. The results were given in mm/decade. The model was run for all the Kharif, Rabi and perennial crops that are in consideration. The resultant monthly irrigation water requirement of different crops under consideration is tabulated in the Table 5below. From the results it can be found that the perennial sugarcane crop has highest water requirement compared to all other crops in both kharif and rabi seasons. For paddy crop, the irrigation requirement is high in Rabi season because of less effective rainfall during the Dalawa (Paddy in Rabi is called as Dalawa) crop period. During the kharif Paddy, the irrigation requirement is comparatively less, because a significant amount of crop water requirement is met by the effective rainfall during that crop season. The same scenario is of concern when the irrigation requirement of maize and groundnut crops is compared in between kharif and rabi seasons. In kharif season, irrigation water requirement of different crops as estimated are: 475 mm for paddy, 35.3 mm for maize, 27.4 mm for groundnut and 89 mm for vegetables. In kharif season, the least irrigation requirement is for the groundnut crop followed by maize, vegetables and paddy.In rabi season the estimated irrigation water requirements are: 821 mm for paddy, 407.8 for maize, 453.9 mm for groundnut, 339.5 for pulses and 320 mm for vegetables. In rabi season, the least irrigation requirement is found for the vegetables crop, followed by pulses, maize, groundnut and paddy. Irrigation water requirement for sugarcane was estimated to be 927 mm.

4. Conclusion

CROPWAT is the effective software with easiness in estimation of irrigation water requirements for different crops under different growing conditions such as soil, climate etc. The irrigation water requirements of different crops in KCD was estimated for both kharif and rabi seasons. In kharif season, the irrigation water requirement was found to range from 89-475 mm and in rabi season the irrigation water requirement for different crops varied from 320-821 mm. For sugarcane irrigation water requirement was found to be 927 mm.

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Table 5. Monthly irrigation water requirement of different crops (in m)										
Month/ crop	**Paddy Kharif**	**Paddy Rabi**	**Maize Kharif**	**Maize Rabi**	**Groundnut Kharif**	**Groundnut Rabi**	**Pulses Rabi**	**Sugarcane Rooted**	**Vegetables Rabi**	**Vegetables Kharif**
January		0.123		0.052		0.0513	0.0736	0.1195	0.08	
February		0.121		0.1137		0.1051	0.1156	0.1017	0.1	
March		0.163		0.1602		0.1588	0.1286	0.1179	0.11	
April		0.099		0.0735		0.1261	0.0048	0.0858		
May								0.0747		
June	0.05							0.0953		0.032
July	0.324		0		0.002			0.0711		0.015
August	0.05		0.0039		0			0.0615		0.036
September	0.032		0.0277		0.014			0.039		0.006
October	0.012		0.0037		0.01			0.0206		
November	0.007	0.025	0		0.001			0.0348		
December		0.29		0.0084		0.0126	0.0169	0.1051	0.03	
TOTAL	0.475	0.821	0.0353	0.4078	0.0274	0.4539	0.3395	0.927	0.32	0.089