RESEARCH PAPER International Journal of Agricultural Engineering | Volume 8 | Issue 1 | April, 2015 | 15–20
e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/8.1/15-20**

Estimation of crop water requirement, effective rainfall and irrigation water requirement for vegetable crops using CROPWAT

■ **R. GANESH BABU, G. RAVI BABU AND H.V. HEMA KUMAR**

Received : 20.09.2014; **Revised :** 06.02.2015; **Accepted :** 19.02.2015

See end of the Paper for authors' affiliation

Correspondence to :

R. GANESH BABU
Department of Soil and Water Engineering, College of Agricultural Engineering, BAPATLA (A.P.) INDIA

■ **ABSTRACT :** Land and water resources are the basic needs of agriculture and for the economic development of any country. As water becomes increasing scare and increasing demand for irrigation water, everywhere, has now focused national attention and public interest on utilization of existing water supplies, integrated irrigation water conservation and management policy and practices. Accurate quantification of evapotranspiration is crucial for better management and allocation of water resources. It is important that the water requirements of crops are known at different management levels within the irrigated area to accomplish effective irrigation management. Estimation of the evapotranspiration and effective rainfall are extremely useful for operation planning and management issues. CROPWAT is a computer model, was used to estimate the reference evapotranspiration, effective rainfall, crop water requirement and irrigation water requirement for the Bapatla region in Andhra Pradesh state, India. Daily meteorological data including rainfall, maximum and minimum temperatures, relative humidity, wind speed and sunshine hours were collected for the period of 2009 to 2013 and used as input data for CROPWAT. Average peak monthly ET_0 was observed to be 8.09 mm/day for the month of June and followed by the 7.55 mm/day for the month of May. Whereas average minimum ET_0 were observed as 3.85 and 3.92 mm/day in the months of December and January, respectively. The average effective rainfall was estimated for the study area as 769.3 mm out of 1060.3 mm annual rainfall. The crop water requirement (ETc) and irrigation water requirement were estimated for vegetable crops during *Rabi* season in the study area (Bapatla) as 516.3 mm and 470.4 mm, respectively.

■ **KEY WORDS :** CROPWAT, Effective rainfall, ET_O, Crop water requirement, Bapatla region

■ **HOW TO CITE THIS PAPER :** Babu, R. Ganesh, Babu, G. Ravi and Kumar, H.V. Hema (2015). Estimation of crop water requirement, effective rainfall and irrigation water requirement for vegetable crops using CROPWAT. *Internat. J. Agric. Engg.*, **8**(1) : 15-20.

Land and water resources are the basic needs of agriculture and for the economic development of any country. The world population is increasing faster than the food supply. The population of India is expected to stabilize around 1640 million by the year 2050. As a result, gross per capita water availability will decline from 1820 m^3/yr in 2001 to as low as 1140 m^3/yr in 2050. India has only 2.4 per cent of land mass and 4 per cent fresh water resources of the world. However, it is required to support 17.31 per cent of the country's population which is growing at 32 per cent per annum since independence. The per capita land availability has reduced from 0.48 ha to 0.13 ha and water availability has been reduced from 5300 cum to 1500 cum (Zhao *et al.*, 2010). As water becomes increasing scare and increasing demand for irrigation water, everywhere, has now focused national attention and public interest on utilization of existing water supplies, integrated irrigation water conservation and management policy and practices.

It is important that the water requirements of crops are known at different management levels within the irrigated area to accomplish effective irrigation management. The crop water requirements are met from the effective rainfall, irrigation water applied and the available soil moisture (Srinivasulu *et al.*, 2003; Srinivasa Prasad *et al.*, 2006 and Shengli *et al.*, 2004).The potential crop evapotranspiration (ET_c) of a crop is the volume of water required by it to meet its evapotranspiration requirements (Trajkovic and Kolokovic, 2009 and Singandhupe and Sethi (2005). The crop irrigation water requirement, therefore, consists of potential crop evapotranspiration (ET_c) minus the effective rainfall. Consideration of effective rainfall can help in predicting more precisely the water requirement of crops and useful for operation planning and management of available water resources.

Irrigation is a costly and scarce input in agriculture and plays an important role in increasing food production. As rainfall is highly stochastic in nature, irrigation has to be planned efficiently. In order to apply irrigation water efficiently, the water requirement of the crops is to be estimated accurately (Vedula and Majumdar, 1992). Several computer models are now available to estimate the crop water requirements. CROPWAT (Smith, 1992 and Allen *et al.*, 1998) a computer programme developed by the Land and Water development division of FAO, Rome, Italy was selected for the present study. The model carries out the calculations of the reference evapotranspiration (ET_0), crop water requirement (ET_c) and the irrigation water requirements of the different crops.

■ METHODOLOGY

The detail methodology of data collection, its analysis and application of model to the study area have been discussed in the following heads:

Study area :

Bapatla was selected as study area and geographically Bapatla is located at latitude of 15.92° N and longitude of 80.49° E with an altitude of 5 m above mean sea level. The experimental site lies in the humid sub-tropical area. During summer it was dry and hot, whereas in winter is cool.

Meteorological data :

Daily meteorological data like rainfall, max. and min. temperatures, relative humidity, wind speed and sunshine hours were collected for the period of 2009 to 2013 from the Postharvest Technology Center, Bapatla and shown in Table A. It shows that the average monthly rainfall was significantly higher in September and October months. Minimum and maximum temperatures were increased significantly and relative humidity was minimum during the May and June months. Sunshine hours were minimum from October to February months during the winter season and the wind speed was maximum in the months of May and June. Soil data and crop data were collected and used in the application of CROPWAT model to vegetable crops for estimation of reference evapotranspiration, crop water requirement

Table A : Average monthly climatic data of the study area (Bapatla)

Month	Minimum temp. (°C)	Maximum temp. (°C)	Humidity (%)	Wind speed (km/day)	Sunshine (hours)
January	17.8	29.8	80	104	11.3
February	18.6	31.3	76	104	11.6
March	21.8	33.1	79	147	12.0
April	25.9	34.3	78	199	12.5
May	28.0	38.3	68	225	12.8
June	27.0	38.3	57	233	13.0
July	25.3	34.3	71	190	12.9
August	25.4	34.3	72	190	12.6
September	25.1	34.1	78	156	12.2
October	24.0	32.4	81	104	11.8
November	20.9	30.8	81	130	11.4
December	18.6	30.3	79	95	11.2
Average	23.2	33.4	75	156	12.1

and irrigation scheduling for the vegetables.

Evapotranspiration :

The CROPWAT module is primary for data input, requiring information on the meteorological station (country, name, altitude, latitude and longitude) together with climatic data. Evapotranspiration consists of evaporation from soil and transpiration from plant body. The evapotranspiration rate from a reference surface, not short of water, is called reference evapotranspiration (ET_0). CROPWAT 8.0 uses the Penman (1948) and Monteith (1965) method to calculate reference evapotranspiration (ET_o) using only temperature, but humidity, wind speed and sunshine should be entered if available. The mathematical expression of the reference evapotranspiration (ET_0) is follows :

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

where,

ET_0 = Reference evapotranspiration (mm/day)

R_n = Net radiation at the crop surface (MJm^{-2} day^{-1})

G = Soil heat flux density (MJm^{-2} day^{-1})

T = Mean daily air temperature at 2 m height (^0C)

u_2 = Wind speed at 2 m height (m/sec)

e_s = Saturation vapour pressure (k Pa)

e_a = Actual vapour pressure curve (k Pa /^0C)

γ = Psychrometric constant (k Pa /^0C).

Effective rainfall :

Effective rainfall is defined as that a part of the rainfall which is effectively used by the crop after rainfall losses due to surface run off and deep percolation have been accounted for. The effective rainfall is the rainfall ultimately used to determine the crop irrigation requirements.

To account for the losses due to runoff or percolation, a choice can be made of one of the four methods given in CROPWAT 8.0 *i.e.*, Fixed percentage, Dependable rain, Empirical formula and USDA Soil Conservation Service methods. For this study USDA Soil Conservation Service method was chosen for calculating the effective rainfall and estimated by using following formula :

$$P_{eff} = P_{month} \times (125 - 0.2 \times P_{month}) / 125 \text{ for } P_{month} \leq 250 \text{ mm}$$

$$P_{eff} = 125 + 0.1 \text{ x } P_{month} \text{ for } P_{month} > 250 \text{ mm}$$

where,

P_{month} = Monthly rainfall and

P_{eff} = Effective rainfall

Crop water requirement :

Crops require the water mainly to meet the evapotranspirational demand. The potential crop evapotranspiration (PET) *i.e.*, crop water requirement was estimated with the following formula :

$$PET = ET_0 \times K_c$$

where, K_c is the crop co-efficient.

In this study, The CROPWAT 8.0 model was used to estimate the crop water requirement. The crop data required by the CROPWAT model are the crop co-efficient at different growth stages, sowing/ planting dates, duration of different crop growth stages, initial and maximum root depths. The crop co-efficients depend on the changing crop characteristics over the growing season. The growth stages of crops are divided into initial stage, development stage, mid season and late season. The general trend of variation of crop co-efficients during different growth stages of vegetable crops is shown in Fig. A.

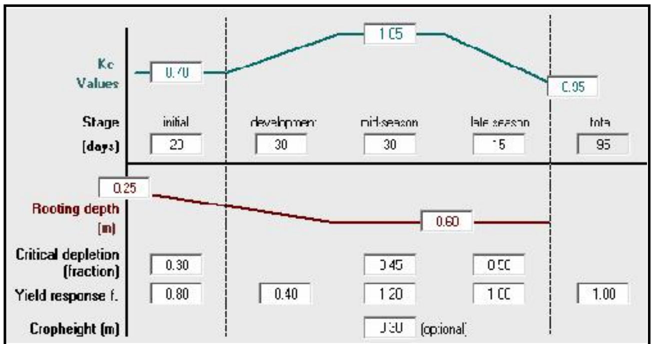

Fig. A : General trend of variation of crop co-efficients during different growth stages of vegetable crops

■ RESULTS AND DISCUSSION

The exprimental findings obtained from the present study have been discussed in following heads:

Reference evapotranspiration :

Estimated monthly reference evapotranspiration (ET_0) for the study area is presented in Table 1. Results of the study shows that the average peak monthly ET_0 was observed to be 8.09 mm/day for the month of June and followed by the 7.55 mm/day for the month of May due to the high temperatures during the months. Whereas, average minimum ET_0 were observed as 3.85 and 3.92 mm/day in the months of December and January, respectively due to winter months (Table 1).

Effective rainfall :

Effective rainfall was estimated as 72.5 per cent of the rainfall *i.e.* 769.2 mm per annum out of the total average annual rainfall 1060.3 mm and the losses estimated as 27.5 per cent of rainfalls in the study area. Table 1 shows that the average monthly rainfall with maximum effective rainfall occurred in October (149.8 mm) followed by September (146 mm), July (118.7 mm) and August (109.5 mm) months. Total rainfall and effective rainfall is depicted in Fig. 1. Khandelwal *et al.*

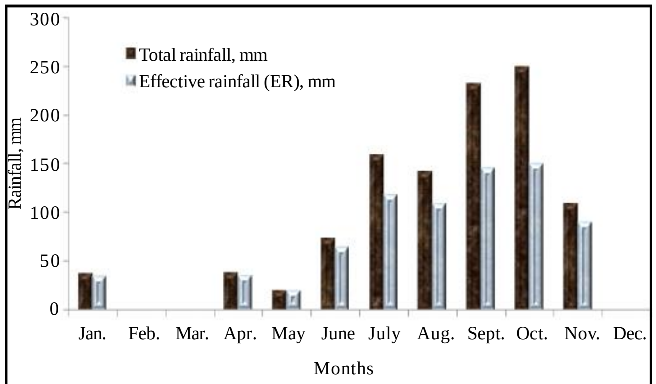

Fig. 1 : Monthly rainfall and effective rainfall of the study area

Table 1 : Estimated monthly effective rainfall along with actual rainfall

Month	Reference evapo-transpiration (ET_0 mm/day)	Rainfall, mm	Effective rainfall (ER), mm	Percentage of ER (%)
January	3.92	37.0	34.8	94.1
February	4.56	0.0	0.0	0.0
March	5.47	0.0	0.0	0.0
April	6.31	38.1	35.8	67.7
May	7.55	20.3	19.6	96.6
June	8.09	73.4	64.8	88.3
July	6.70	159.3	118.7	74.5
August	6.56	141.5	109.5	77.4
September	6.01	232.4	146.0	62.8
October	5.14	248.9	149.8	60.2
November	4.34	109.4	90.3	82.5
December	3.85	0.0	0.0	0.0
Total/Average	5.71	1060.3	769.3	72.5

Table 2 : Crop water requirement for *Rabi* vegetable crops based on the historical weather data of Bapatla (Hear 1 dec is equal to 10 days)

Month	Dec.	Stage	Crop co-efficient Kc	ETc mm/day	ETc mm/dec	Effective rainfall mm/dec	Irr. Req. mm/dec
Feb.	2	Init	0.70	3.19	28.7	0.0	28.7
Feb.	3	Init	0.70	3.40	27.2	0.0	27.2
March	1	Deve	0.73	3.77	37.7	0.0	37.7
March	2	Deve	0.83	4.56	45.6	0.0	45.6
March	3	Deve	0.95	5.45	59.5	0.1	59.8
April	1	Mid	1.02	6.16	61.6	9.6	52.0
April	2	Mid	1.02	6.45	64.5	14.4	50.2
April	3	Mid	1.02	6.88	68.8	11.8	57.0
May	1	Late	1.00	7.16	71.6	6.4	65.2
May	2	Late	0.96	7.23	50.6	2.6	46.9
			Total		516.3	44.8	470.4

(1996) estimated the evapotranspiration of wheat under semi arid environment.

Crop water requirement :

Estimation of the crop water requirement (ETc) was carried out by calling up successively the appropriate climate data, together with soil and crop data files and the corresponding planting dates. The crop water requirement was estimated for vegetable crops at study area as 516.3 mm during *Rabi* season and also estimated the crop water requirements at different growing stages of vegetable crops during *Rabi* season using CROPWAT based on the climate data, rainfall data, crop data, cropping pattern data and soil data and furnished in Table 2 and Fig. 2. Similar work related to the topic was also done Raut and Jadhav (2012).

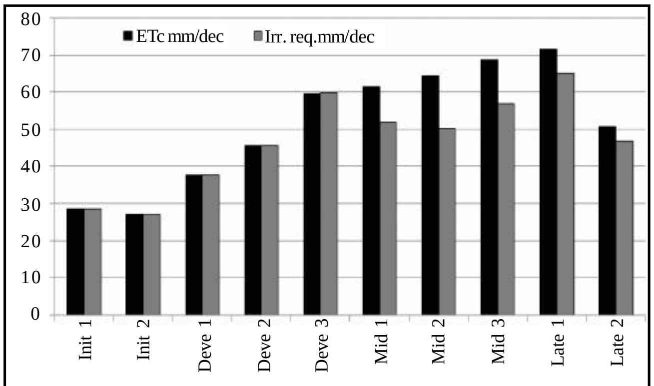

Fig. 2 : Crop water requirement and irrigation water requirement of the okra crop

Conclusion :

From the study it is concluded that reference evapotranspiration, effective rainfall, crop water requirement and irrigation water requirement can be estimated using CROPWAT with the input of climatic data like rainfall, max. and min. temperatures, relative humidity, wind speed and sunshine hours. By application of the CROPWAT to the study area, the average effective rainfall was estimated for the study area as 769.3 mm out of 1060.3 mm annual rainfall. Reference evapotranspiration was estimated during the study period and found that the average peak monthly ET_0 was observed to be 8.09 mm/day for the month of June and followed by the 7.55 mm/day for the month of May. Whereas average minimum ET_0 were observed as 3.85 and 3.92 mm/day in the months of December and January, respectively. The crop water requirement (ETc) and irrigation water requirement were estimated for vegetable crops during *Rabi* season in the study area (Bapatla) as 516.3 mm and 470.4 mm, respectively.

Authors' affiliations:

G. RAVI BABU, Department of Soil and Water Engineering, College of Agricultural Engineering, BAPATLA (A.P.) INDIA

H.V. HEMA KUMAR, Department of Agricultural Structures, College of Agricultural Engineering, BAPATLA (A.P.) INDIA

REFERENCES

Allen, R., Pereira, L.A., Raes, D. and Smith, M. (1998). Crop evapotranspiration, FAO Irrigation and Drainage Paper No. 56. FAO, ROME, ITALY.

Khandelwal, M.K., Gupta, S.K. and Tyagi, N.K. (1996). Mismatch between canal water supply and demand in Ukai-Kakrapar Irrigation Command-35-37. Waterlogging and Soil Salinity in Ukai-Kakrapar Command-Causes and Remedial Measures, Walmi (ANAND) INDIA.

Monteith, J.L. (1965). Evaporation and environment. In: The state and movement of water in living organism. 19th Symp. *Soc. Exp. Biol.*, 205-234.

Penman, H.L. (1948). Natural evaporation from open water, bare soil and grass. Proceedings of the royal society of London. Series A. *Mathemat. & Phy. Sci.*, **193** (1032) : 120-145.

Raut, D.V. and Jadhav, S.B. (2012). Use of computer software for comparison of crop water requirements to actual water applied in canal command area of Jayakwadi project. *Internat. J. Agric. Engg.*, **5**(1) : 37-40.

Shengli, Q., Willardson, L.S., Deng, W., Jum li, X. and Jiang liu, C. (2004). Crop water deficit estimation and irrigation scheduling in Western Jilin province, Northeast China. *Agric. Water Mgmt.*, **71** (1) : 47-60.

Singandhupe, R.B. and Sethi, R.R. (2005). Estimation of reference evapotranspiration and crop co-efficient in wheat under semi-arid environment in India. *Archiv. Agron.& Soil Sci.*, **51**(6) : 619-631.

Smith, M. (1992). CROPWAT, a computer programme for irrigation planning and management. FAO Irrigation and Drainage paper No.46. FAO, ROME, ITALY.

Srinivasa Prasad, A., Uma Mahesh, N.V. and Viswanath, G.K. (2006). Optimal irrigation planning under water scarcity. *J. Irrig. & Drain. Engg.*, **132**(3) : 228-237.

Srinivasulu, A., Satyanarayana, T.V., Ravi Kumar, M. and Sai Sudha, J.L.N. (2003). Crop water requirement in comparison to actual applied in some canal commands of Krishna Western Delta. *J. Agric. Engg.*, **40**(4) : 43-50.

Trajkovic, S. and Kolokovic, S. (2009). Estimating reference evapotanspiration using limited weather data. *J. Irrig. & Drain. Engg.*, **135**(4) : 443-449.

Vedula and Majumdar (1992). Irrigation scheduling by dynamic programming. *J. Irrig. & Drain. Engg., ASCE*, **118**(2) : 220-226.

Zhao, W., Liu, B. and Zhang, Z. (2010). Water requirements of maize in the middle Heihe River basin, China. *Agric. Water Mgmt.*, **97** (2) : 215-223.