

## Estimation of Crop Water Requirement of Maize Crop Using FAO CROPWAT 8.0 Model

M. Roja<sup>1\*</sup>, Ch. Deepthi<sup>2</sup> and M. Devender Reddy<sup>3</sup>

<sup>1</sup>Ph. D Scholar, <sup>2</sup>Assistant Professor, <sup>3</sup>Professor,

Department of Agronomy, M S Swaminathan School of Agriculture  
Centurion University of Technology and Management, Paralakhemundi, Odisha, India

\*Corresponding Author E-mail: [roja@cutm.ac.in](mailto:roja@cutm.ac.in)

Received: 5.05.2020 | Revised: 9.06.2020 | Accepted: 16.06.2020

### ABSTRACT

To use optimum amount of water for crops and reduce irrigation quantity, some form of irrigation scheduling should be used by the farming community. Unscientific and injudicious application of groundwater in this region resulted in depletion of the groundwater table. To achieve effective utilization of the groundwater resources, there is a need to estimate the crop water requirement for different crops at different management levels to accomplish effective irrigation management. Crop water requirements of maize crop in north coastal districts of Andhra Pradesh was calculated using FAO Cropwat 8.0 a computer simulation model. The simulation study was conducted with the objectives of determining irrigation water requirement and irrigation scheduling for some major crops like maize and sugarcane. The Penman - Monteith method was used for evapotranspiration calculation in the model. 80% of critical soil moisture depletion was considered for irrigation. The model predicted the daily, decadal as well as monthly crop water requirement at different growing stages of maize crop. The crop water requirement and irrigation requirement for maize crop 238.6 mm and 212.6 mm. Considering the above findings it was suggested to use the Cropwat 8.0 model to predict the crop water requirements for different crops.

**Keywords:** Cropwat 8.0, Crop water requirement, Maize, Gross irrigation and Net irrigation.

### INTRODUCTION

Water is the most important and critical input for agriculture and the demand for efficient use of irrigation water for crops is intensifying in view of changing climate. Irrigation water supplies are decreasing day by day and

scarcity has been seen in many areas of the world. In India among all the consumers agriculture is the largest end user of water where much effort has to be kept for its efficient use in agriculture (Surendran et al., 2013).

**Cite this article:** Roja, M., Deepthi, C. H., & Devender Reddy, M. (2020). Estimation of Crop Water Requirement of Maize Crop Using FAO CROPWAT 8.0 Model, *Ind. J. Pure App. Biosci.* 8(6), 222-228. doi: <http://dx.doi.org/10.18782/2582-2845.8148>

Increased water demand brought about by rapid population growth has created the necessity to increase food production through the expansion of irrigation and industrial production to meet basic human needs. The primary objective of irrigation is to apply water to maintain crop Evapotranspiration (ET) when precipitation is insufficient. Uneven and erratic distributions of monsoon, soil moisture stress prevailing during summer season are considered as the major limiting factors for lower yields. Precise information is required for crop water requirements, irrigation withdrawal as a function of crop, soil type and weather conditions to achieve effective planning. The rainfall and evapotranspiration ultimately determine water balance, crop water and irrigation requirements of different crops of the region.

Crop water requirement depend on climatic conditions, crop area and type, soil type, growing seasons and crop production frequencies (FAO, 2009 & George et al., 2000). Factors affecting the value of the crop water requirement are the value of Crop Coefficient (Kc) and potential evapotranspiration value (ET<sub>0</sub>). The combination of two separate processes, whereby water is lost on one hand by evaporation from the soil surface and on the other hand by transpiration from a plant, is called evapotranspiration. However, a detailed study by comprising all the data on water requirement and availability is also not available under this study area (North coastal districts of Andhra Pradesh). Demand (crop water requirements) of major crops in North coastal districts of Andhra Pradesh has been sorted with the long term climatic data by using CROPWAT 8.0 model (FAO, 2009). This CROPWAT software program was developed by the Food and Agriculture Organization (FAO) as a tool to assist irrigation engineers and agronomists in performing the usual calculations for water irrigation studies and mainly in the management and design of irrigation schemes (Salam et al., 2019). CROPWAT facilitates the estimation of the crop evapotranspiration, crop water requirements and irrigation schedule with different cropping patterns for irrigation

planning (Kuo et al., 2006; Gowda et al., 2013; Gouranga & Verma, 2005; Martyniak et al., 2006; Dechmi et al., 2003 & Zhiming et al., 2007).

The main functions of CROPWAT are

- a) To calculate: Reference evapotranspiration, crop water requirements and crop irrigation requirements.
- b) To develop: irrigation schedules under various management conditions and scheme water supply.

The FAO Penman-Monteith method is used in the present study as it is recommended as the sole standard method for the computation of the reference evapotranspiration. The FAO Penman Monteith method requires radiation, air temperature, air humidity and wind speed data. The irrigation schedule recommendations for various crops should be location-specific, considering the soil types and agro-ecological conditions (Solomon et al., 2018). CROPWAT 8.0 is a significant practice used by scientists for the assessment of crop evapotranspiration, CWR, and irrigation scheduling.

There is lack of information with respect to North coastal districts of Andhra Pradesh on Crop water requirements for maize grown in this area which are calculated through which there is a scope for scheduling irrigation for these crops. Hence an attempt has been made to calculate the crop water requirements and schedule the irrigation for these crops.

## MATERIALS AND METHODS

### 2.1 Study Location

The study area was north coastal districts of Andhra Pradesh (srikakulam, vizianagaram and visakhapatnam) with an area of 23537 km<sup>2</sup> and population of 9,338,177. This study area lies in the altitude from 17.68 °N to 18.29 °N with an longitude of 83.21 °E - 83.89 °E.

### 2.2 Crop water requirement

The crop water requirement is the amount of water equal to what is lost from a cropped field by the ET and is expressed by the rate of ET in mm/day. Estimation of CWR is derived from crop evapotranspiration (ET<sub>c</sub>) which can be calculated by the following equation.

$$ET_c = K_c \times ET_0$$

Where,  $K_c$  is the crop coefficient. It is the ratio of the crop  $ET_c$  to the  $ET_0$ , and it represents an integration of the effects of four essential qualities that differentiate the crop from reference grass, and it covers albedo (reflectance) of the crop–soil surface, crop height, canopy resistance, and evaporation from the soil. Due to the  $ET$  differences during the growth stages, the  $K_c$  for the crop will vary over the developing period which can be divided into four distinct stages: initial, crop development, mid-season, and late season. The reference evapotranspiration  $ET_0$  is calculated by FAO Penman- Monteith method, using decision support software –CROPWAT 8.0 developed by FAO, based on FAO Irrigation and Drainage Paper 56 (FAO, 2002). The FAO CROPWAT program (FAO, 2009) incorporates procedures for reference crop evapotranspiration and crop water requirements and allow the simulation of crop water use under various climate, crop and soil conditions ([www.fao.org](http://www.fao.org)).

### 2.3 Meteorological data

Meteorological data of ten years was collected from Naira meteorological station located in srikakulam district with having latitude of  $18.38^{\circ}N$ , longitude of  $83.90^{\circ}E$  and altitude of 9m have been presented in table 1. Meteorological parameters used for calculation of  $ET_0$  are latitude, longitude and altitude of the station, maximum and minimum temperature ( $^{\circ}C$ ), maximum and minimum relative humidity (%), wind speed (km/day) and sunshine hours which was collected and the average values have been fed to the model. Rainfall data collected from the same station is also fed to the software which will generate the effective rainfall data.

### 2.4 Crop data

Major crops grown in this region are rice, black gram, green gram, groundnut, sugarcane, sesame, pearl millet, mesta and finger millet. CROPWAT requires the crop data like, crop coefficient,  $K_c$  values (initial, mid and late growth stages), rooting depth, length of plant growth stages, critical depletion and yield response factor which were taken from FAO Irrigation and drainage paper 56. The yield response factor ( $K_y$ ) is the ratio of relative yield reduction to relative evapo-transpiration

deficit that integrates the weather, crop and soil conditions that make crop yield less than its potential yield in the face of deficit evapotranspiration. Sowing and harvesting date were taken according to the guide from agricultural operations over this area. Sowing dates were taken at 15 days interval starting from December 15<sup>th</sup>.

### 2.5 Soil data

Soil type in this area is a red sandy loam. The software needs some general soil data like total available soil moisture, maximum rain infiltration rate, maximum rooting depth, initial soil moisture depletion and initial available soil moisture. These information obtained from FAO manual 56.

### 2.6. Irrigation Schedule

Irrigation scheduling determines the correct measure of water to irrigate and the correct time for irrigation. The CROPWAT model calculates the  $ET_0$ , crop water requirement and irrigation requirements to develop the irrigation schedules under different administration conditions and water supply plans.

## RESULTS AND DISCUSSION

Estimation of the crop water requirement was carried out by using the historical weather data of the Naira, srikakulam district (Table 2). The data which was entered in the CROPWAT software included the details like country (India), climatic station (Naira), type of crop, date of cultivation, and soil type (sandy loam). Automatically software will compute the  $ET_0$ , effective rainfall, and total irrigation requirement for the respective crop once the data is fed to the model. For the application of irrigation, the critical soil moisture depletion was considered at 80%. The model predicted the daily, decadal as well as monthly crop water requirement at different growing stages of maize crop. The crop water requirement for the maize crop 238.6 mm and irrigation requirement was of 212.6 mm respectively. (Table 3 and Fig.1) It has been found that there is no yield reduction (Table 4 ) in maize crop with maximum rainfall efficiency at 80% critical depletion and refilling the soil to field capacity whereas, The detailed results of total gross irrigation, total net irrigation, actual

water use by crop and potential water use by crop is given in the Table 5. Six irrigation schedules have been scheduled for maize crop (Table 6). In the below figures, (TAM) is the total available moisture or the total amount of water available to the crop. The (RAM) is the readily available water or the portion of (TAM) that the plant can get from the root zone without facing water stress. From the results, it was found that the yield reduction will not occur at any growing stage with maximum rainfall efficiency as predicted with

irrigation at 100% critical depletion and by refilling the soil to the field capacity. Rainfall efficiency was 42.8 % with total effective rainfall of 23.8 mm. The total net irrigation varied from the irrigation requirement due to change in effective rainfall efficiency. Higher temperatures lead to increase in evapotranspiration and water requirements more frequent irrigation schedule. Shift in crop sowing and planting dates show a shift in crop production periods return which has impact on crop water requirement.

**Table 1: Details of the crop required as per the CROPWAT model**

| Crop Name | Planting date | Harvesting date | Critical depletion | Rooting depth | Crop growth periods |             |     |      | Total |
|-----------|---------------|-----------------|--------------------|---------------|---------------------|-------------|-----|------|-------|
|           |               |                 |                    |               | Initial             | Development | Mid | Late |       |
| Maize     | 15-11         | 19-03           | 0.55               | 1.2 m         | 20                  | 35          | 40  | 30   | 125   |

**Table 2: Climate characteristics, rainfalls, and ET<sub>0</sub> of Naira area (average for 2000–2019 period) obtained using CROPWAT software**

| Month          | Min Temp<br>°C | Max Temp<br>°C | Humidity<br>% | Wind<br>km/day | Sun<br>hours | Rad<br>MJ/m <sup>2</sup> /day | ET <sub>0</sub><br>mm/day |
|----------------|----------------|----------------|---------------|----------------|--------------|-------------------------------|---------------------------|
| January        | 16.7           | 30.4           | 68            | 2              | 5.1          | 13.4                          | 2.21                      |
| February       | 18.9           | 33.2           | 67            | 3              | 6.4          | 16.6                          | 2.90                      |
| March          | 23.4           | 34.8           | 70            | 4              | 5.0          | 16.2                          | 3.22                      |
| April          | 26.3           | 36.9           | 69            | 6              | 5.9          | 18.5                          | 3.98                      |
| May            | 27.5           | 36.8           | 70            | 6              | 3.4          | 14.9                          | 3.42                      |
| June           | 27.5           | 35.8           | 75            | 4              | 1.5          | 12.0                          | 2.89                      |
| July           | 26.2           | 32.8           | 78            | 3              | 1.7          | 12.3                          | 2.82                      |
| August         | 26.4           | 32.7           | 79            | 3              | 2.9          | 13.9                          | 3.08                      |
| September      | 26.2           | 32.6           | 83            | 2              | 3.2          | 13.7                          | 3.03                      |
| October        | 24.6           | 32.5           | 79            | 2              | 5.3          | 15.4                          | 3.21                      |
| November       | 20.7           | 31.3           | 74            | 2              | 5.8          | 14.5                          | 2.73                      |
| December       | 17.6           | 30.0           | 70            | 2              | 3.4          | 10.8                          | 1.95                      |
| <b>Average</b> | <b>23.5</b>    | <b>33.3</b>    | <b>74</b>     | <b>3</b>       | <b>4.1</b>   | <b>14.4</b>                   | <b>2.96</b>               |

**Table 3: Daily and Decadal Crop Water Requirement of maize in the study area**

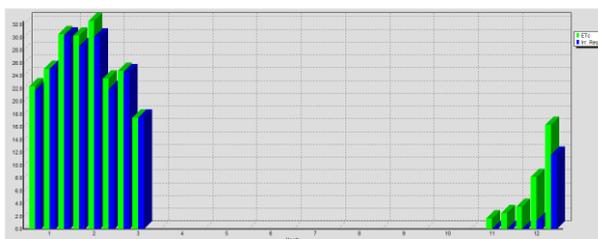
| Month | Decade | Stage | Kc<br>coeff | ETc<br>mm/day | ETc<br>mm/dec | Eff rain<br>mm/dec | Irr. Req<br>mm/dec |
|-------|--------|-------|-------------|---------------|---------------|--------------------|--------------------|
| Nov   | 2      | Init  | 0.10        | 0.27          | 1.6           | 10.9               | 0.0                |
| Nov   | 3      | Init  | 0.10        | 0.25          | 2.5           | 14.6               | 0.0                |
| Dec   | 1      | Deve  | 0.16        | 0.35          | 3.5           | 11.0               | 0.0                |
| Dec   | 2      | Deve  | 0.44        | 0.82          | 8.2           | 6.9                | 1.3                |
| Dec   | 3      | Deve  | 0.75        | 1.48          | 16.3          | 4.7                | 11.6               |
| Jan   | 1      | Mid   | 1.05        | 2.24          | 22.4          | 0.6                | 21.7               |
| Jan   | 2      | Mid   | 1.14        | 2.51          | 25.1          | 0.0                | 25.1               |
| Jan   | 3      | Mid   | 1.14        | 2.77          | 30.5          | 0.2                | 30.3               |
| Feb   | 1      | Mid   | 1.14        | 3.03          | 30.3          | 1.7                | 28.6               |
| Feb   | 2      | Late  | 1.12        | 3.25          | 32.5          | 2.4                | 30.1               |
| Feb   | 3      | Late  | 0.98        | 2.95          | 23.6          | 1.7                | 21.9               |
| Mar   | 1      | Late  | 0.80        | 2.48          | 24.8          | 0.3                | 24.5               |
| Mar   | 2      | Late  | 0.60        | 1.93          | 17.4          | 0.0                | 17.4               |
|       |        |       |             |               | <b>238.6</b>  | <b>55.0</b>        | <b>212.6</b>       |

**Table 4: Yield reduction at 80 % of critical depletion - maize**

| Stage label                | A    | B    | C    | D    | Season % |
|----------------------------|------|------|------|------|----------|
| Reduction in ETc           | 0.0  | 0.0  | 0.0  | 0.0  | 0.0      |
| Yield response factor      | 0.40 | 0.40 | 1.30 | 0.50 | 1.25     |
| Yield reduction            | 0.0  | 0.0  | 0.0  | 0.0  |          |
| Cumulative yield reduction | 0.0  | 0.0  | 0.0  | 0.0  |          |

**Table 5: Total gross net irrigation and rain efficiency -Maize**

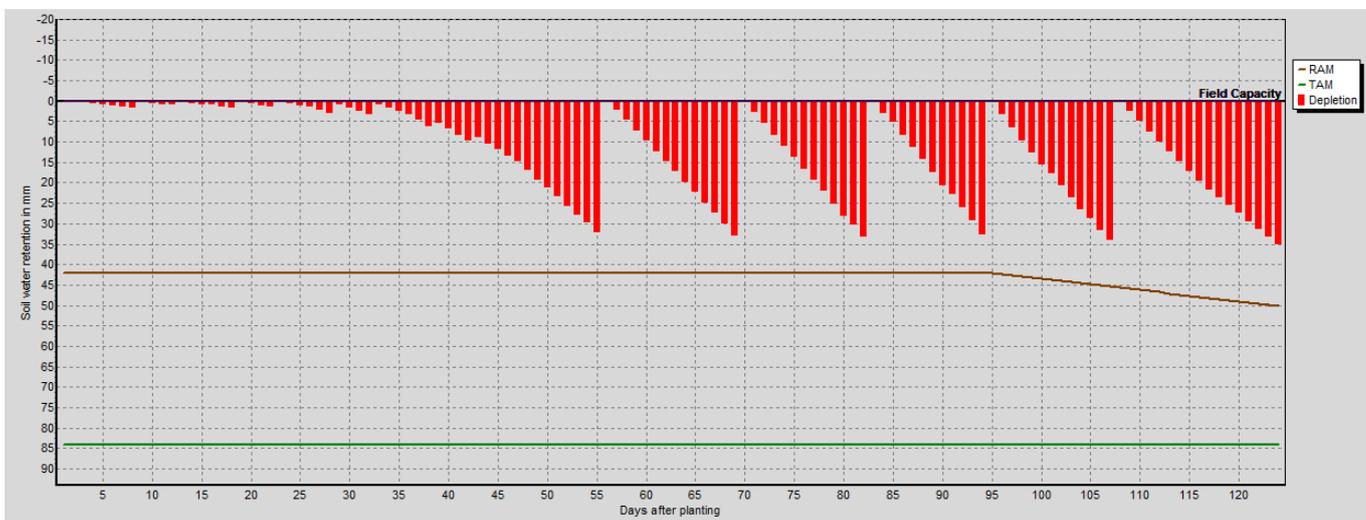
|                                 |          |                               |          |
|---------------------------------|----------|-------------------------------|----------|
| Total gross irrigation          | 313.9 mm | Total rainfall                | 55.5 mm  |
| Total net irrigation            | 219.8 mm | Effective rainfall            | 23.8 mm  |
| Total irrigation losses         | 0.0 mm   | Total rain loss               | 31.7 mm  |
| Actual water use by the crop    | 236.7 mm | Moist deficit at harvest      | 35.2 mm  |
| Potential water use by the crop | 236.7mm  | Actual irrigation requirement | 212.9 mm |
| Efficiency irrigation schedule  | 100.0%   | Efficiency rain               | 42.8 mm  |



**Fig. 1: Crop water requirement of the maize crop**

**Table 6: Irrigation schedules for maize crop during the study period as per the CROPWAT model**

| Date   | Day | Stage | Rain mm | Ks fraction | Eta % | Depletion % | Net Irrigation | Deficit mm | Loss mm | Gross Irrigation mm |
|--------|-----|-------|---------|-------------|-------|-------------|----------------|------------|---------|---------------------|
| 15 Nov | 1   | Init  | 0.0     | 1.00        | 100   | 50          | 42.3           | 0.0        | 0.0     | 60.4                |
| 9 Jan  | 56  | Mid   | 0.0     | 1.00        | 100   | 41          | 34.3           | 0.0        | 0.0     | 49.0                |
| 23 Jan | 70  | Mid   | 0.1     | 1.00        | 100   | 42          | 35.6           | 0.0        | 0.0     | 50.8                |
| 5 Feb  | 83  | Mid   | 0.0     | 1.00        | 100   | 43          | 36.4           | 0.0        | 0.0     | 52.0                |
| 17 Feb | 95  | Mid   | 1.2     | 1.00        | 100   | 41          | 34.6           | 0.0        | 0.0     | 49.5                |
| 2 Mar  | 100 | End   | 0.0     | 1.00        | 100   | 44          | 36.6           | 0.0        | 0.0     | 52.3                |
| 19 Mar | End | End   | 0.0     | 1.00        | 0     | 42          |                |            |         |                     |



**Fig. 2: Irrigation scheduling graph for maize graph**

**CONCLUSION**

An attempt has been made to compute the crop water requirements of maize in North coastal districts of Andhra Pradesh using CROPWAT 8.0 model of FAO. Proper and optimal scheduling of irrigation using CROPWAT 8.0 enabled the efficient water use. The Penman - Monteith method was used for evapotranspiration calculation in the model. 80% of critical soil moisture depletion was considered for irrigation. The model predicted the daily, decadal as well as monthly crop water requirement at different growing stages of maize crop. The crop water requirement and irrigation requirement for maize crop 238.6 mm and 212.6 mm. From the results it is clear that efficient water management becomes crucial and critical in normal or deficit rainfall years. In view of the above findings it was recommended to use the Cropwat 8.0 model to predict the crop water requirements for different crops with high degree of accuracy and can suggest the crop pattern and crop rotation to farmers.

**REFERENCES**

- Dechmi, F., Playa, E., Faci, J. M., Tejero, M., & Bercero, A. (2003). Analysis of an irrigation district in north-eastern Spain II. Irrigation evaluation, simulation and scheduling. *Agricultural Water Management* 61, 93–109.
- FAO, (2002). Crop Evapotranspiration Guidelines for Computing crop water requirement. *Irrigation and Drainage Paper No. 56*.
- FAO, (Food and Agriculture Organization). (2009). CROPWAT Software, Food and Agriculture Organization, Land and Water Division; Available at: [http://www.fao.org/nr/water/infores\\_databases\\_cropwat.html](http://www.fao.org/nr/water/infores_databases_cropwat.html).
- George, B., Shende, S., & Raghuwanshi, N. (2000). Development and testing of an irrigation scheduling model. - *Agricultural Water Management*, 46(2), 121–136.
- Kar, G., & Verma, H. N. (2005). Climatic water balance, probable rainfall, rice crop water requirements and cold period in AER 12.0 in India. *Agricultural Water Management* 72, 15–32.
- Gowda, T. P., Manjunaththa, S. B., Yogesh, T. C., & Satyareddim, S. A. (2013). Study on Water Requirement of Maize (*Zea mays* L.) using CROPWAT Model in Northern Transitional Zone of Karnataka. *Journal of Environmental Science, Computer Science and Engineering & Technology*, 2(1), 105-113.
- Kore, J. R., Nimbalkar, P. T., & Hirave, P. (2017). Crop water requirement and irrigation scheduling of some selected crops using cropwat 8.0: a case study of khadakwasla dam irrigation project, *International Journal of Civil Engineering and Technology* 8(5), 342-349.
- Kuo, S., Ho, S., & Liu, C. (2006). Estimation irrigation water requirements with derived crop coefficients for upland and paddy crops in Chia Nan Irrigation Association, Taiwan. *Agricultural Water Management* 82, 433–451.
- Martyniak, L., Dabrowska-Zielinska, K., & Szymczyk, R. (2006). Validation of satellite-derived soil-vegetation indices for prognosis of spring cereals yield reduction under drought conditions—Case study from central-western Poland. *Advances in Space Research*, 8, 1–6.
- Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019). *Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq Water*, 11, 756.
- Bhat, S. A., Pandit, B. A., Khan, J. N., Kumar, R., & Jan, R. (2017). Water Requirements and Irrigation Scheduling of Maize Crop using CROPWAT Model *International*

- Journal of Current Microbiology and Applied Science* 6(11), 1-9.
- Abirdew, S., Mamo, G., & Mengesha, M. (2018). Determination of Crop Water Requirements for Maize in Abshege Woreda, Gurage Zone, Ethiopia *Journal of Earth Science & Climatic Change* 9(1), 1000439.
- Surendran, U., Sushanth, C. M., Mammen, G., & Joseph, E. J. (2015). Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India. *ICWRCOE*: 1211-1219.
- Zhiming, F., Dengwei, L., & Yuehong, Z. (2007). Water Requirements and Irrigation Scheduling of Spring Maize Using GIS and CROPWAT model in Beijing-Tianjin-Hebei Region. *Chinese Geographical Science* 17(1), 56-63.