Research Article
Volume 10:8, 2021

Irrigation and Drainage Systems Engineering

ISSN: 2168-9768 Open Access

Investigation of Crop Water Requirement and Irrigation Schedules of Maize Crop in Addis Zemen District, Amhara Region, Ethiopia

Dawit Yihunie*

Department of Water, Irrigation and Energy, South Gonder Administration Zone, Ethiopia

Abstract

The North East and South East side of the country have limited water resource that is the cause of reducing precipitation patterns would significantly affect livestock production and potentially food security. Recently drought risk has affected high land areas and trends suggest that the risk has been increasing in Ethiopia. The annual rainfall across the country has fluctuated significantly which indicates that high seasonal anomalies in rainfall- a major contribute of food intensity. GIS is an important tool that can be used for optimal allocation of water resources of an irrigation project. CROPWAT 8.0 and CLIMEWAT 2 Tool window support dissection technology has been done identify the analysis of evapotranspiration, crop water requirement, irrigation water need and irrigation schedule in Addis Zemen, Amhara region, Ethiopia. Several input data (temperature, humidity, and wind speed) were used to calculate the reference evapotranspiration by Penman-Monteith method was 3.89mm/day. Crop and irrigation water requirement analysis in CROPWAT plat form were 476.8 and 460.9mm/dec respectively. Crop water requirement was categorize under very low sensitive (early stage), low sensitive stage (late stage) high sensitive stage (develop stage) and very high sensitive (middle stage). The irrigation water need throughout all growing season was 456.4mm. Irrigation was scheduled from October 9, 2021 to February 27, 2021.

Keywords: CROPWAT 8.O • Irrigation schedule • Addis Zemen • Reference evapotranspiration.

Introduction

The north-East and South- East of (Ethiopia) already have limited water availability, and therefore reduced precipitation patterns would significantly affect livestock production and potentially food security [1,2]. Through Ethiopian policies consider population as a resource, population growth continues to outpace growth in agricultural production and hence the challenge of addressing poverty and food insecurity has increased. In addition, population growth, agricultural expansion and urbanization contribute to land degradation [3]. Recently, however, drought risk has also affected highland areas and trends suggest that the risk has been increasing [4,5] given that multiple factors affect food security.

The relationship between climate risk and agricultural production is consistent with community perceptions. According to a study in the Abay and Baro-Akobo River Basins of Western Ethiopia, farmers perceived recent climate change as decrease in rain fall [6] . The annual rainfall across the country has fluctuate significantly since the 19880s [2,7]. This consitentent with other perceived trends [8]. This indicates high seasonal anomalies in rainfall- a major contributor to food intensity. The mountainous nature of the country contributes to the complex of agricultural and livestock production systems, including relationships with markets. Moreover, the West- East and North-South rainfall difference affect the type of crops and livestock that are raised [9]. The contribution of surface and groundwater irrigation development today's aggregate food supply is sometimes over looked as evaluations of policies and projects focus on identifying problems rather than benefits.

Despite the problem focuses of the irrigation literature the generally accepted estimates of the contribution of irrigation to global food production are in the range of 25 to 50 percent [10], a share that is set to rise as the new expensive biocenology inputs come on stream. GIS is an important tool that can be used for optimal allocation of water resources of an irrigation project. irrigation water management and for irrigation scheduling have built a database program for enhancing irrigation district management, to manage detailed information about district water management and to promote better on-farm irrigation practices. The window dissection support of CROPWAT 8.0 and CLIMWAT 2 software has been helped us the analysis of evapotranspiration, crop water need and irrigation schedule in the farm land. The models were developed by the Food and Agriculture Organization (FAO) as tool to assist irrigation engineer and calculations of for water irrigation studies and mainly in the management and design of irrigation scheme [11]. In this study area the irrigation water requirements and irrigation schedule of maize crop studied uses the CROPWAT Plat form.

Location of Study Area

The study area (36 km^2) was conduct on Shine River which is the upper basin of Lake Tana and located in Rib watershed in Addis Zemen District in South Gondar Zone, Amhara region, Ethiopia. It is situated 747 km north of the capital city, Addis Ababa and 67 km of North West of Debre tabor. The geographically location of the area is 13˚38'24.84''N and 36˚63'41.44''E respectively, within an average elevation of 1975 meters above sea level. According to the Ethiopian Meteorology Agency the mean daily maximum and minimum rainfall of this area is about 150 and 5mm respectively. The maximum and minimum average temperature of the study area is 26˚C and 14˚C respectively and the total average temperature is 20˚C. Water availability is one of the limiting factors for economic development and agricultural productivity in this area. The natural land use and cover in the study area has been plain and clean area which is suitable for agricultural irrigation activities. Water management has become an extremely essential measure to take in this area. (Figure 1)

Methodology

CROPWAT 8.0 for new open window technology is decision- support plat form based on a number of equations, developed by FAO to calculate reference evapotranspiration (ETo), crop water requirement (CWR), Irrigation scheduling, and irrigation water requirement (IR), using rainfall, soil, crop,

***Address for Correspondence:** Dawit Yihunie, Department of Water, Irrigation and Energy, South Gonder Administration Zone, Amhara region, Ethiopia, E-mail: dawityihunie19@gmail.com*

Received 20 July 2021; **Accepted** 03 August 2021; **Published** 10 August 2021

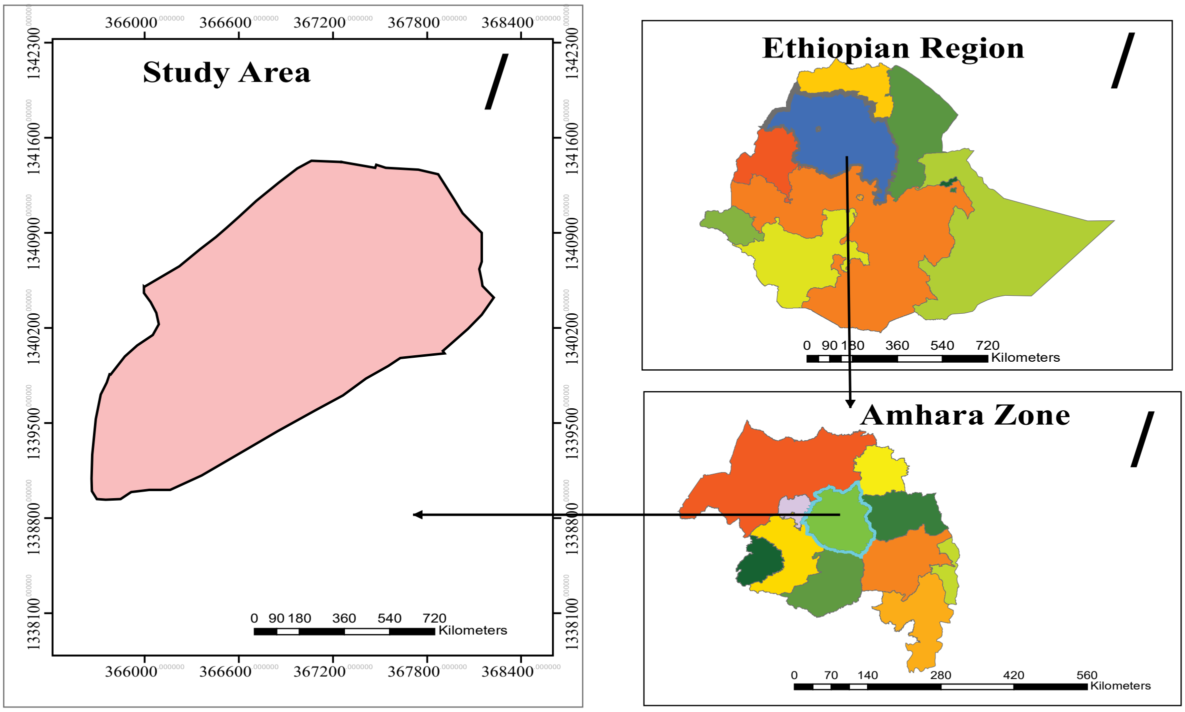

Figure 1. Location map of the study area.

and climate data [12] . This program includes general data for various crop features, local climate, and soil properties to improve irrigation schedules and computation of scheme water supply for different crop patterns under irrigated and rain fed conditions [12]. The data requirement for CROPWAT software are namely rainfall data, climate data, soil data, and crop data [13]. The CLIMWAT 2.0 is the climatic database to be used in association with the CROPWAT program and which allows the calculation of IRs for different crops for a range of climatological stations around the world [12]. CLIMWAT contains seven long- term monthly maximum and minimum temperature (˚C), wind speed (km/h), mean relative humidity (%), sunshine hours (h), rainfall data (mm), and effective rainfall (mm) [11]. The crop data for mize was obtained from the FAO Manual 56 details was added to the CROPWAT program, including root depth, crop coefficient, critical depletion, Yield responses factor, and length of plant growth stages [11]. Planting dates were taken according to the guide to Ethiopian Metrological Agency which categorize under rainy and dry season. The soil parameters obtained from the FAO CROPWAT 8.0 model include detail information on the soil near the climatic station, such as available initial moisture depletion, maximum rainfall infiltration rate, and rooting depth. The United states Department of Agriculture (USID) soil conservation (S. C.) method was used in this study [12].

Wind speed

Wind speed is one of the parameter that is needed for CROPWAT modele. Since the wind speed that applied in CROPWAT model is in km/day. The horizontal component of the air movement parallel to the earth´s surface is generally referred to as wind while the vertical components are referred to as the air currents [14]. Data on wind velocity is required in the evaporation studies. Wind speed varies with the height above the ground. However, the wind speed at any height can be approximately obtained from the known wind speed at the known height of observation. Wind speed data converted in CROPWAT models format by using the following formula [15].

$$U_2 = \frac{4.868}{\ln\left(67.75z - 5.42\right)} \times U_z \qquad (1)$$

Where U_2=wind speed at two meters, U_z= wind speed in Z meter elevation, and Z altitude of measured wind speed. Table 1 shows monthly average wind speed in Addis Zemen station (2m) above surface.

Wind speed has a great effect on the rate of evaporation in that higher the wind speed takes away the moisture in air which facilitate or favors evaporation when its movement is turbulent. Laminar movements have not significant effect.

Sunshine hours

Sunshine duration is available in total hours per month is needed for the CROPWAT model. It pays the main evaporation factor and it has a direct relationship with evaporation. The area attains its maximum and minimum sunshine hours during February and July respectively Table (2) show monthly average sunshine is reflection or result of cloud cover during summer and winter in Addis Zemen station.

Relative Humidity

Relative humidity is another input of climatological data in to CROPWAT model. Its relative measure amount of moisture in the air to the amount needed to saturate the air at the same temperature [16]. It attains its maximum and minimum values in the months of July and February respectively. This is related to the rainy season and dry season of Ethiopia in that druid summer, its value raise and winter its value lowers.

Temperature

The average maximum and minimum temperature are required data for CROPWAT model. In this study area the maximum and minimum temperatures are 27˚C and 11.3˚C respectively.

Estimation of Evapotranspiration ETO

Reference Evapotranspiration ET_0 is often calculated using the penman-Monteith [10,17] method. It is the sum of the water used by plants in a given area in transpiration and the water evaporated from the adjacent soil in the area in any specified time. Transpiration is the processes by which water vapor escapes from the living plant principally through the more convenient to estimate the evapotranspiration directly together. Evapotranspiration represents the most important aspects of water loss in the hydrologic cycle.

$$ET_o = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}U_2(es-ea)}{\Delta+\gamma(1+0.34U_2)} \quad (2)$$

Where, ET_0 the evapotranspiration (mm/day, Rn is the net radiation (MJ/(m[2]/day)), G is the soil heat flux density (MJ/(m²/day)), U_2 is the wind speed at a hight of 2meteres above the surface(m/s), es is the saturated vapor pressure(kpa), ea is the actual vapor pressure of the air at standard screen height(kpa), γ is the psychomotor constant(kpa/˚C), Δ is the slope of the saturation vapor pressure curve between the average air temperature and dew point(kpa/C°/), T is the mean daily air temperature(˚C).

Crop water requirements

Crop water requirement is the amount of water equal to what is lost from a cropped filed 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 [17].

$$ET_c = K_c \times ET_o \quad (3)$$

Where Kc is the crop coefficient, it is the ratio of the crop Etc and ETo, and it requirements an integration of the effects of four essential qualities that differentiate the crop from reference grass, and it covers reflectance of the crop- soil surface, crop height, 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, development, mid-season, and late season [18].

Irrigation Schedule

Irrigation schedule determines the correct measure of water to irrigate and the correct time for watering. CROPWAT plat form contains water supply plans [19]. Thus to determine the irrigation schedule could be used when no significant rainfall occurs during all growing season.

Result and Discussion

The temporal data were added in to CROPWAT and CLIMWAT software application in Addis Zemen station, Ethiopia, such as type of crop, date of cultivation and clay soil type. Thus temporal data were used to calculate the following parameters ETO, effective rainfall, and total irrigation requirements for the studied crop. (Table 1)

Reference Evapotranspiration and Effective Rainfall

Reference evapotranspiration and effective rainfall have been generated from different impute climatic parameters throughout the year. Those are minimum and maximum temperature, humidity, wind speed and sunshine. The low relative humidity, high temperature and high wind speed have influence to increases evaporation during dry season [12]. Variations in ET_o shows weathering fluctuation in the study area. Effective rainfall is the part of rainfall which is effectively used by the crop after surface runoff and deep infiltration, it used to evaluate crop water requirement. Evapotranspiration and effective rainfall could be estimated from CROPWAT model by Penman-Monteith and rainfall from USIDA S. C respectively. Those are essential to calculate crop water requirement and irrigation schedule of crop maize [10, 13]. The average annual evapotranspiration and effective rainfall is 3.89 and 664.2mm respectively. (Table 2)

Maize crop water requirement

This is the amount of water that is equals to the water loss by evapotranspiration. Crops have different water requirement depending upon the place, climate, soil type, cultivation method, effective rain and the total water required for crop growth is not equally distributes over its whole life span . Thus crop water requirement is categorize under very low sensitive (early stage), low sensitive (late stage), high sensitive (develop stage), and very high sensitive (mid stage), when the crop was at their productive stage. The variation observed here can be due to the crop coefficient as shown equation (3). Although the Kc value varied little, it was not constant in any

Table 1. Maize crop temporal data.

				Crop growth period			
Crop Name	**Planting and Harvesting date**	**Critical depletion(fraction)**	**Rooting depth(m)**	**Initial**	**Develop**	**Mid**	**Late**
Maize	01- October-27- February 2021	0.6	0.3	30	40	46	34

Table 2. Temporal variability climate data.

Months	Min Temp °c	Max Temp °c	Humidity hours	Wind speed km/day	Sunshine hours	Radiation MJ/m²/ day	ETo mm/day	Rain mm	Effective rain mm
January	9.9	27.8	52	164	8.2	18.9	3.88	6	0
February	10.9	29.5	49	164	9.2	21.8	4.52	2	0
March	11.9	29.8	46	164	9.1	23	4.98	0	0
April	12.1	29.3	47	129	8.3	22.3	4.75	11	0
May	12.1	29.5	56	164	6.8	19.8	4.47	32	9.2
June	12	26.9	70	164	5.6	17.7	3.75	110	64
July	12.2	23.8	79	103	2.1	12.5	2.64	355	260
August	12	24	79	86	23	12.9	2.64	319	231.2
September	11.6	25.2	75	103	6.7	19.4	3.59	129	79.2
October	10.8	27.2	65	138	8.4	20.9	3.97	51	20.6
November	10.4	27.3	59	138	9.1	20.4	3.85	13	0
December	10.3	27.6	55	120	8.7	19.1	3.6	4	0
Average	11.3	27.3	61	136	7	19.1	3.89	1032	664.2

growth stage, this also expressed as the seasonal crop water requirement. Crop water required of maize is 476.8mm throughout all growth season. The peak months of crop water requirement are December and January. (Table 3)

Irrigation water need and Irrigation schedule

CROPWAT 8.0 plat form technology used us both crop irrigation water need and irrigation schedule program to improve irrigation management in the farm land. This water irrigation management is a system of controlling mechanism of the amount, timing, and rate of irrigation schedules of maize crops. The net irrigation requirement in the water amount required for the growth of the crop that is essential to add the capacity of the soil. The losses such as runoff, seepage, evaporation, and percolation takes place during application and transport of irrigation water [22]. As table 4 indicated the irrigation water required for the crops based on the model simulated in all growing season is 456.4 mm has been brought on the farm land. Irrigation water need could be calculated from crop water need and effective rainfall.

$$IN = ET_c - P_e \tag{4}$$

Where, IN = irrigation water need mm, Etc. = crop water requirement mm and Pe = effective rainfall mm. (Table 4 and 5)

Total irrigation water need in ninety days from November to January is 358.5mm. Thus net irrigation depth is 70. From this, five applications will be needed. Every eighteen applications from ninety days uses the irrigation schedule for crops would be over the total growth period of hundred fifty days. The irrigation schedule in total growing season is 560mm. Therfor, irrigation schedule to be the month of peak irrigation water demand could be calculated as 150÷18=8 applications, which is 8×70=560mm. (Table 6-8) (Figure 2)

As table 7, 8 and Fig. 2 show irrigation schedule throughout the periods starting from initial to the late growing crops. Where, RAM= readily available moisture, TAM= available moisture. (Table 9)

Conclusion

The CROPWAT 8.0 and CLIMWAT 2.0 window dissection support technology has been applied in the Addis Zemen, Amhara region, Ethiopia to analysis the evapotranspiration, crop water requirement, irrigation water need and irrigation schedule of mize crop. The metrological data were converted in to CROPWAT 8.0 plat form. Thus the output shows that in crop water requirement very low sensitive (early stage), low sensitive (late stage), high sensitive (develop stage) and very high sensitive (middle stage) and the irrigation water need of maize is 456.4mm from total growing season (October- February). Irrigation schedule has been scheduled from 9-

Table 3. Crop water requirement.

Month	Decade	Stage	Kc coefficient	Etc mm/day	Etc mm/dec	Eff rain mm/dec	Irr Req
October	1	Initial	0.3	1.15	11.5	12.2	0
October	2	Initial	0.3	1.19	11.9	5.1	6.8
October	3	Developmental	0.3	1.19	13.1	3.4	9.6
November	1	Developmental	0.45	1.75	17.5	0.1	17.3
November	2	Developmental	0.68	2.61	26.1	0	26.1
November	3	Deve	0.91	3.42	34.2	0	34.2
December	1	Mid	1.14	4.18	41.8	0	41.8
December	2	Mid	1.22	4.39	43.9	0	43.9
December	3	Mid	1.22	4.5	49.5	0	49.5
January	1	Mid	1.22	4.62	46.2	0	46.2
January	2	Mid	1.22	4.73	47.3	0	47.3
January	3	Late	1.15	4.73	52	0	52
February	1	Late	0.9	3.88	38.8	0	38.8
February	2	Late	0.64	2.91	29.1	0	29.1
February	3	Late	0.43	2	14	0	14
					476.8	20.9	456.6

Table 4. Shows irrigation water need from total growth season.

Parameters	Oct	Nov	Dec	Jan	Feb
ET crop mm/decade	36.5	77.8	135.2	145.5	81.9
Pe mm/ decade	20.7	0.1	0	0	0
IN mm/decade	15.8	77.7	135.5	145.5	81.9

Table 5. Illustrate moths of peak irrigation water need.

Months of peak irrigation water need	November	December	January	Sub- Total
IN mm/dec	77.7	135.5	145.5	358.7

Table 6. Peak irrigation water demand.

Parameter	Oct	Nov	Dec	Jan	Feb	Total
IN mm	15.8	77.7	135.5	145.5	81.9	456.4
Net irrigation mm	112	112	112	112	112	560

Table 7. Mize irrigation schedule.

Date	Day	Stage	Rain mm	Ks fract	Eta%	Depl%	Net. Irr mm	Deficit mm	Loss mm	Gr.Irr mm	Flow L/S/ha
9-Nov	40	Dev	0	1	100	55	14.3	0	0	20.5	0.06
15-Nov	46	Dev	0	1	100	51	13.3	0	0	19	0.37
21-Nov	52	Dev	0	1	100	58	15	0	0	21.4	0.41
26-Nov	57	Dev	0	1	100	61	15.9	0	0	22.7	0.53
30-Nov	61	Dev	0	1	100	53	13.7	0	0	19.6	0.57
4-Dec	65	Dev	0	1	100	61	15.7	0	0	22.5	0.65
8-Dec	69	Dev	0	1	100	61	15.7	0	0	22.5	0.65
12-Dec	73	Mid	0	1	100	66	17.1	0	0	24.5	0.71
15-Dec	76	Mid	0	1	100	51	13.2	0	0	18.8	0.73
19-Dec	80	Mid	0	1	100	66	17.1	0	0	24.5	0.71
22-Dec	83	Mid	0	1	100	52	13.4	0	0	19.1	0.74
25-Dec	86	Mid	0	1	100	52	13.5	0	0	19.3	0.74
29-Dec	90	Mid	0	1	100	67	17.4	0	0	24.8	0.72
1-Jan	93	Mid	0	1	100	52	13.6	0	0	19.5	0.75
5-Jan	97	Mid	0	1	100	67	17.5	0	0	25	0.72
9-Jan	101	Mid	0	1	100	67	17.5	0	0	25	0.72
12-Jan	104	Mid	0	1	100	54	14.1	0	0	20.1	0.78
15-Jan	107	Mid	0	1	100	55	14.2	0	0	20.3	0.78
18-Jan	110	Mid	0	1	100	50	13.1	0	0	18.7	0.72
21-Jan	113	Mid	0	1	100	55	14.2	0	0	20.3	0.78
24-Jan	116	Mid	0	1	100	51	13.3	0	0	19	0.73
28-Jan	120	Mid	0	1	100	69	18	0	0	25.8	0.75
1-Feb	124	Late	0	1	100	69	18.1	0	0	25.8	0.75
6-Feb	129	Late	0	1	100	72	18.8	0	0	26.9	0.62
11-Feb	134	Late	0	1	100	71	18.4	0	0	26.3	0.61
18-Feb	141	Late	0	1	100	76	18.8	0	0	28.3	0.47
27-Feb	End	End	0	1	0	67					

Table 8. Total irrigation parameters.

Total	Irrigation parameters		
Total gross irrigation	580mm	Total rainfall	76.3mm
Total net irrigation	406mm	Effective rainfall Total rain loss	51.4mm
Total irrigation losses	0	Total rain loss	24.8mm
Actual water use by crop	474.8mm	Moist deficit at harvest	17.8mm
potential water use by crop	474.8mm	Actual irrigation requirement	423.4mm
Efficiency irrigation schedule Deficiency irrigation schedule	100%	Efficiency rain 0.0	67.5%

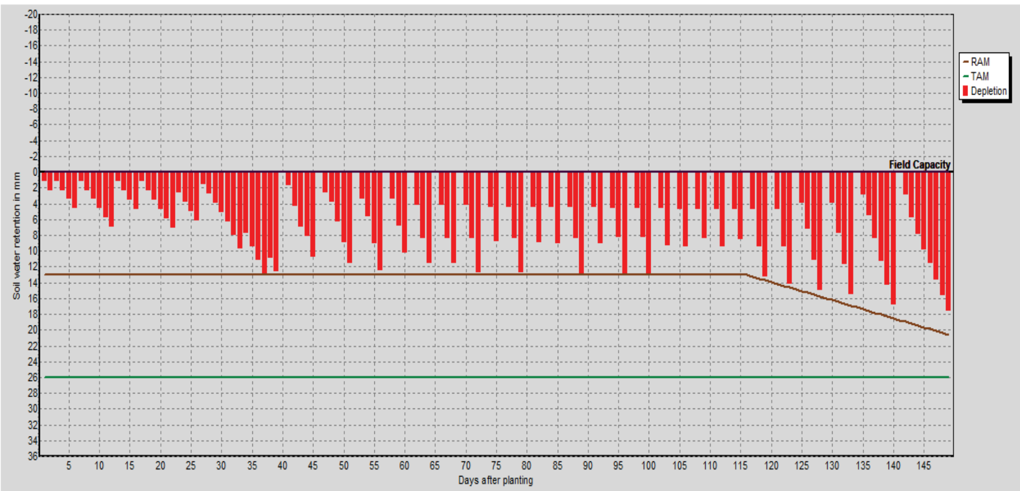

Figure 2. Duration of the crop irrigation.

Table 9. Yield reductions.

Yield reduction (%)	Reduction Parameters				
Stage able	A	B	C	D	Season
Reduction in ETc	0	0	0	0	0%
Yield response factor	0.4	1	1.3	0.5	1%
Yield reduction	0	0	0	0	0%
Commutative yield reduction	0	0	0	0	

November to 27- February. This study helps us to improve the management of water resources and the productivity through policies based on these findings.

References

1. Funk, Christopher C, Joel Michaelsen and Michael Marshall. "Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel". Remo sensing of drought: Innovative monitoring approaches. Boca Raton: CRC press/Taylor and Francis 10 (2011): 331-358.
2. Dinku, Tufa. "Climate analysis and application of Map Room". Climate Data Library, NMA/IRI (2012)1-2.
3. Sonja, Fransen and Kuschminder K. "Migration in Ethiopia: History, Current Trends and Future Prospects". Paper Series: Migration and Development Country Profiles, Maastricht Graduate School of Governance, Maastricht University 10 (2009): 1- 41.
4. Riche B, Hachileka E, Auwor C B and Hammill A. "Climate related vulnerability and adaptive capacity in Ethiopian´s Borena and Somali communities". Care Insights (2009)1- 82.
5. Markos E. "Demographic response to Ecological degradation and Food insecurity in drought prone in Northern Ethiopia". The University of Groningen (1997):1-373.
6. Bewket W and Alemu D. "Farmer´s perceptions of climate change and its agricultural impacts in the Abay and Baro-Akobo River Basins, Ethiopian". *Ethiop J Dev Res* 32 (2011):1-605.
7. Muktor, Reshid. "LEAP - Livelihoods, Early Assessment and protection". Innovative Climate Risk Management for Food Security (2013) 1- 4.
8. "A climate trend analysis of Ethiopia". Informing climate change Adaptation series, USGS and USAID 10 (2012):1-6.
9. Park, William A, Funk C, Michelson J, Rausher SA and Robert Son et. al. "Recent summer precipitation trends in Great Horn of Africa and the emerging roll of Indian Ocean Sea surface temperatures". *Climate Dynamics* 39 (2011):011-1222.
10. FAO, Rome. Reference Mankombu, Swaminathan. "Population, Environment and Food Security Issues in Agriculture". Consultative Group for International Agricultural Research: Washington, D. C 23 :(1994)1-45.
11. Derek, Clarke, Smith M, El-Askari K. "Crop Wat for Windows: User Guide". University of Southampton, UK (2001)1-130.
12. "CROPWAT: Land and Water Division". FAO (2018)1-2.
13. Reddy, Jay rami P. "A text book of hydrology". Laximi publications (P) LTD. New Delhi 530:(1996)
14. Munoz, Giovanni and Grieser, Jurgen. "CLIMWAT 2.0 for CROPWAT". Water Resources, Development and Management Service and the Environment and Natural Resources Service of the Food and Agriculture Organization of the UN, Rome (2006).
15. Shariatli MR. "An estimate of water requirements of rain filed crops and or chards in Iran. Tehran, Agricultural training center (1997).
16. Shaw, Elizabeth M. "Hydrology in practice". Second edition, Chapman and Hall, New York (1988): 539.
17. Luis Santos, Pereira, Allen RG, Smith M, Raes D "Crop evapotranspiration estimation with FAO 56: Past and future". *Agric Water Manag* 147 (2015): 4–20.
18. Allen, Richard G, Pereira, LS, Raes D, Smith M. "Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements - FAO Irrigation and Drainage Paper 56". FAO, Italy (1998)
19. Allen, Richard G, Pereira LS, Smith M, Raes D and Wright JL et. al. "FAO-56 dual crop coefficient method for estimating evaporation from soil and application extensions". *J Irrig Drain Eng* 131(2005): 2–13.
20. Yitayal Addis, Alemayehu, Steyn JM, Annandale JG. "FAO-type crop factor determination for irrigation scheduling of hot pepper (*Capsicum annuum L.*) Cultivars". *S Afr J Plant Soil 26*(2009): 186–194.

How to cite this article: Dawit Yihunie. "Investigation of Crop Water Requirement and Irrigation Schedules of Maize Crop in Addis Zemen District, Amhara Region, Ethiopia." *Irrigat Drainage Sys Eng* 10 (2021): 281.