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Estimation of Irrigation scheduling for Tomato using CROPWAT 8.0 model: The case of Assosa, North-West Ethiopia.

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Abstract

Irrigation scheduling is answering when and how much water to apply. Application of simulation model as a tool for decision regarding to irrigation scheduling in which CROPWAT 8.0 was used in this case. The aim was to estimate crop water requirement of Tomato, irrigation requirement and time of irrigation or irrigation interval using CROPWAT8.0 model. Inputs for the model like, soil, climate, crop and rain fall data were collected. The highest reference evapotranspiration was 3.77mm/day which was at March and the lowest was 3.01mm/day obtained at December. The lowest daily crop water requirement was 2.11mm obtained at the second decade of December and the highest was 4.18mm obtained at the second decade of March. The water requirement of Tomato and irrigation requirement were 433.2mm and 416.9mm respectively throughout the growing seasons. The average irrigation interval was 12days which means for the total growth period of tomato and it can be use the same agro-ecology. As much as possible, it is better to use the irrigation interval depending on the growth stage of the crop in which soil moisture stress could not be a limiting factor to obtain maximum yield with considering input-outputs. Generally, estimation of irrigation scheduling using CROPWAT 8.0 model is important to generate information quickly for users.

Keywords: Assosa, CROPWAT, Estimation, Irrigation scheduling, Tomato

1. Introduction

Irrigation scheduling is the practice of using some method to decide when to start an irrigation system and how much water to apply. No matter what method is used, they all start with knowing when and how much rain has been received on the field and then using some mechanism to decide when to irrigate (Thomas *et al*., 1999).

The role of simulation models in understanding the processes in the soil-plant-atmosphere system has increased significantly in recent years (Ines *et al*., 2001). Several alternative schedules generated and evaluated according to impacts on yields and on percolation of excess applied water referring to each soil type and to conditions of very low, average, high and very high demand (Cancela *et al*., 2006). Crop water requirements vary in time and space due to climate, management, phonological stage of the crop, and cultivar, then, their assessment must be local (Doorenbos and Pruitt, 1977). Application of computer-based simulation models as tools for providing support for decision-making in agricultural research has increased tremendously in the last three decades (Igbadun, 2012). The aim was to estimate crop water requirement of Tomato, irrigation requirement and time of irrigation or irrigation interval using CROPWAT8.0 model.

2. Materials and Methods

2.1. Description of the study area

The study was focused in Assosa, Benishangul gumuz Regional state, found in the Upper Blue Nile (Abay) River Basin, Ethiopia. Assosa is found at a distance of about 665 km to the North West of Addis Ababa. It is located at 9^{0}40’0’’ N -10^{0}23’20’’ N latitude and 34^{0}8’20’’ E-34^{0}51’40’’ E longitude at about 1560 meters above sea level (m.a.s.l).

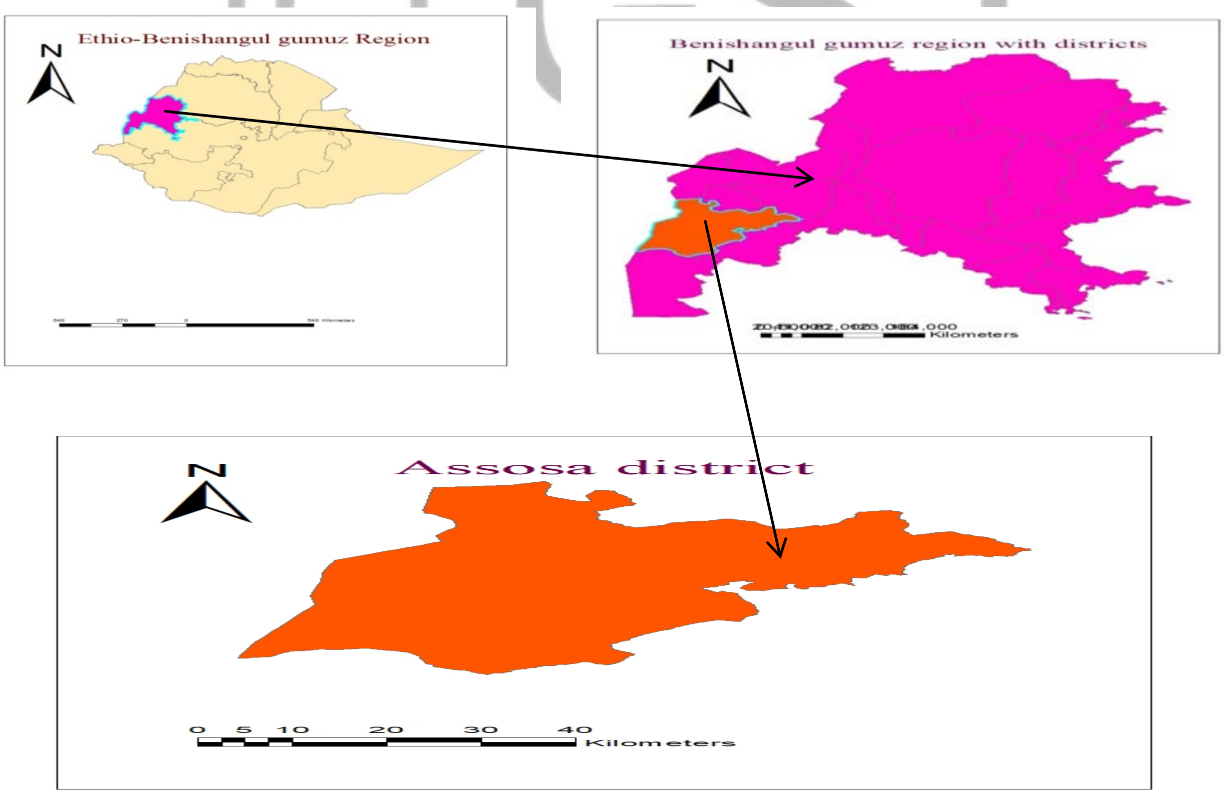

Figure 1: Location map of the study area

The agro-climatic zone of the area is hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall in June, July, August and September. The mean annual minimum and maximum temperatures of the area for the same years were 14.63 and 28.61^{O}C respectively (Moges, 2019).

2.2. CROPWAT 8.0 model description

CROPWAT 8.0 is a decision-support computer program based on a number of equations, Developed by the Food and Agricultural Organization (FAO) to calculate reference evapotranspiration (ETo), crop water requirement (CWR), irrigation scheduling, and irrigation water requirement (IR), using rainfall, soil, crop, and climate data (FAO,2009). The program includes general data for various crop features, local climate, and soil properties and helps improve irrigation schedules and the computation of scheme water supply for different crop patterns under irrigated and rain fed conditions.

The main purpose of CROPWAT is to calculate crop water requirements and irrigation schedules based on data provided by the user. These data can be directly entered into CROPWAT or imported from other applications (FAO, 2009). For the calculation of crop water requirements (CWR), CROPWAT needs data on evapotranspiration (ETo). CROPWAT allows the user to either enter measured ETo values, or to input data on temperature, humidity, wind speed and sunshine, which allows CROPWAT to calculate ETo using the Penman-Monteith formula.

CROPWAT normally calculates CWR and schedules for one crop, it can also calculate a scheme supply, which is basically the combined crop water requirements of multiple crops, each with its individual planting date a so-called cropping pattern (FAO, 2009).

2.3. Data collection and Analysis

Input Data collection for the model

Soil characteristics: soil data was used to calculate irrigation scheduling. The data like, Texture, Field capacity (FC), Permanent wilting point (PWP), Bulk Density, water holding capacity and etc. were important.

Climate data: Daily weather variables [Rainfall, air temperature (Maximum and Minimum), Wind speed, Relative humidity (RH), Wind speed at two meter height (U_2) and sunshine hours].

Crop data: crop data were needed for the CWR calculations. Those were, sowing date, harvesting time, Growing day, Growth stages, rooting depth, yield response factor and crop height which is optional.

Rainfall data

Rainfall data were used by CROPWAT to compute effective rainfall data as input for the CWR and scheduling calculations. The data required for CROPWAT 8.0 was monthly rainfall, commonly available from climatic stations. Rainfall records of 35 years were collected. The amount of rainfall which was depended upon in 1 out of 4 or 5 years corresponding to a 75 or 80% probability of exceedance and representing a dry year.

Effective rainfall

Rainfall that effectively used by the crop after rainfall losses due to surface run off and deep percolation had been accounted. For the determination of effective rainfall, a fixed percentage method was used.

Determination of reference evapotranspiration

Evapotranspiration was computed using CROPWAT 8.0 model as a measure of evaporative demand of the atmosphere. Reference evapotranspiration (ETo) was estimated with the FAO Penman-Monteith equation (Allen *et al*., 1998) using the ETo calculator program, included in the CROPWAT 8.0 software (FAO, 2015).Monthly meteorological recordings data were collected including the geographical location of the study area.

Monthly reference evapotranspiration values (ETo) were then computed using a CROPWAT 8.0 for windows (FAO, 2006). The monthly long-term ETo data obtained from CROPWAT 8.0 model was then fitted to different standard frequency distributions models using a computer based routine package. The distribution that best fits the data was selected by applying the chi-square statistical test of good-ness of fit and it was used to work out monthly ETo value occurrence at 80% probability level. ETo was calculated as equation (1) from CROPWAT8.0 model.

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma(900T + 273)u2(es - ea)}{\Delta + \gamma(1 + 0.34u2)\ (3.5)}$$

(1)

Where:

ETo: reference evapotranspiration (mm/day)

Rn: net radiation at the crop surface ($MJ/m^2/day$)

G: soil heat flux density ($MJ/m^2/day$)

T: mean daily air temperature at 2 m height (^oC)

es: saturation vapor pressure (kPa)

ea: actual vapor pressure (kPa)

es - ea: saturation vapor pressure deficit (kPa)

Δ: slope vapor pressure curve ($kPa/^oC$)

γ: psychrometric constant ($kPa/^oC$)

Crop coefficient (Kc)

Crop coefficient (Kc) is defined as the ratio of the actual evapotranspiration of a disease free crop grown in a large field adequately supplied with water to the reference evapotranspiration. It is usually expressed as:

$$Kc = \frac{ETc}{ETo} \quad (2)$$

Where: - ETc: crop evapotranspiration, ETo: reference evapotranspiration

The Kc-value was obtained from the literature. The value varies with crop, development stage of the crop, and to some extent with wind speed and relative humidity. For most crops, the Kc-value increases from a low value at times of crop emergence to a maximum value during a period when the crop reaches full development (for most crops at flower initiation), and declines as the crop matures.

Kc represents an integration of the effects of four primary characteristics that distinguish the crop under analysis from the reference crop. These characteristics are: crop height, albedo (reflectance) of the crop-soil surface, canopy resistance and evaporation from soil, especially exposed soil (FAO, 2009).

Determination of crop water requirement and irrigation requirement

CROPWAT 8.0 was computed crop water requirement by feeding the computed monthly ETo values together with the necessary crop and soil data. In calculating the irrigation requirement, monthly rainfall data was important. In addition, the monthly rainfall data calculated and ETo values, the crop type and cropping calendar together with the required soil characteristics fed to compute irrigation requirement of the crops selected.

$ETc = Kc * ETo$

(3)

Defined in equation (2)

2.3.5. Irrigation scheduling

Irrigation scheduling was worked out using CROPWAT 8.0 windows by selecting two scheduling criteria – fixing the interval and adjusting the depth to a constant value for no yield reduction and minimum water loss; and the 100% readily available soil moisture depletion.

3. Results and Discussion

3.1. Reference evapotranspiration and effective rainfall

The highest reference evapotranspiration (ETo) was 3.77mm/day which was at March and the lowest was 3.01mm/day obtained at December (Chart 1). The ETo and crop water requirement are directly related which means as ETo increases, the water requirement of crop also increases and the reverse also true. The maximum effective rainfall was 33.5mm and the minimum was 0.2mm which were recorded at the month of April and January respectively.

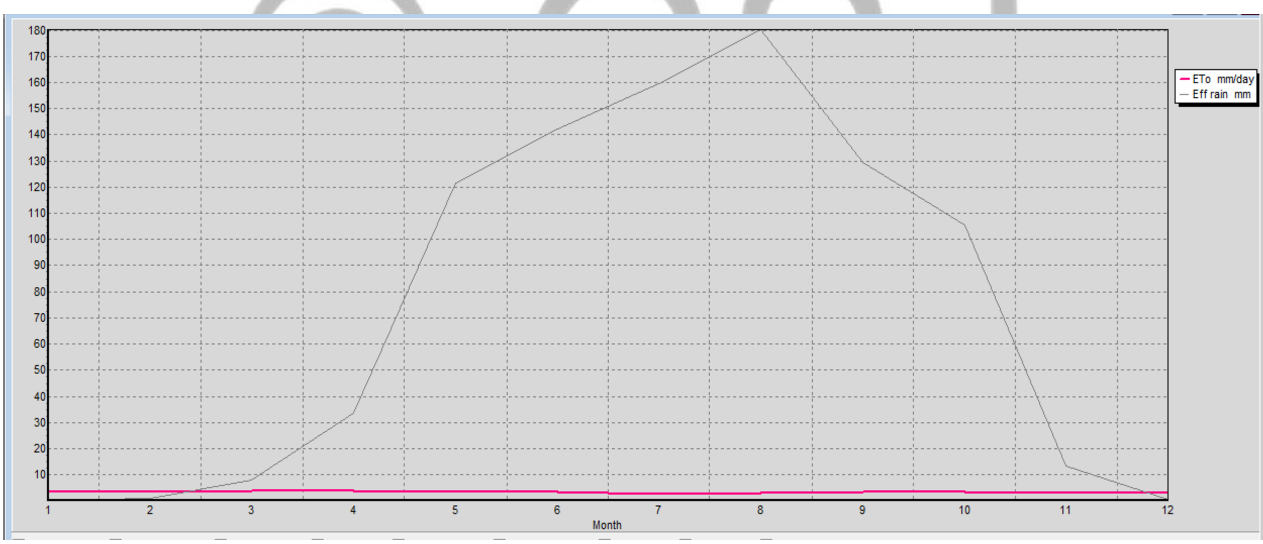

Chart 1: Reference evapotranspiration and effective rainfall

3.2. Crop water and irrigation requirements

As effective rainfall increase, the amount of water applied for irrigation will be decreased. Since the requirement amount of water by the crop is supported by moisture that is available in the soil due to effective rainfall, efficient use of water will be adapted which mean that saving of irrigation water that is applied to the soil. For the determination of water requirement, crop coefficient (Kc) was used. The Kc values for the stages were taken from FAO Irrigation and

Drainage paper-33 and considering into the study area case by creating slope graph in the Microsoft excel so that the values were changed. As shown (Table 1), the lowest daily crop water requirement was 2.11mm obtained at the second decade of December and the highest was 4.18mm obtained at the second decade of March. The water requirement of Tomato and irrigation requirement were 433.2mm and 416.9mm respectively throughout the growing seasons (Table 1).

Table 1: Kc, Crop water requirement and irrigation requirement of Tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.70	2.15	21.5	0.5	21.1
Dec	2	Init	0.70	2.11	21.1	0.0	21.1
Dec	3	Deve	0.71	2.21	24.3	0.0	24.3
Jan	1	Deve	0.81	2.61	26.1	0.1	26.0
Jan	2	Deve	0.93	3.08	30.8	0.1	30.7
Jan	3	Deve	1.05	3.52	38.7	0.1	38.6
Feb	1	Mid	1.12	3.79	37.9	0.1	37.8
Feb	2	Mid	1.12	3.83	38.3	0.1	38.2
Feb	3	Mid	1.12	3.96	31.7	0.9	30.8
Mar	1	Mid	1.12	4.09	40.9	1.3	39.6
Mar	2	Late	1.11	4.18	41.8	1.8	40.0
Mar	3	Late	1.06	4.06	44.6	4.9	39.7
Apr	1	Late	1.01	3.93	35.4	5.7	29.0
					433.2	**15.6**	**416.9**

3.3. Irrigation scheduling

The irrigation interval was varying depending on the growth stage of tomato. According to the growth stage, the interval of irrigation for initial, developmental, mid-season and late season stages were 10days, 12days, 13days and 14days respectively (Table 2). As shown in (Table 2), the total net irrigation and total gross irrigation requirements were 458.4mm and 764.0mm respectively. The average irrigation interval was 12days which means for the total growth period of tomato and it can be use the same agro-ecology. As much as possible, it is better to use the irrigation interval depending on the growth stage of the crop in which soil moisture stress could not be a limiting factor to obtain maximum yield with considering input-outputs.

Table 2: Irrigation scheduling of Tomato

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
1 Dec	1	Init	0.0	0.55	55	66	37.7	0.0	0.0	62.8	7.27
10 Dec	10	Init	0.0	1.00	100	37	24.7	0.0	0.0	41.2	0.53
20 Dec	20	Init	0.0	1.00	100	36	27.7	0.0	0.0	46.1	0.53
31 Dec	31	Dev	0.0	1.00	100	36	31.6	0.0	0.0	52.6	0.55
12 Jan	43	Dev	0.0	1.00	100	40	40.1	0.0	0.0	66.8	0.64
24 Jan	55	Dev	0.0	1.00	100	42	46.5	0.0	0.0	77.5	0.75
5 Feb	67	Mid	0.0	1.00	100	40	48.1	0.0	0.0	80.2	0.77
18 Feb	80	Mid	0.0	1.00	100	41	49.5	0.0	0.0	82.5	0.73
3 Mar	93	Mid	0.8	1.00	100	41	49.7	0.0	0.0	82.8	0.74
16 Mar	106	End	0.0	1.00	100	43	51.8	0.0	0.0	86.3	0.77
30 Mar	120	End	0.0	1.00	100	43	51.1	0.0	0.0	85.2	0.70
9 Apr	End	End	0.0	1.00	0	23					

Total gross irrigation	764.0	mm	Total rainfall	20.2	mm
Total net irrigation	458.4	mm	Effective rainfall	19.1	mm
Total irrigation losses	0.0	mm	Total rain loss	1.1	mm
Actual water use by crop	428.3	mm	Moist deficit at harvest	27.6	mm
Potential water use by crop	429.2	mm	Actual irrigation requirement	410.2	mm

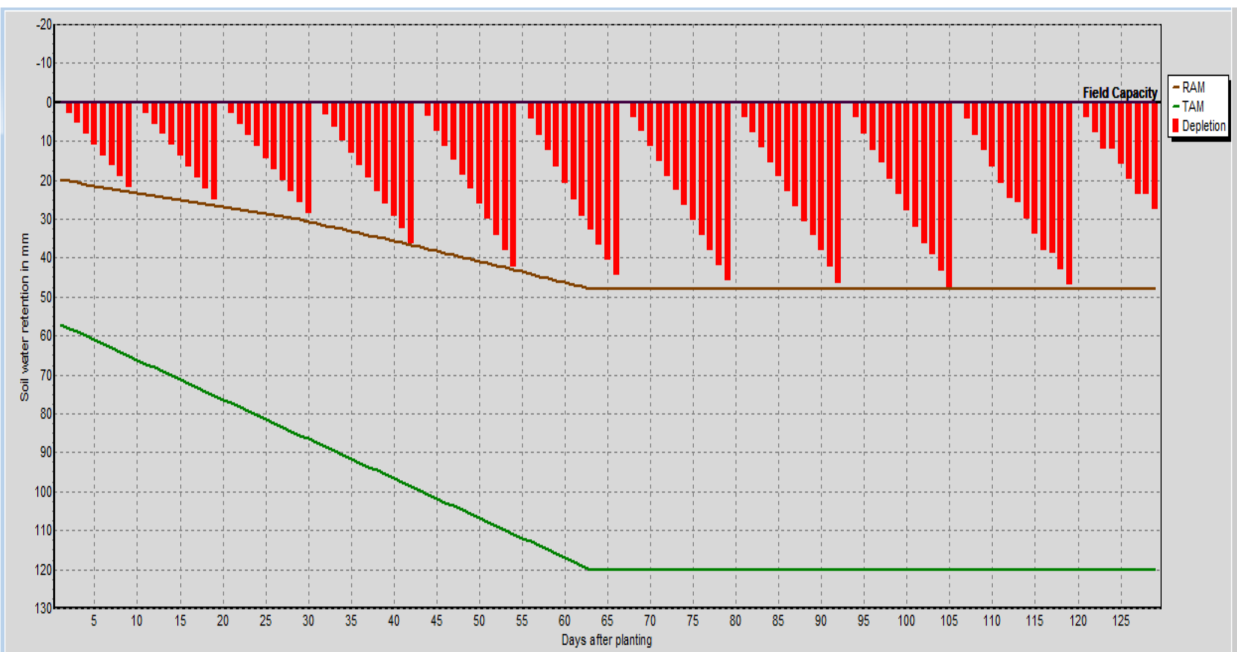

Chart 2: Irrigation scheduling graph for Tomato

4. Conclusions

CROPWAT 8.0 model uses climate, rainfall, soil and crop data as input for scheduling. The crop water and irrigation requirements were 433.2mm and 416.9mm respectively throughout the growing season. The total net irrigation and total gross irrigation requirements were 458.4mm and 764.0mm respectively. The average irrigation interval was 12days which means for the total growth period of tomato and it can be use the same agro-ecology. As much as possible, it is better to use the irrigation interval depending on the growth stage of the crop in which soil moisture stress could not be a limiting factor to obtain maximum yield with considering input-outputs. Generally, estimation of irrigation scheduling using CROPWAT 8.0 model is important to generate information quickly for users.

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