Estimation of Crop Water Requirement using CROPWAT Model for Maize, A Case Study of Raya Azebo District, Ethiopia

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Abstract

Water is the major limiting factor for crop production. A lot of water resources have been exploited for irrigation purpose. Irrigation systems essential to enhance crop productivity in order to meet future food demand and ensure food security. Unscientific and injudicious application of groundwater in this district 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 Raya Azebo districts was calculated using FAO Cropwat 8.0 a computer simulation model. The simulation study was conducted with the objectives of determining irrigation water requirement maize. The study was carried out to estimate the crop water requirement of maize by using the climatic data, crop evapotranspiration (ETc) and reference crop evapotranspiration (ETo) for each crop were determined using CROPWAT 8.0. The study shows that crop water requirement of maize with a growing period of 125 days to maturity requires 504.0 mm depth of water on off season and 457.8 mm on main season respectively. The result shows that in off season the crop water requirement of maize was needed more water than the main season, due to the climatic condition and in the main season the effective rainfall is more available than the off season. This study proved that the CROPWAT model is useful for calculating the crop irrigation needs for the proper management of water resources.

Keywords: CROPWAT, Model, Crop water requirement, Maize, Eto

DOI: 10.7176/JRDM/74-03

Publication date: March 31st 2021

1. INTRODUCTION

Maize (Zea mays L.) is one of the grain crops of the grass family (F. Rhoads and C. Yonts, 2000) and the world's most important crops besides rice and wheat (J. Zhao and X. Yang, 2017).

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).

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 (ETo). 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.

Models that simulate the effect of water stress on yield can be valuable tools in irrigation management. However, testing of a model is necessary for its use in a new area while planning water requirement of a crop.

CROPWAT facilitate the estimation of crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning and management. Penman-Monteith method (Allen et al. 1998) has been reported to yield consistently more accurate reference evapotranspiration (ETo) estimates across a wide range of climate condition (Jensen et al. 1990; Kashyap and Panda 2001; Irmak et al. 2003).

Different crops have different water use requirements under the same weather condition. Estimation of crop water requirements (ETc) is one of the main components used in irrigation planning, design and operation (Rowshon et al., 2013). (Jensen et al. 1990), provided detailed reviews of the methods commonly used to determine evapotranspiration and estimated crop water requirements.

One way to determine the crop water requirement is by utilizing software Cropwat 8.0 compiled by FAO (Allen et al. 1998).

2. MATERIALS AND METHODS

2.1 Study Location

Tigray is located in the northern part of Ethiopia with an altitude ranging between 400 to almost 4,000 m above mean sea level. It is located between 12° 15' N and 14° 57' N, and 36° 27' E and 39° 59' E. It covers an area of about 53,000 km² (CSA, 2015). The study was conducted in Raya Azebo district, Southern Zone of Tigray,

Ethiopia. Administratively, Raya Azebo is subdivided into 18 kebeles at an altitude ranging from 930 to 2,300 m above mean sea level (Tesfay et al., 2014).

The climate is predominantly semi-arid with irregular rainfall accompanied by frequent drought periods. Average annual rainfall ranges from 800 to 1,000 mm per year reducing to 400 mm (Edwards et al., 2006).

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 (ETc) which can be calculated by the following equation.

ETc = Kc X ETo

Where, Kc is the crop coefficient. It is the ratio of the crop ETc to the ETo, 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 Kc 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 ETo 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).

2.3. Soil data

The soil type in this area is a loam and clay. 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. This information obtained from FAO manual 56.

3. RESULT AND DISCUSSION

3.1. Maize crop

Estimation of the crop water requirement was carried out by using the historical weather data of the observatory data of the study area (Table 2). The data which was entered in the CROPWAT software included the details type of crop, date of cultivation, harvest and soil type.

Automatically software will compute the ETo, effective rainfall, and total irrigation requirement for the respective crop once the data is fed to the model.

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

Crop Name	Season	Planting date	Harvesting date	Critical depletion	Rooting Depth	Crop growth periods				
						IS	DS	MS	LS	Total
Maize	Off season	15-01	20-05	0.55	1.0m	20	35	40	30	125
Maize	Main Season	15-06	20-10	0.55	1.0m	20	35	40	30	125

3.2. Reference evapotranspiration (ETo)

The following table (2) gives the Reference Evapotranspiration (ETo) for all the months in a year, in which the highest reference evapotranspiration is found in the month June (4.7 mm/ day) and the lowest Reference evapotranspiration is found in the month January (3.3 mm/ day) and November (3.77 mm/ day) due to differential changes occurs in the weather conditions like temperature, sunshine hours, humidity and wind speed.

In dry season, the resulting low relative humidity combined with high temperatures led to increased evapotranspiration over this period of a year. Inversely the low values of ETo in rainy season may be due to the high frequencies of rainfall combined with high relative humidity and relative low temperatures. As the trend of ETo affecting by climatic factors such as temperatures, solar radiation, and rainfall as well as wind, relative humidity of the air consequently ETo is a climatic parameter. With the variations of these parameters ETo were vary greatly within and between seasons. The results are in accordance with Adeniran et al. (Adeniran et al., 2010), which showed that ETo was lowest during the peak of the rainy season to highest during the peak of the dry season.

Table 2. Long term monthly average climatic data of the study district

Month	T_{min} °C	T_{max} °C	RH %	Wind km/hr	Sun hours	Rad MJ/m²/day	ETo mm/day
January	11.5	27.2	73	69	7.9	18.4	3.33
February	12.8	27.1	70	86	9.4	22.0	4.02
March	13.5	29.5	68	86	8.7	22.4	4.44
April	13.8	29.7	67	95	8.7	22.9	4.65
May	15.3	32.5	58	52	9.1	23.3	4.69
June	15.8	35.0	60	43	8.6	22.2	4.70
July	15.6	31.5	90	52	6.5	19.1	4.04
August	15.0	29.7	95	43	6.5	19.3	3.89
September	14.3	30.8	74	52	6.6	19.2	3.96
October	13.1	29.8	69	86	9.2	22.0	4.36
November	12.1	28.6	67	69	9.0	20.1	3.77
December	11.3	27.1	69	69	8.8	19.0	3.40

3.3. Crop Water Requirement, Effective rainfall and Irrigation Requirement

Knowledge of crop irrigation water requirements and irrigation time schedules improves irrigation management in the field. Irrigation water management is about controlling the amount, timing, and rate of irrigation in an efficient and planned manner.

From the below results (Table 2 and 3), It shows that for maize in off season and main season, it requires 504.0 and 457.8mm crop water requirement, 36.2 and 122.1mm effective rain fall and 468.3 and 335.7mm irrigation requirement respectively. It shows that in off season the crop water requirement of maize was needed more water than the main season, due to the climatic condition and in the main season the effective rainfall is more available than the off season.

Table 3. Crop Water Requirement, Effective rainfall and Irrigation Requirement for Maize on Off Season

Month	Decade	Stages	Kc Coef	ETc (mm/day)	ETc (mm/dec)	Eff rain (mm/dec)	Irr. Req (mm/dec)
Jan	2	Init	0.40	1.34	8.0	0.0	8.0
Jan	3	Init	0.40	1.43	15.7	0.0	15.7
Feb	1	Deve	0.46	1.76	17.6	0.0	17.6
Feb	2	Deve	0.68	2.75	27.5	4.6	22.9
Feb	3	Deve	0.89	3.70	29.6	8.4	21.2
Mar	1	Deve	1.09	4.70	47.0	0.0	47.0
Mar	2	Mid	1.19	5.30	53.0	7.8	45.2
Mar	3	Mid	1.19	5.39	59.2	0.0	59.2
Apr	1	Mid	1.19	5.47	54.7	10.2	44.5
Apr	2	End	1.19	5.55	55.5	0.0	55.5
Apr	3	End	1.12	5.21	52.1	5.7	47.4
May	1	End	1	4.67	46.7	0.0	46.7
May	2	End	0.88	4.15	37.4	0.0	37.4
Total					504.0	36.7	468.3

Table 4. Crop Water Requirement, Effective rainfall and Irrigation Requirement for Maize on Main Season

Month	Decade	Stages	Kc Coef	ETc (mm/day)	ETc (mm/dec)	Eff rain (mm/dec)	Irr. Req (mm/dec)
Jun	2	Init	0.40	1.88	11.3	0.0	16.9
Jun	3	Init	0.40	1.79	17.9	0.0	26.9
July	1	Deve	0.45	1.90	19.0	10.9	14.7
Jul	2	Deve	0.65	2.64	26.4	16.8	11.4
Jul	3	Deve	0.88	3.53	38.8	11.7	26
Aug	1	Mid	1.11	4.36	43.6	10.0	30.1
Aug	2	Mid	1.17	4.55	45.5	12.8	31
Aug	3	Mid	1.17	4.58	50.3	15.1	33.6
Sep	1	Mid	1.17	4.60	46.0	14.6	29.9
Sep	2	Mid	1.16	4.61	46.1	0.0	44.8
Sep	3	End	1.08	4.41	44.1	5.7	40.2
Oct	1	End	0.97	4.15	41.5	12.6	29.9
Oct	2	End	0.87	3.90	27.3	11.9	14.6
Total					**457.8**	**122.1**	**335.7**

4. CONCLUSION

The study results enhance our understanding of the water requirements of maize in the study district, which will consequently help improve the management of water resources and the productivity through policies based on these findings. The use of scientific tools like CROPWAT can assess the CWRs with a high degree of accuracy and suggest the crop pattern and crop rotation that farmers can readily accept.

These results can be used for a most efficient water use and to optimize production of the maize in the study district. The results of this study can be used by water resource planners for future planning, thereby helping to save water in meeting the CWRs, and can be used as a guide for farmers to select the amount of irrigation for the crops being studied.

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