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Estimation of Total Water Demand in the Command Area of Bapatla Channel

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Abstract

Estimating irrigation water requirements is prerequisite for water project planning and management. A study was carried out to determine the crop water requirement of selected crops for the command area of Bapatla channel. The major crops include paddy and maize for two seasons (*kharif* and *rabi*). CROPWAT 8.0 was used to estimate the reference evapotranspiration, crop water requirement and irrigation water requirement. The information about climatic conditions, soil types and cropping pattern were obtained for the period of 2012-13 to 2016-17 (5 years) and used as input data for CROPWAT. Average peak monthly reference evapotranspiration (ET_o) was observed to be 6.65 mm day^{-1} for the month of May. Whereas average minimum ET_o was observed as 3.28 mm day^{-1} in the month of December. The results obtained as the TWD (Total Water Demand) of Bapatla channel command for two seasons (kharif and rabi) of crops paddy and maize was found to be 6500.04 ha-m in the year 2012-13. Similarly, for 2013-14, 2014-15, 2015-16 and 2016-17 years TWD was found to be 6325.18, 6521.42, 3102.40 and 5376.19 ha-m, respectively. It was observed that total water demand (TWD) was least in the year 2015-16 (3102.40 ha-m) and maximum in the year 2014-15 (6521.42 ha-m).

Keywords: CROPWAT, evapotranspiration, effective rainfall, total water demand

1. Introduction

Water for agriculture is becoming increasingly scarce in the light of growing water demands from different sectors (IWMI, 2010). Analysis showed that the total crop water requirement of all major crops increased with the rising temperature thereby increasing the simulated irrigation water demand (Surendran et al., 2014). Crop water requirements (CWR) refer to the amount of water required to compensate the evapotranspiration losses from a cropped field during a specified period. Crop water requirements are expressed usually in mm day^{-1}, mm $month^{-1}$ or mm $season^{-1}$ and they are used for the management purposes: in the estimation of irrigation water requirements, irrigation scheduling and water delivery scheduling.

The primary objective of irrigation is to apply water to soil to meet crop evapotranspiration (ET_c) requirement when rainfall is insufficient to raise crops till harvesting. Cropwat is a FAO model for irrigation management designed by Smith (1991). It is meant as a practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out estimation for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. 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 can be derived from this. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large-scale irrigation projects in most developing countries of the world. The objective of this study was to determine crop water requirements of major crops like paddy and maize for the two seasons (kharif and rabi) in Bapatla channel command area using CROPWAT 8.0.

2. Materials and Methods

2.1. Study area

The Study was carried out in Bapatla channel command, the tail end of Commamuru canal of Krishna Western Delta (KWD), which is the part of lower Krishna basin in Andhra Pradesh. It lies between latitudes 15.84˚ and 16.00˚ N and, longitudes 80.37˚ and 80.50˚ E with an altitude of 6m above mean sea level. The study area belongs to sub-humid region. Bapatla channel command follows in Guntur and Prakasam districts with total 11 villages. The command area of Bapatla channel is 6548.27 ha.

2.2. Data collection

Daily meteorological data was collected for the period from 2012 to 2017 from Meteorological station, Bapatla. Cropping pattern data and yield details were collected from agriculture office as shown in Table 1.

The above data and climate data were used in the application of CROPWAT model for estimation of reference evapotranspiration, crop water requirement and irrigation water requirement of selected crops like paddy and maize for the two seasons (kharif and rabi). In the study area, most of the soils are clay soils (69.66%) and sandy loam soils (30.34%), respectively.

Table 1: Crop details in Bapatla channel command area

Sl. No.	Year	Crop	Season	Sowing date	Harvesting date	Yield (kg ha^{-1})	Area of crop (ha)
1.	2012-13	Paddy	*Kharif*	15/09	12/01	2149	4991.80
2.		Paddy	*Rabi*	25/11	14/03	2246	271.95
3.		Maize	*Rabi*	25/11	14/03	1874	980.63
						Total	6244.37
4.	2013-14	Paddy	*Kharif*	15/09	12/01	2249	5331.32
5.		Paddy	*Rabi*	25/11	14/03	2729	419.47
6.		Maize	*Rabi*	25/11	14/03	1727	795.21
						Total	6546.00
7.	2014-15	Paddy	*Kharif*	15/09	12/01	3145	5068.09
8.		Paddy	*Rabi*	25/11	14/03	2925	388.09
9.		Maize	*Rabi*	25/11	14/03	1995	1069.08
						Total	6525.26
10.	2015-16	Paddy	*Kharif*	15/09	12/01	2125	2548.20
11.		Paddy	*Rabi*	25/11	14/03	3568	40.37
12.		Maize	*Rabi*	25/11	14/03	2347	456.68
						Total	3045.25
13.	2016-17	Paddy	*Kharif*	15/09	12/01	3125	4218.78
14.		Paddy	*Rabi*	25/11	14/03	3022	319.45
15.		Maize	*Rabi*	25/11	14/03	1789	542.74
						Total	5080.97

2.3. Estimation of crop water requirement

The term crop water requirement is defined as the "amount of water required to compensate the evapotranspiration loss from the cropped field". "Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration". The crop ET (ET_C) was estimated by FAO Penman-Monteith equation:

$ET_c = ET_o * K_c$

Where, ET_c = actual evapotranspiration by the crop (mm day^{-1}), K_c= crop coefficient at a specific growth stage

ET_o = reference evapotranspiration (mm day^{-1}) and it is determined by:

$$ET_0 = \frac{0.408\Delta(R_n-G)+\gamma\frac{900}{T+273}U_2(e_s-e_a)}{\Delta+\gamma(1+0.34U_2)}$$

Where, R_n = net radiation at the crop surface [MJ m^{-2} day^{-1}],

G=Soil heat flux density [MJ m^{-2} day^{-1}],

T=Mean daily air temperature at 2 m height [°C],

u_2=Wind speed at 2 m height [m s^{-1}],

e_s=Saturation vapour pressure [kPa],

e_a=Actual vapour pressure [kPa],

e_s-e_a=Saturation vapour pressure deficit [kPa],

Δ=Slope vapour pressure curve [kPa °C^{-1}],

γ=Psychrometric constant [kPa °C^{-1}].

2.3.1. Gross irrigation requirement (GIR)

The daily gross irrigation requirements for paddy and maize crops were computed using the following relationship: where, NIR (Net irrigation requirement) = TWR–ER

=Crop water requirement + Special water needs – ER

ER=Effective rainfall, mm

USDA Soil Conservation method is used for calculating the effective rainfall (Kassam and Smith, 2001). In this method the effective rainfall can be calculated according to

ER=R(125-0.2*R)/125 for R<250 mm and

ER=125+0.1*R for R>250 mm

Where, R=Rainfall, mm

η_a=Application efficiency (%)

In case of paddy, the special water needs include land preparation requirement, percolation losses and leaching. In the present study, percolation loss from paddy fields was assumed to be 2 mm day^{-1}. Paddy fields require about 10 days of land preparation. Water requirement for land preparation of paddy during these 10 days was taken as 200 mm. Since the percolation losses were already considered in computing water requirements of paddy, a higher value of 85% was used for the application efficiency in the case of paddy in comparison with 65% for the ID crops as recommended by Ministry of Irrigation, Govt. of India for arriving at gross irrigation requirements of paddy in the command area (Sarma and Rao, 1997).

3. Results and Discussion

3.1. Reference evapotranspiration (ET_o)

Calculated average monthly climatic data and reference evapotranspiration of the study area were shown in Table 2. From Table 2, it was observed that the average peak monthly reference evapotranspiration (ET_o) was observed to be 6.65 mm day^{-1} for the month of May. Whereas average minimum ET_o was observed as 3.28 mm day^{-1} in the month of December and minimum temperature was observed in the month of January (18°C) and maximum temperature in the month of May (38.26°C).

Table 2: Average monthly climatic data and reference evapotranspiration of the study area

Sl. No.	Month	Minimum Temp. (°C)	Maximum Temp. (°C)	Humidity (%)	Wind Speed (km day^{-1})	Sunshine hours (hours)	ETo (mm day^{-1})
1.	January	18.00	30.38	77.20	101.80	7.90	3.45
2.	February	19.00	31.32	75.60	118.00	7.30	3.88
3.	March	22.48	33.20	74.00	147.40	8.40	4.89
4.	April	26.18	34.80	72.80	197.20	8.40	5.64
5.	May	27.82	38.26	65.00	211.60	9.00	6.65
6.	June	26.64	36.96	64.80	207.60	9.00	6.46
7.	July	25.90	35.36	66.60	218.60	9.10	6.24
8.	August	25.40	34.84	70.20	190.40	8.80	5.80
9.	September	25.14	33.62	77.60	144.80	8.30	5.00
10.	October	23.76	33.10	78.20	108.20	8.20	4.35
11.	November	20.92	30.92	79.80	108.80	7.70	3.54
12.	December	18.48	30.26	78.80	101.20	7.90	3.28

Monthly rainfall and effective rainfall (ER) of the study area for five years were calculated and tabulated in Table 3. Highest rainfall (1495.30 mm) and effective rainfall (1379.54 mm) were observed in the year 2013-14.

3.2. Crop coefficients

The crop coefficients (K_c) at different crop growth stages for paddy and maize crops were selected from Irrigation and Drainage Paper 56 (Allen et al, 1998) and adjusted for local climatic conditions as per the guidelines. The crop coefficients for paddy crop were found to be 1.05, 1.13 and 0.53 for the initial stage, mid-season and late season respectively and the crop coefficients for maize crop were found to be 0.15, 1.19 and 0.49 for the initial stage, mid-season and late season respectively. To determine consumptive use or crop evapotranspiration, K_c values are taken from the CROPWAT 8.0 for every 10 days of the crop season by substituting the above crop factors.

3.3. Total water demand

For the Bapatla channel command area, total water demand was computed for the five years from 2012-13 to 2016-17 during two crop seasons of paddy crop (kharif and rabi) and maize crop for rabi season. Gross irrigation requirement of individual crops was calculated on the daily basis and then calculated monthly gross irrigation requirement.

For getting total water demand (TWD) for the entire year of the channel, gross irrigation requirement level of all crops was summed. Total water demand was calculated at monthly intervals and presented the calculations in Table 4 for five years. It was found that 6500.04 ha-m of water was required for irrigating entire command area in the year 2012-13. Similarly, for 2013-14, 2014-15, 2015-16 and 2016-17 years also, TWD was calculated and found to be 6325.18, 6521.42, 3102.40 and 5376.19 ha-m, respectively. Total water demand for the 5 years during kharif and rabi seasons was presented

Table 3: Monthly rainfall and effective rainfall (ER) data of the study area for 5 years

Sl. No.	Month	2012-13		2013-14		2014-15		2015-16		2016-17	
		Rainfall (mm)	ER (mm)	Rainfall (mm)	ER (mm)	Rainfall (mm)	ER (mm)	Rainfall (mm)	ER (mm)	Rainfall (mm)	ER (mm)
1.	January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.	February	60.20	54.40	8.00	7.90	0.00	0.00	0.00	0.00	0.00	0.00
3.	March	0.00	0.00	0.00	0.00	1.50	1.50	0.00	0.00	0.00	0.00
4.	April	12.00	11.77	0.00	0.00	11.90	11.82	0.00	0.00	0.00	0.00
5.	May	39.50	38.25	18.00	17.63	0.00	0.00	180.50	160.11	3.50	3.48
6.	June	130.40	122.74	35.20	34.43	185.60	178.96	140.10	136.83	156.40	145.59
7.	July	137.30	133.03	326.70	304.51	126.20	120.44	131.70	122.35	47.50	46.39
8.	August	158.20	152.97	214.60	200.02	109.70	104.45	289.00	268.72	261.60	228.87
9.	September	150.80	142.86	399.80	366.78	225.00	204.39	231.20	210.74	469.80	373.68
10.	October	145.00	138.56	433.80	391.72	147.00	134.16	27.60	27.34	77.10	73.68
11.	November	381.80	308.37	39.20	37.19	206.20	181.63	132.70	122.50	0.00	0.00
12.	December	0.00	0.00	20.00	19.36	2.80	2.79	39.00	37.01	24.20	23.98
13.	Total	1215.20	1102.95	1495.30	1379.54	1015.90	940.13	1171.80	1085.61	1040.10	895.67

Table 4: Monthly total water demand for five years (2012-13 to 2016-17) in Bapatla channel command

Sl. No.	Month	Total water demand (ha-m)				
		2012-13	2013-14	2014-15	2015-16	2016-17
1.	August	575.18	621.84	494.52	232.82	441.86
2.	September	2133.38	1767.92	2025.09	1011.22	1528.57
3.	October	932.98	821.07	980.52	543.31	938.51
4.	November	954.98	1148.73	975.97	462.54	1006.18
5.	December	1090.91	1144.13	1122.45	492.92	830.94
6.	January	520.96	533.29	569.61	239.79	411.21
7.	February	211.23	208.67	258.37	88.55	156.99
8.	March	80.42	79.52	94.89	31.24	61.93
9.	Total	6500.04	6325.18	6521.42	3102.40	5376.19

in the Figure 1. From the Figure 1, it was observed that total water demand (TWD) was least in the year 2015-16 (3102.40 ha-m) and maximum in the year 2014-15 (6521.42 ha-m). Net irrigation water requirement of Tarikere command area was reported to be 292.7 mm year^{-1} (Nithya and Shivapur, 2016) whereas, gross water requirement (GWR) under Appapuram Channel Command was estimated to be 124.39 M.cum (Ratna Raju et al., 2016).

Benin's sub-basin of Niger River (BSBNR) annual reference evapotranspiration (ETo) was estimated at 1967 mm. The lowest monthly value of ETo of 123 mm, was observed in August month, middle of the rainy season while the highest value 210 mm was observed in March within dry season. The crop evapotranspiration (ET_c) and the crop irrigation requirements were estimated at 651 mm and 383 mm, respectively in rainy season and 920 mm and 1148 mm,

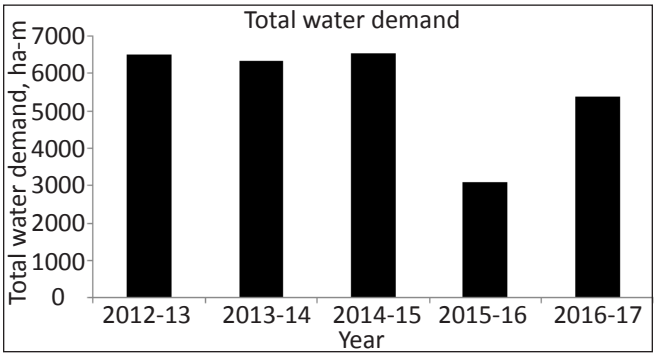

Figure 1: Total water demand for 5 years during kharif and rabi seasons in the Bapatla channel command area

respectively within a dry season (Bouraima et al., 2015). The crop water requirement for the groundnut Kharif and Rabi crops in the Anantapur region was estimated to be 591.3 mm

and 443.3mm, respectively and for the vegetables, cotton, rice, grains and maize in the Anantapur region are to be 594.1 mm, 878.6 mm, 1110.6 mm, 699.9 mm and 679.3 mm, respectively (Babu et al., 2014).

4. Conclusion

Reference evapotranspiration, effective rainfall and crop water requirement can be estimated using CROPWAT with input of climatic data. The Reference evapotranspiration was estimated during the study period and found that the average peak monthly ET_o was observed to be 6.65 mm day^{-1} for the month of May. Whereas average minimum ET_o was observed as 3.28 mm day^{-1} in the month of December. Total water demand (TWD) of Bapatla channel command for two seasons (kharif and rabi) of crops paddy and maize was found to be 6500.04 ha-m in the year 2012-13. Similarly, for 2013-14, 2014-15, 2015-16 and 2016-17 years also, TWD was found to be 6325.18, 6521.42, 3102.40 and 5376.19 ha-m, respectively.

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