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Estimation of Maize Crop Water Requirement using CROPWAT: The Case of Abobo District, Southwest Ethiopia

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Abstract

Water is the main limiting factor for crop production. A lot of water resources have been exploited for irrigation purpose. Therefore, the objective of this study paper was to determine crop water requirement, effective rainfall and irrigation water requirement of Maize crop using CROPWAT. Today on worldwide there is a shortage of water, therefore, it is essential to adopt water saving agriculture as a counter measure as well as efficient use of irrigation water is becoming increasingly important. In growing crop, irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits. In this study different data like: climate data (sunshine hour, maximum and minimum temperature, humidity and wind speed) and rainfall, soil data, crop data were used. The analyzed data indicated that crop water requirement was estimated using CROPWAT 8.0 model. A maize variety with a growing period of 125 days to maturity would require 683.9 mm depth of water, while 243.3 mm would be required as supplementary irrigation depth.

Keywords: Crop water requirement; Climate; Maize

Introduction

Agriculture is the main source of livelihood for about 85% of Ethiopia's population, contributing 50% of the GDP and generating more than 80% of the foreign exchange earnings. It is controlled by small-scale crop-livestock mixed farming systems, and cereals are the most significant food crops, occupying about 77% of the total cultivated area. Production technologies are mainly characterized by low agricultural inputs using old-style farming methods [1].

Evapotranspiration estimation is important in many fields of the agricultural sciences. Changes in evaporative demand have an impact on agriculture [2], which is the biggest consumer of fresh water. The FAO-Penman method is accurate for ET0 estimation in both humid and arid climatic conditions. Hence, the FAO Penman-Monteith methodology is currently considered the standard method for estimating ET0 in agriculture .

Maize is critical for food security in Ethiopia. More than 9 million smallholders grow maize on about 2 million, and around 88% of their production is used for food consumption. In terms of calorie intake, maize is the most important staple crop for the rural Ethiopian population [3]. Thus, Abobo district is one of the rural areas of Ethiopia where maize is considered the main crop grown.

According to the, the water-limited yield potential of maize in Ethiopia is on average 12.5 t/ha, implying that farmers realize only around 30% of that potential. Maize is the main crop grown in the waterless areas of Ethiopia, and the production is undertaken under water-worried conditions. Abobo district is one of the most environmentally susceptible areas in Ethiopia, where rainfed crop production has extended rapidly over recent decades. The warming trend enforces its influence on crop production by raising the evaporative demand, particularly in regions like the Abobo district where rainwater is already scarce [4]. Declined growing season rainfall with high evaporative demand will increase the risk of low yields in rainfed crop production. Therefore, it's essential to assess the current crop water use of maize, which can be used to improve rainfed crop production, and prepare adaptation options for particular sites.

Materials and Methods

Location of the study area: The study area, Abobo district, is located at 42 km south of Gambella town and about 808 km west of Addis Ababa. It lies between 07°50'47" to 08°01'59" N and 34°28'59"- to 34°34'37"E with altitude ranging from 446 to 490 meters above sea level (masl) and slope from flat (0.2–0.5%) to gently sloping (2–5%) [5].

Climate : The climate of the region is influenced by the tropical monsoon, which is characterized by high rainfall in the wet period from May to October and little rainfall during the dry period from November to April. The average annual rainfall is 955.5 mm, whereas the mean minimum and mean maximum monthly temperatures range from 16.2 to 21.2°C and 32.1 to 38.2°C.

Crops grown : Agriculture for Abobo district is the main and important economic sector which is mixed agriculture type. The major crops grown by farmers include maize (Zea mays L.), sorghum (Sorghum bicolor), and groundnut (Arachis hypogaea). The study area is potentially favorable agriculture [6].

Data types and Sources

Meteorological data: Meteorological data was used as input to the CROPWAT model to compute reference crop evapotranspiration (ETo). Based on these objectives, the meteorological data required for this study were collected from the Ethiopian National Meteorological

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Services Agency (NMSA) at Addis Ababa office. Ten years (2012-2021) Abobo station climatological records of rainfall, maximum and minimum temperature, sunshine duration, humidity and wind speed were used in FAO Penman Monteith method [7].

Soil data: Before the start of soil sample collections, the area where the maize crop is mostly grown in the study area was identified. Based on this 60 auger representative soil samples were collected from maize farmland at intervals of 30 cm up to 90 cm for determination of some soil physical properties. For the analysis, the standard procedures of were used. FC and PWP were used for the calculation of reference evapotranspiration (ETo) by using the CROPWAT model. This ETo was used to calculate Crop Evapotranspiration (ETc).

Crop data: The crop coefficient (Kc) values used in the simulation of the CROPWAT model were taken from FAO (2006) [8]. The values of 0.30, 1.20 and 0.80 were used for Kc initial, Kc mid and Kc final. The lengths of crop development stages for maize taken are 20, 35, 40 and 30 for the four distinct growth stages i.e. initial, crop development, mid-season and late season and a total of 125 for the whole growing season were taken from FAO (1998) that used in the simulation.

Methodology

Reference evapotranspiration (ETo): The most common procedure for estimating crop water use or crop evapotranspiration (ETc) is the crop coefficient (Kc) approach. The FAO Penman-Monteith method is the standard recommended method for the definition and computation of ETo, which represents the evaporative demand of the atmosphere, independent of the crop type, crop development and crop management practices. This method consists of a combination of three equations [9].

According to Penman-Monteith combination method is one of the most accurate methods to evaluate ETo at different time steps. A standardization of this method has been proposed by the Food and Agriculture Organization (FAO). It is known as FAO-56 Penman-Monteith application, and it can be considered as a worldwide standard. The daily average reference evapotranspiration (ETo) is given in (mm/day) according this equation as,

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

Where, ETo- reference evapotranspiration [mm day-1],

Rn- net radiation at the crop surface [MJ m-2 day-1],

G- soil heat flux density [MJ m-2 day-1],

T- mean daily air temperature at 2 m height [°C],

u2- wind speed at 2 m height [m s-1],

es- saturation vapour pressure [kPa],

ea- actual vapour pressure [kPa],

es - ea saturation vapour pressure deficit [kPa],

Δ - slope vapour pressure curve [kPa °C-1],

γ- psychrometric constant [kPa °C-1].

Estimation of crop evapotranspiration (ETc) : A variety of empirical methods have been developed to estimate crop evapotranspiration (ETc) from readily available climatic parameters. Crop evapotranspiration or crop water use can be assessed by multiplying the reference evapotranspiration (ETo) by the crop coefficient, based on the following relationship:

$$ETcrop = Kc \times ETo \quad (2)$$

Where, Kc is crop coefficient,

Crop evapotranspiration is estimated through Kc and ETo over the growing season. The effect of both crop transpiration and soil evaporation are integrated into a single crop coefficient (Kc) incorporating crop characteristics and average effects of evaporation from the soil [10].

All calculation procedures used in CROPWAT 8.0 are based on the FAO publications No. 56 and 33. The advantage of using the CROPWAT model as a tool for assessing crop water use is that it is simple and easy to use, and it requires only monthly inputs of climate and rain data, coupled with crop parameters and soils data, to calculate water and irrigation requirements [11].

Model Description

CROPWAT 8.0 is a decision-support computer program based on a number of equations, developed by the FAO to calculate reference evapotranspiration (ET0), crop water requirement (CWR), irrigation scheduling, and irrigation water requirement (IR), using rainfall, soil, crop, and climate data [12].

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 rainfed conditions.

Results and Discussion

Climate: Climate is the main factors that affect the crop water requirement of the crop climatic factor include temperature (minimum and maximum temperature), humidity, wind, sun, radiation and reference evapotranspiration. The average of those climatic factor in Abobo Destrict are 17.3 and 32.8 degree Celsius minimum and maximum temperature respectively,61% of humidity,67km/day speed of wind ,16.2hr of sun ,33.0MJ/m2/day radiation of sun and 6.15mm/day of reference evapotranspiration [13].

Effective rainfall: It is the part of total annual rainfall which is useful directly and indirectly for meeting the crop water requirement in production of crop at the site where it is fall. This effective rainfall may vary depending on the soil type, characteristic of rainfall, topography, ground water characteristics and management practice. For the case Abobo District the total amount of effective rainfall is 794.9mm per annual.

The maize crops in the district of Abobo kc values is 0.30 at initial stage and 1.20 at mid season. The total day required for the growth of maize crop is takes 125 days that means at initial stage growth it takes 20 days, at development stage it takes 35 days ,at mid season stage 40 days and at late season 30 days [14].The rooting depth is one of the factor that determined crop and soil type and it is varies from 0.30m to 1.0m and crop height is 2.0m.However, for the maize crop the kc values ranges from 0.30 to 1.20 and during the harvest date it should be 0.80. In case of the growth stage of maize it takes 125 days from initial to harvest date.

Soil: Soil is one of the factor that affect the growth of the plant or crop according to FAO the soil type around Abobo distirict is included under clay soil [15]. Therefore, the total available soil moisture (FC-

WP) is 140mm/meter, 40mm/day maximum rain water infiltration rate, 90cm maximum rooting depth and 70mm/meter of initial available soil moisture.

Net Irrigation Requirement (NIR) and Irrigation Schedule: 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.

The total gross irrigation mean and the total net irrigation mean are 114.3 mm and 80.0mm for maize respectively. There are six irrigation schedules for maize [16].

The NIR is the water quantity required for the growth of the crop, or it is the amount of water necessary to reach the field capacity of the soil. NIR depends on the climate and cropping pattern. Data on irrigation efficiency are needed to convert NIR to gross irrigation requirement. The different losses, such as runoff, seepage, evaporation, and percolation, take place during application and transport of irrigation water. Operations, such as leaching, transplantation, and land preparation, require certain amounts of water. Thus, CWR includes ET, losses during the application of water needed for these purposes as in Equation (3).

$$NIR=ETc-Eff.rain \quad (3)$$

This kind of analysis helps farmers to choose the type of crops for cultivation based on the availability of water. 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 [17].

Crop water requirement of maize: The crop water need is the amount (or depth) of water that equals the water loss by ET. Crops have different water requirements depending upon the place, climate, soil type, cultivation method, effective rain, etc., and the total water required for crop growth is not equally distributed over its whole life span.

As indicated in, a maize variety with a growing period of 125 days to maturity would require 683.9 mm depth of water, while 243.3mm would be required as supplementary irrigation in the study area, and 243.3 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 [18].

Conclusion

Irrigation management plays a significant role in effectively and efficiently using the available water sources to meet the variation of cropping patterns. The main target of this paper is to apply the CROPWAT 8 irrigation water management model for the determination of crop water requirement. This model used to know climatic condition, rainfall, soil type, crop water requirement, crop pattern and schedule of irrigation and scheme of irrigation.

Finally, in this study results shows as the way of knowing the irrigation water requirement based CROPWAT 8.0 model it is most useful and effective if there is no availably or shortage of data .

References

1. Abate T, Shiferaw B, Menkir A, Wegary D, Kebede, et al. (2015) Factors that transformed maize productivity in Ethiopia. Food Security 7: 965-981.
2. Allen RG, Pereira LS, Raes D, Smith M (1998) FAO Irrigation and drainage paper No. 56. Rome: FAO of the United Nations 56: 156.
3. Amara DMK, Kamanda PJ, Patil PL, Kamara AM (2016) Land suitability assessment for maize and paddy production in Bogur microwatershed using remote sensing and GIS techniques. IJEAB 1: 238561.
4. Arndt C, Robinson S, Willenbockel D (2011) Ethiopia's growth prospects in a changing climate: A stochastic general equilibrium approach. Glob Environ Change 21: 701–710.
5. Belay A, Demissie T, Recha JW, Oludhe C, Osano PM, et al. (2021). Analysis of climate variability and trends in Southern Ethiopia. Climate 9: 96.
6. Berhane G, Paulos Z, Tafere K, Tamru S (2011) Foodgrain consumption and calorie intake patterns in Ethiopia. IFPRI 23: 1-17.
7. Bodner G, Nakhforoosh A, Kaul HP (2015) Management of crop water under drought: A review. Agron Sustain Dev 35: 401-442.
8. Emeka N, Ikenna O, Okechukwu M, Chinenye A, Emmanuel E (2021). Sensitivity of FAO Penman–Monteith reference evapotranspiration (ETo) to climatic variables under different climate types in Nigeria. JWCC 12: 858-878.
9. Ewaid SH, Abed SA, Al-Ansari N (2019). Crop water requirements and irrigation schedules for some major crops in Southern Iraq. Water 11: 756.
10. Jafari M, Kamali H, Keshavarz A, Momeni A (2021) Estimation of evapotranspiration and crop coefficient of drip-irrigated orange trees under a semi-arid climate. Agric Water Manag 248: 106769.
11. Molua EL, Lambi CM (2006) Assessing the impact of climate on crop water use and crop water productivity: The CROPWAT analysis of three districts in Cameroon. University of Pretoria: Pretoria, South Africa 44.
12. Roja M, Deepthi C, Devender Reddy M (2020) Estimation of Crop Water Requirement of Maize Crop Using FAO CROPWAT 8.0 Model. Indian J Pure Appl Biosci 8: 222-228.
13. Rost S, Gerten D, Hoff H, Lucht W, Falkenmark M, Rockström J (2009) Global potential to increase crop production through water management in rainfed agriculture. Environ Res Lett 4: 044002.
14. Solangi GS, Shah SA, Alharbi RS, Panhwar S, Keerio HA, et al. (2022) Investigation of irrigation water requirements for major crops using CROPWAT model based on climate data. Water 14: 2578.
15. Tanton TW, Heaven S (1999) Worsening of the Aral Basin crisis: Can there be a solution? J Water Resour Plan Manag 125: 363-368.
16. Teshome A, De Graaff J, Kassie M (2016) Household-level determinants of soil and water conservation adoption phases: Evidence from North-Western Ethiopian highlands. Environ Manag 57: 620-636.
17. Van Dijk M, Morley T, van Loon M, Reidsma P, Tesfaye K, et al. (2020) Reducing the maize yield gap in Ethiopia: Decomposition and policy simulation. Agric Sys 183: 102828.
18. Zotarelli L, Dukes MD, Romero CC, Migliaccio KW, Morgan KT (2010) Step by step calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method). IFAS 8.