Journal of
Earth Science & Climatic Change

Abirdew et al., J Earth Sci Clim Change 2018, 9:1
DOI: 10.4172/2157-7617.1000439

Research Article Open Access

Determination of Crop Water Requirements for Maize in Abshege Woreda, Gurage Zone, Ethiopia

Solomon Abirdew*, Girma Mamo and Mengistu Mengesha

Department of Natural Resource Management, Wolkite University, Ethiopia

Abstract

In Ethiopia where crop production overly depends on rainfall and temperature, studying the variability of these climate variables at a local scale is essential to devise proper strategies that enhance adaptive capacity. In light of this, a study was conducted in Abshege Woreda, Gurage Zone to determine crop water requirement of maize, which is major food crop of the area. Ten years i.e., (2006-2015) Indibir station climatological records of (sunshine duration hr/day), maximum and minimum temperature (OC), humidity (%) and wind speed (km/day) at 2 meters height were used in FAO Penman Monteith method. Secondary data were used to collect important soil parameters required for determination of crop water requirement in the study area such as field capacity (FC), permanent wilting point (PWP), initial soil moisture depletion (as % TAM) and available water holding capacity (mm/meter) while data for maximum rain infiltration rates (mm/day) and maximum rooting depth (cm) were obtained from literature based on similar textural class of the soil in the study area. Lengths of total growing periods of the crop was determined from ten years climate data and planting date was 10th May acquired from OAWBA and farmers of the area. Crop coefficients (k_c), rooting depth, depletion level and other agronomic parameters were obtained from FAO guidelines (No 56) for each growth stage. The analyzed data indicated that Crop water requirement was estimated using CROPWAT 8.0 for window. A maize variety with a growing period of 140 days to maturity would requires 423 mm depth of water, while 101 mm would be required as supplementary irrigation depth.

Keywords: Crop water requirement; Climate; Maize

Introduction

The amount of water required to compensate for the evapotranspiration loss from the cropped field is defined as crop water requirement. The values for crop evapotranspiration and crop water requirement are therefore, identical (except opposite sign), crop water requirement refers to the amount of water that needs to be supplied (positive sign), while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (negative sign). The experimentally determined ratios of ET_c/ET_o, called crop coefficient, is used to relate crop evapotranspiration under standard conditions (ET_c) to ET_o i.e., reference evapotranspiration, which is an atmospheric parameter. The net irrigation water requirement represents the difference between the crop water requirement and effective rainfall.

The CROPWAT model is widely used to estimate ET_o and ET_c. In actual fact, CROPWAT is a computer program for irrigation planning and management, developed by FAO [1]. However the same principle holds for rain-fed crop production as well. Its basic function includes the calculation of reference crop evapotranspiration, crop water requirement and scheme irrigation requirement. Although several methods exist to determine ET_o, the Penman Monteith method has been recommended as the appropriate combination method to determine ET_o from climatic data on: temperature, humidity, sunshine and wind speed are required [2].

The highest value of ET_o is experienced in areas that are hot, dry, windy and sunny. In many cases it is possible to obtain estimates of ET_o for a given locality from the meteorological service [3]. Study conducted at Arba Minch by Mekonen, a maize variety with a growing period of 135 days to maturity would require 535.8 mm depth of water, while 307.2 mm would be required as supplementary irrigation depth with effective rainfall of 259.6 mm during the period of January to May 1st. In rain-fed cropping, the estimated crop water requirement is an important parameter to use alternate practices like mulching, reducing plant population by certain percentage in order to reduce the stiff competition and many more others.

Objective

The objective is to determine crop water requirements for maize production.

Methodology

Location

The study was conducted in Abshege Woreda, Gurage Zone of SNNPRS, Ethiopia (Figure 1). The geographical coverage of the study area is 8° 17' 22.6" N and 37° 46' 55.98" E at an elevation range of 1050 to 1883 m.a.s.l. It has a total area of about 57313.85 ha of which 40119.7 ha is cultivated.

Estimation of crop water requirements for maize production

Secondary data were used to collect important soil parameters required for determination of crop water requirement in the study area such as field capacity (FC), permanent wilting point (PWP) and initial soil moisture depletion (as % TAM). Available water holding capacity/ total available soil moisture (mm/meter) was determined from FC and PWP, while data for maximum rain infiltration rates (mm/day) and maximum rooting depth (cm) were obtained from literature based on similar textural class of the soil in the study area [4]. Ten years (2006-

***Corresponding author:** Solomon Abirdew, Lecturer and Researcher, Department of Natural Resource Management, Wolkite University, Ethiopia, Tel: 251927109605; E-mail: absolomon0@gmail.com

Received December 21, 2017; **Accepted** January 23, 2018; **Published** January 27, 2018

Citation: Abirdew S, Mamo G, Mengesha M (2018) Determination of Crop Water Requirements for Maize in Abshege Woreda, Gurage Zone, Ethiopia. J Earth Sci Clim Change 9: 439. doi: 10.4172/2157-7617.1000439

Copyright: © 2017 Abirdew S, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

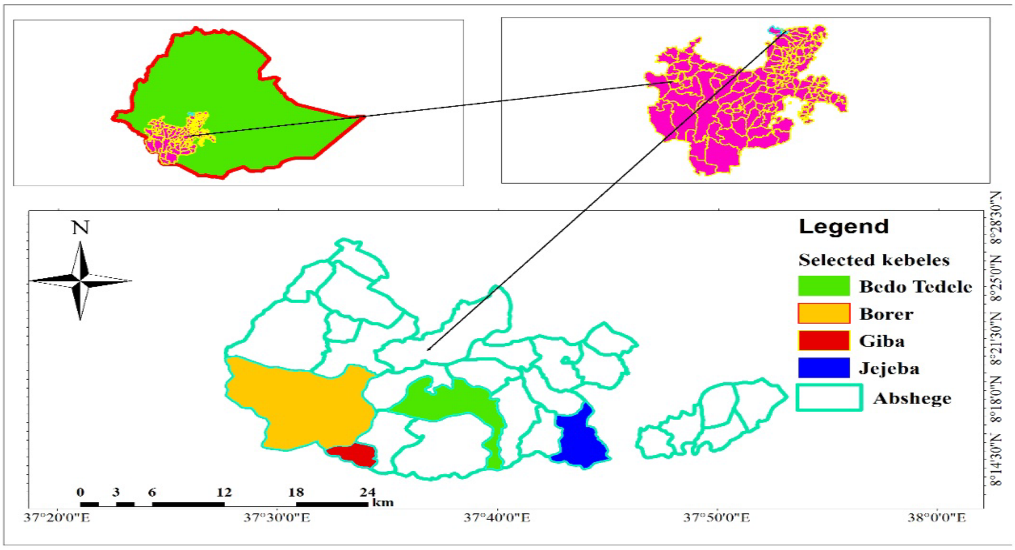

Figure 1: Location map of the study area.

2015) Indibir station climatological records of (sunshine duration hr/day), maximum and minimum temperature (OC), humidity (%) and wind speed (km/day) at 2 meters height were used in FAO Penman Monteith method [5].

Reference crop evapotranspiration for maize crop grown in the area was estimated from long term climate parameters (2006-2015) in CROPWAT 8.0 software. In the study area there is only 10 years long term climatological data on sunshine hours, humidity and wind speed. Therefore, in estimating ET_o, 10 years Indibir station climatological records of sunshine hours, maximum and minimum temperature, humidity and wind speed at 2 meters height were used in CROPWAT 8.0 software. Mathematical Penman Monteith form of the combination equation is as follows:

$$\frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}U2(es-ea)}{\Delta+\gamma(1+0.34U2)}$$

Where, ET_o is reference crop evapotranspiration (mm/day), R_n is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), T is mean daily air temperature (OC) at 2 m height, es is saturation vapour pressure (kPa), ea is actual vapor pressure (kPa), es-ea is saturation vapor pressure deficit (kPa), Δ is slop vapor pressure curve (kpa/OC), U_2 is the average wind speed at 2 m height (m/s) and γ is psychrometric constant (kPa/OC).

In addition to meteorological data used to compute the ET_o, crop related data is required to estimate the crop water requirements on daily, decadal and monthly bases. Crop water requirements were computed for maize crop which is widely grown as a food crop in the study area. Lengths of total growing periods of the crop was obtained from OAWBA and farmers of study area and again the planting date was 10th May acquired from OAWBA and farmers of the area. Crop coefficients (k_c) defined as the ratio of the crop evapotranspiration (ET_c) of a disease free crop grown in a large field adequately supplied with water to the reference crop evapotranspiration (ET_o), rooting depth, depletion level and other agronomic parameters were obtained from FAO guidelines (No 56) for each growth stage [6]. A crop coefficient (k_c) for maize is 0.3 for initial, 0.8 developments, 1.2 flowering and 0.5 for late growth stages [7]. CROPWAT 8.0 software was used for analyzing ET_o and ET_c of maize. Experimentally determined ratio of ET_c/ET_o, crop coefficient (k_c) used to relate ET_c to ET_o. Mathematically expressed as:

$$CWR=ET_{c=}k_c \times ET_o$$

Where; CWR=Crop Water Requirement, ET_c=Crop Evapotranspiration, ET_o=Reference Crop Evapotranspiration, k_c=Crop Coefficient.

Results and Discussion

Estimation of crop water requirements for maize production under local climate

Reference crop evapotranspiration (ET_o): As shown in Tables 1 and 2, belg reference crop evapotranspiration ranged from 406.70 mm to 511.60 mm with an average of 478.10 mm and CV of 34.6%. The maximum belg reference crop evapotranspiration (511.60 mm) recorded in 2013 while the minimum belg reference crop evapotranspiration was 406.7 mm registered in 2010. Kiremt reference crop evapotranspiration ranged from 330.50 mm to 466.80 mm with a mean of 372.10 mm and CV of 10.6%. The maximum kiremt reference crop evapotranspiration was 466.8 mm and it was recorded in year 2006, whereas the minimum kiremt reference crop evapotranspiration was 330.5 mm and it is occurred in year 2010. Similarly, annual reference crop evapotranspiration ranged from 1361.1 mm to 1185.5 mm with a mean of 1295.8 mm and CV of 3.7%. The maximum annual reference crop evapotranspiration was 1361.10 mm and it was registered in year 2010, whereas the minimum annual reference crop evapotranspiration was 1185.50 mm and it occurred in year 2006 (Table 2). Similar Studies conducted in the central Rift Valley of Ethiopia also showed annual crop evapotranspiration of 1994 mm/year for the period of 1977 to 2012.

As shown in the Table 2, the belg reference crop evapotranspiration 2006-2015 (478.1 mm) was greater than belg rainfall (318.4 mm) of the same period in the study area. The maximum monthly reference crop evapotranspiration of 147.4 mm/month was occurred in the month of March 2009, and the minimum value (74.5 mm/month) was occurred

Citation: Abirdew S, Mamo G, Mengesha M (2018) Determination of Crop Water Requirements for Maize in Abshege Woreda, Gurage Zone, Ethiopia. J Earth Sci Clim Change 9: 439. doi: 10.4172/2157-7617.1000439

Parameters	Min	Max	Mean	SD	CV (%)
Jan	103.9	133.4	116.8	8.7	7.4
Feb	90.6	129.3	112.5	11.9	10.6
Mar	112.1	147.4	131.1	12.9	9.8
Apr	104.5	136.5	121.9	10.3	8.4
May	95.6	126.9	112.5	10.2	9.1
Jun	85.2	114.1	95.8	10.1	10.5
Jul	74.5	122.3	92.3	17.6	19.5
Aug	77.8	117.1	85.8	12.2	14.3
Sep	86.6	113.4	98.1	7.6	7.7
Oct	100.9	123.8	110.3	7.6	6.9
Nov	95.9	124.6	109.1	8.1	7.4
Dec	93.6	125.8	109.5	9.8	8.9
Belg	406.7	511.6	478.1	34.6	7.2
Kiremt	330.5	466.84	372.1	39.4	10.6
Annual	1185.5	1361.1	1295.8	48.4	3.7

Table 1: Descriptive statistics of monthly, belg, kiremt and annual reference evapotranspiration (ETo in mm) in the study area (2006-2015).

Month	Decade	Stage	kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dek	mm/dek	mm/dek
May	3	Init	0.30	1.12	12.4	10.8	1.6
Jun	1	Init	0.30	1.22	12.2	14.0	0.0
Jun	2	Deve	0.34	1.16	11.6	13.7	0.0
Jun	3	Deve	0.54	2.13	21.3	20.4	0.9
Jul	1	Deve	0,75	2.94	29.4	40.1	0.0
Jul	2	Deve	0.95	3.92	39.2	37.2	2.0
Jul	3	Mid	1.12	4.25	46.8	36.4	10.2
Aug	1	Mid	1.13	4.36	43.6	45.0	0.0
Aug	2	Mid	1.13	4.53	45.3	54.3	0.0
Aug	3	Mid	1.13	4.33	47.6	30.2	17.5
Sep	1	Late	1.12	4.22	42.2	11.6	30.6
Sep	2	Late	0.94	3.67	36.7	17.2	19.5
Sep	3	Late	0.72	2.34	23.4	8.7	14.7
Oct	1	Late	0.53	1.61	11.3	5.1	4.0
		Total			423.0	344.7	101.0

Table 2: Crop water requirement of maize in the study area.

in the month of July 2012 (Table 2). Lowest ET_os were recorded during kiremt season, in the month of July (74.5 mm) followed by August (77.8 mm) and June (85.2 mm), while maximum monthly ET_o occurred in the month of March (147.4 mm) followed by April (136.5 mm) and January (133.4 mm). Monthly SD and CV of ET_o varied from 7.6 mm to 17.6 mm and 6.9% to 19.5%, respectively (Tables 1 and 2).

Crop water requirement: As indicated in Table 2, a maize variety with a growing period of 140 days to maturity would require 423 mm depth of water, while 101 mm would be required as supplementary irrigation in the study area, and 101 mm depth of water is required as supplementary irrigation for maize crop grown in the area during dry spells and drought for an individual farmer to offset the effect of water stress on maize yield. Therefore, absence of supplementary irrigation during dry spells would result in reduced maize yield. A similar study undertaken at Arba Minch by Mekonen also reported that a maize variety with a growing period of 135 days to maturity requires 535.8 mm depth of water and to meet this 307.2 mm is required to be given as supplementary irrigation.

The current irrigation volume of the study Woreda is 957 m^3, which is irrigate only 0.95 ha of land which is less than one hectare. Hence, inline of the present in climate change water is becoming scarce, and the administration of the area should work to expand irrigation, and water harvesting technology in order to reduce an incoming impacts of climate change and variability. Provision of irrigation is likely to play a strategic role in either stabilizing the production of grains or in supporting a low risk, high value production system with a strong commercial focus during rainfall shortage and prolonged dry spell.

Conclusion

Crop water requirement of maize also showed that a maize variety with a growing period of 140 days to maturity requires 423 mm depth of water, to need this 101 mm required as supplementary irrigation to overcome the observed deficit in rainfall.

References

1. Abdalla NM, Zhang X, Ishag A, Gamareldawla H (2010) Estimating reference evapotranspiration using CROPWAT model at Guixi Jiangxi Province. State Key Laboratory of Hydrology and Water Resources and Hydraulic Engineering, Hohai University, China.
2. Allen R, Pereira S, Raes D, Smith M (1998) Crop evapotranspiration: A guideline for computing crop water requirements. FAO Irrigation and Drainage Paper No 56. FAO Water Resources, Development and Management Service, Rome, Italy, 300.
3. FAO (1986) Soil and water conservation in Sub-Saharan Africa issue and options. FAO, Rome, Italy.
4. Savva AP, Frenken K (2001) Irrigation manual: Planning, development, monitoring and evaluation of irrigated agriculture with farmer participation. Sprinkler irrigation systems: Planning, design, operation and maintenance 3: 8.
5. Ayana M (2011) Deficit irrigation practices as alternative means of improving water use efficiencies in irrigated agriculture: Case study of maize crop at Arba Minch, Ethiopia. African Journal of Agricultural Research 6: 6226-6235.
6. Smith M, Kivombi D, Heng L (2001) Use of FAO CROPWAT model in deficit irrigation studies. Deficit irrigation practices. Water Report No. 22, FAO, Rome, Italy.
7. Mengiste Y (2015) Agricultural water productivity optimization for irrigated Teff (Eragrostic Tef) in water scarce semi-arid region of Ethiopia Agricultural water productivity optimization for irrigated Teff (Eragrostic Tef) in water scarce semi-arid region of Ethiopia. CRC Press, Balkema.