NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

ESTIMATION OF CROP WATER REQUIREMENT USING CROPWAT 8.0 FOR DIFFERENT IRRIGATED CROPS IN ADDIS ZEMEN, AMHARA REGION, ETHIOPIA

M.Sc. THESIS

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We certify that we have read the thesis submitted by Henok Seman Debawo titled **“CROP WATER REQUIREMENT ESTIMATION BY USING CROPWAT 8.0 FOR VARIOUS IRRIGATED CROPS IN ADDIS ZEMEN, AMHARA REGION, ETHIOPIA** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby certify that every bit of data, documents, analyses, and results contained in this thesis were gathered and presented in accordance with the academic regulations and ethical standards of the Institute of Graduate Studies at Near East University. I also declare that as required by these regulations and conduct, I have totally cited and referenced data and information’s that are not unique to this study.

HENOK SEMAN DEBAWO

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Abstract

ESTIMATION OF CROP WATER REQUIREMENT USING CROPWAT 8.0 FOR DIFFERENT IRRIGATED CROPS IN ADDIS ZEMEN, AMHARA REGION, ETHIOPIA

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Water is the main governing element for agricultural productivity. Many water resources are being used for irrigation purposes. Irrigation systems are critical for increasing crop yield and meeting future food demand while guaranteeing food security. Reduced precipitation patterns due to the country's scarce water supply in the north and south east sides would have a substantial impact on livestock productivity and might threaten food security. High land areas have recently been at risk from drought, and patterns indicate that Ethiopia has seen an increase in this risk. The country's annual rainfall has varied greatly, indicating that huge seasonal anomalies in rainfall are a crucial factor in the intensity of the food supply. To manage irrigation effectively and to achieve optimal water resource utilization, it is essential to estimate the water requirements of diverse crops at varying levels of management. Using CROPWAT 8.0 the computer simulation model of FAO, the amount of water needed by various crops in the Addis Zemen District was determined. The goal of the simulation study was to calculate how much water would be needed to irrigate 14 different crops. Using CROPWAT 8.0, reference crop evapotranspiration (ET_O) and crop evapotranspiration (ET_C) were calculated for every crop. This study demonstrated the use of the CROPWAT model for estimating crop irrigation requirements for efficient water resources management.

Key words:crop water requirement (cwr), evapotranspiration (et), irrigation scheduling, irrigation, addiszemen district

ÖZET

ADDIS ZEMEN, AMHARA BÖLGESİ, ETİYOPYA'DA FARKLI SULANAN BİTKİLER İÇİN CROPWAT 8.0 KULLANARAK BİTKİ SU İHTİYACININ TAHMİNİ

HENOK SEMAN DEBAWO
MA, ÇEVRE MÜHENDİSLİĞİ BÖLÜMÜ
Mayıs, 2023, 74 sayfa

Su, tarımsal verimliliğin ana yönetim unsurudur. Birçok su kaynağı sulama amaçlı kullanılmaktadır. Sulama sistemleri, mahsul verimini artırmak ve gıda güvenliğini garanti ederken gelecekteki gıda talebini karşılamak için kritik öneme sahiptir. Ülkenin kuzey ve güneydoğu taraflarındaki kıt su kaynağı nedeniyle azalan yağış düzenleri, hayvancılık verimliliği üzerinde önemli bir etkiye sahip olacak ve gıda güvenliğini tehdit edebilir. Yüksek araziler son zamanlarda kuraklık riski altındadır ve desenler, Etiyopya'nın bu riskte bir artış gördüğünü göstermektedir. Ülkenin yıllık yağış miktarı büyük ölçüde değişti ve bu da, yağıştaki büyük mevsimsel anormalliklerin gıda arzının yoğunluğunda çok önemli bir faktör olduğunu gösteriyor. Sulamayı etkili bir şekilde yönetmek ve optimum su kaynağı kullanımına ulaşmak için, farklı yönetim seviyelerinde çeşitli mahsullerin su gereksinimlerinin tahmin edilmesi esastır. FAO'nun bilgisayar simülasyon modeli CROPWAT 8.0 kullanılarak, Addis Zemen Bölgesi'ndeki çeşitli mahsullerin ihtiyaç duyduğu su miktarı belirlendi. Simülasyon çalışmasının amacı, 14 farklı ürünü sulamak için ne kadar suya ihtiyaç duyulacağını hesaplamaktı. CROPWAT 8.0 kullanılarak, her mahsul için referans mahsul evapotranspirasyonu (ETO) ve mahsul evapotranspirasyonu (ETC) hesaplandı. Bu çalışma, verimli su kaynakları yönetimi için mahsul sulama gereksinimlerinin tahmin edilmesi için CROPWAT modelinin kullanıldığını göstermiştir.

Anahtar kelimeler: mahsulün su ihtiyacı (cwr), evapotranspirasyon (et), sulama planlaması, sulama, addiszemen bölgesi

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CHAPTER I
INTRODUCTION

1.1 Introduction

Water is one of the main agricultural inputs, supporting the expansion of irrigation agriculture. Because irrigated agriculture greatly contributes to food security, the eradication of poverty, and economic progress, effective management of an irrigation system is essential (Mozumdar L, 2012). To improve water management and handle related issues, comprehensive irrigation water management systems are required. (Awulachew, 2007). The bulk of Ethiopia's cropland is grown using a rain-fed method, despite the fact that the country's economy is primarily dependent on agriculture (Awulachew, 2010).

Although Ethiopia possesses a lot of water resources from precipitation, surface runoff, and subterranean sources, it has also seen severe drought for the previous 40 years, as well as large geographical and temporal changes in water supplies. Ethiopia experiences crop production failures as a result of the significant spatial and temporal unpredictability of rainfall. The need for food is escalating as a result of the population's rapid growth, which is expected to continue indefinitely (Merga, B., & Ahmed, A, 2019). Intense competition for water, unpredictable rainfall, a lack of resources, and climate change are just a few of the problems Ethiopian farmers face. The Ethiopian government began making large investments in the development of irrigation infrastructure during the past 20 years as a result of realizing these challenges.

One of Ethiopia's nine regions, Amhara National Regional State (ANRS) spans from 9° to 14°N and 36° to 40°E. It has aland area of total 1,61828.4 square kilometers (16,182,840 hectares), which stands for 11% of the country's entire area, and is home to an estimated 19.24 million people (ANRS BoFED, 2021 population projection).

Nearly 90% of the population of the Region is distributed spatially in rural areas, where agriculture is the primary economic activity. As a result, the agricultural industry provides the majority of the population with their primary sources of income and employment. Additionally, it contributes significantly to the nation's overall GDP and export revenues. Although the region has a high potential for agriculture, its productivity is still poor, largely because of unpredictable rainfall and outdated agricultural practices; its development has not been quick enough to keep up with the obstacles it has faced (Merga, B., & Ahmed, 2019). The industry's reliance on rain-fed production, the underuse of modern agricultural inputs, insufficient infrastructure development, subpar marketing, etc. are some of the key challenges that hinder the sector's quick expansion. Due to these limitations and the region's rapid population expansion, there are now widespread food shortage and poverty issues (Diriba, G., 2020).

The majority of farmers in the area engage in mixed farming, which involves raising both crops and animals. Rainfall is very important for crop production, which dominates the area's economy. However, the sector's production capacity is not keeping up with the region's actual demand. Food self-sufficiency is not guaranteed at the home level, especially in the region's woredas that are prone to drought.

The sector confronts at least two significant economic difficulties. The inability to produce enough grain crops to supply the region's fast expanding population with all of the food it needs is the first problem. The second issue is the inability to produce the raw materials and savings needed to boost the over development of the industrial catagory and the urban economy as a whole in order to create the employment opportunities needed to absorb the extra labor used in agriculture and to reduce poverty in both urban and rural areas.

The area, however, is rich in natural resources, including adequate irrigable land areas and water potential. According to estimates, the region's total irrigation potential is around 1,200,000 ha, of which 620,428 ha (51.7% of the total) are now being used for irrigation (ANRS BOA, 2012). To use these potentials, considerable effort and commitment are thus absolutely necessary. The expansion of irrigation on all scales enables a sustainable increase in agricultural output and helps smallholder farmers overcome the challenge of relying solely on natural rainfall. The Amhara regional government has created a strategy of sustainable irrigation development and environmental rehabilitation in accordance with the national government's irrigation development policies and strategies in order to reduce these production gaps. Through supplemental (throughout the rainy season) as well as full irrigation (on the summer), this technique aims foe reducing issues caused by unpredictable and unequal rainfall distribution. As a result, sustained and higher crop yields can be attained.

Crop water requirement is affected by thetype of crop, weather, growing seasons, soil type and frequency of crop output.Potential evapotranspirationand Kc (Crop Coefficient)value are two parameters influencing the result of the crop water need (ETo). Evapotranspiration is the combined effect of two distinct mechanisms in which the water escapes by evaporation against the soil surface as well as transpiration from the plant body.

When evaluating a crop's water requirements, a model must be evaluated before being employed in a new setting. With varied cropping patterns, CROPWAT 8.0 and CLIMWAT 2 supports the estimation of irrigation schedules, crop evapotranspiration alsoirrigational water requirements for irrigation management and planning. According to studies, the Penman-Monteith technique often generates more accurate reference evapotranspiration (ETo) predictions under a variety of meteorological conditions (Allen et al., 1998). Under the same weather conditions, diverse crops require varying amounts of water. It is One of the major aspects used in irrigation development,operation andplanning is the estimation of crop water requirement (ETc). Adeniran (2010) give extensive assessments of the approaches typically applied to quantify evapotranspiration and predict agricultural water requirements. Using the FAO-compiled software Cropwat 8.0 is one approach of determining the crop water requirement (P. Banik and S. Ranjan, 2014).

1.2 Problem statement

Farmers in the region generally conduct mixed farming where they raise crops and rear animals. In the study area agricultural output mostly rely on irrigation the command area may grow several kinds of crops However; the production capacity of the industry is lagging behind the actual demand of the region. In the study area the major problems are

- Using fixed amount of CWR for every year (dry, wet and normal years)
- CWR distribution is not considered in space all over the basin.
- • Farmers typically over-irrigate their agricultural land because they lack awareness of CWR and believe that excess water will result in a higher yield.
- Farmers do not have knowledge of irrigation schedule hence there is substantial loss of water due to superfluous irrigation

1.3 Objectives of the study

The study's objectives are as follows:

- Determine crop water requirements(CWR) of various crops in different climatic scenarios by examining the historical and prospective trend of precipitation, temperature, and evapotranspiration over the research area.
- To propose irrigation scheduling for the selected crops.
- To analyse crop factor (K_C) at different stages.

1.4 Thesis Organization

The first chapter explains the topic's introduction, problem statement, and study purpose, while the second chapter discusses past studies conducted on or connected to the study field. Furthermore, Chapter 3 will define and describe the study area, Chapter 4 will detail the methods and procedures used to achieve the study's objectives, Chapter 5 will discuss the research findings, and Chapter 6 will present the conclusion and recommendations.

CHAPTER II

LITRATURE REVIEW

2.1 Introduction

Water is essential to human survival. Without water, neither humans nor animals or plants can survive. Water covers over 70% of the earth's surface, however there is a relatively limited supply of pure water that may be used.

In the future, judicious use of water in agriculture will be critical, as water scarcity grows by the day, and this can be accomplished by applying the precise or correct amount of water at the exact or specific moment. One of the key components of the hydrologic cycle, reference crop evapotranspiration (ETo), is critical for calculating crop water requirements. CROPWAT is a practical tool designed to assist agronomists, agrometeorologists and irrigation engineers in performing basic calculations for evapotranspiration and crop water use studies, as well as the design and administration of irrigation systems.

Feng (2007) conducted a study to assess agricultural water requirements and irrigation schedule for wheat and cabbage crops in a designated location near the Water Resources Management and Engineering Institute in Samiala, Vadodara district, Gujarat, India. They concluded that irrigation should be done at critical depletion to guarantee that crop yields are reduced as little as possible.A simulation study was conducted with the goals of determining irrigation water requirements and irrigation schedule of spray-irrigated directed seeded rice (DSR) and wheat. They found that irrigation must be done at the critical depletion point to ensure that wheat yields are reduced by 0% and rainfall efficiency is maximized.

2.2 CWR. Crop water requirements

Crop water requirements are defined as "the depth of water consumed by a crop after accounting for unavoidable irrigation application losses." The CWR consistently refers to a crop cultivated in an ideal situation, such as a uniform crop that is actively growing, completely shade the ground, free of illnesses, and with favorable soil conditions (including productivity and water). As a result, the crop achieves its maximum output potential under the given growing conditions. The CWR is primarily determined by ETo, rainfall effects, soil conditions, and crop type (FAO, 1984). O. Toda (2005) studied potential as well as actual evapotranspiration using the Penman-Matis approach. The potential evapotranspiration throughout the growth season was

6.16 times higher than the normal evapotranspiration, according to the research. In a study conducted by U. Surendran in 2015, the CROPWAT model was employed to determine crop evapotranspiration and yield responses to water. In 2011, during the kharif season, an experiment was carried out at the Main Agricultural Research Station in Dharwad to examine the water needs of maize grown under rainfed conditions there. Ewaid (2019) carried out research on deficit irrigation, water conservation, and reducing theill effects of over irrigations.

CWR is the quantity of water (in millimeters) needed for a free of illness crop to evapotranspiration (ETc) by as much as it requires in order to grow in a big field with unlimited soil conditions,fertilityas well assoil water, and generate to the best of its ability in the given growing surroundings. The CWR, which stands as the sum of ETc throughout a crop's entire developmental period, which is related to the definition of ETc ("crop evapotranspiration") , which describes the average daily amount of evapotranspiration (millimetres per day) of a specific crop that can be affected by the crop's growth phases, conditions in the environment, and crop management in order to meet the crop's potential yields. ETa is the evapotranspiration rate that must be adjusted to current conditions anytime management or environmental variables stray from optimal. CWR and ETc ideas have the potential to benefit both irrigated and rain-fed crops.

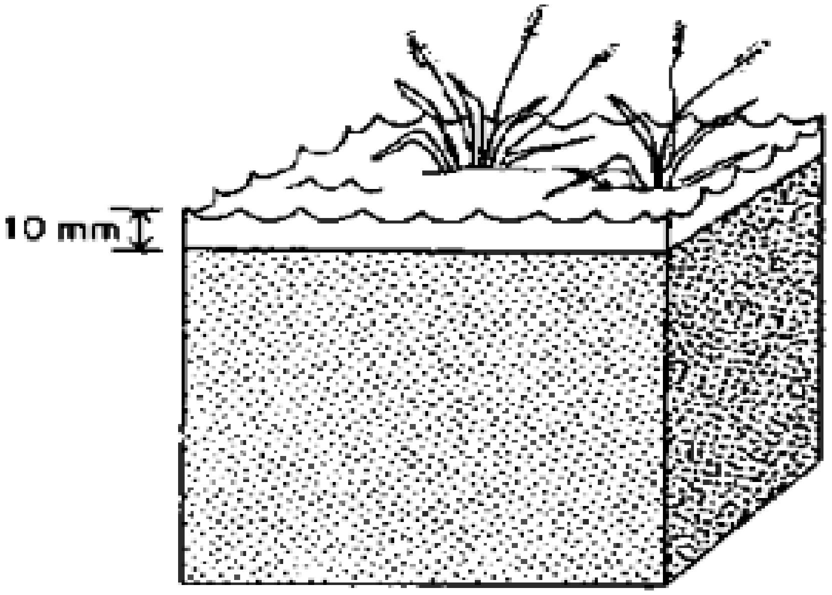


Fig 2.1 Crop water requirement of 10mm/day

The concept of IWR (irrigation water requirement), which is the gross water depth (millimetres) that must be given to a crop in order for it to entirely meet its specific crop water requirement, must be incorporated into the concept of crop water requirement (CWR) for irrigated crops. The IWR is a component of the CWR that cannot be met through rainfall, groundwater contribution, or soil water storage. This water depth is additionally included in IWR whenever a leaching fraction is needed to ensure adequate salt leaching within the soil profile. IWR must be transformed into gross irrigation needs in order to account for the effectiveness of the irrigation systems used.

2.3 Estimation methods for Potential evapotranspiration

There are many alternative potential evapotranspiration estimating techniques, but the choice of technique affects the hydrological model's hydrological model's simulation accuracy. The impact of various PET calculation techniques on the HBV model's simulation accuracy was examined by Lindstrom (1997). However, they discovered that the temperature-corrected Penman technique enhanced the simulation accuracy while that Priestley-Taylor method produced better results. As a consequence, the Priestley-Taylor approach was the most effective choice, as it increased the negative PET in wintertime by accounting for soil heat flow. There are three types of evapotranspiration estimating approaches based on their mechanisms: energy-based, mass transfer-based, and temperature-based. Using the concept of an energy balance, the energy-based approach predicts potential evapotranspiration.

According to Abtew (1996), Turc (1961), Makkink (1957), Jensen and Haise (1963), Priestley and Taylor (1972), McGuinness and Bordne (1972), Hargreaves (1975) as well as Doorenbos and Pruitt (1977) eight energy-based methodologies were compared by Xu and Singh in 2000. When Makkink, Priestley, Taylor, and Abtew used the Penman-Monteith approach, he discovered that the findings were superior than those of the other methods. Many researchers suggested certain temperature-based techniques when there were few climatic data available.the Hargreaves method, The Blaney-Criddle approach and the Thornthwaite method produce superiorresults of simulation than the other six types of temperature-based methods, according to an analysis of seven such methods conducted by Xu et al. in 2001. One of the earliest methods is mass transfer-based; it calculatespotential evaporation of free water surface and primarily takes into account the impact of wind speed and air pressure deficit (Singh et al., 1997).

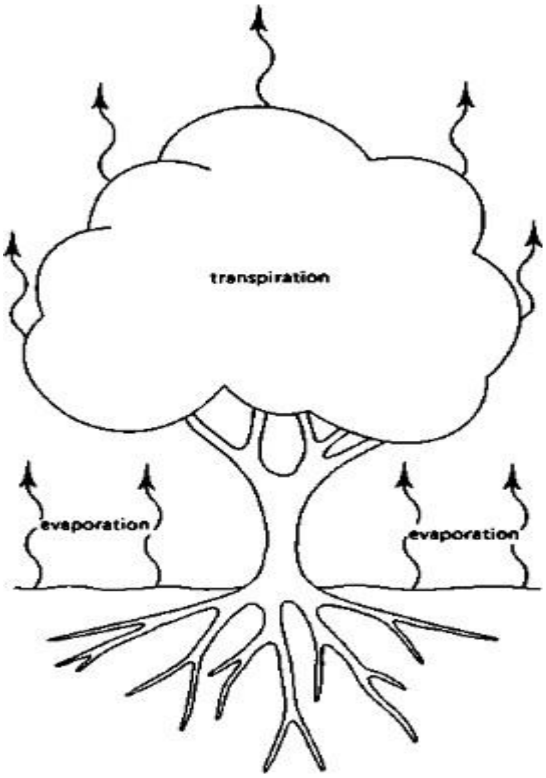


Fig 2.2 Evapotranspiration

In 1802, Dalton presented the initial approach to calculating potential evaporation, which Penman refined in 1948 using transfer of mass principles. The CROPWAT Model is utilized in this work for determining potential evapotranspiration. As an initial step in accurately estimating irrigation water requirements, Hashem A (2016) established a mathematical structure to quantify every day Reference Evapotranspiration (ETo). Furthermore, the model outcome was compared with ETo estimates generated by CROPWAT, an irrigation software program utilized for ETo computation and scheduling of irrigation. To create the basis for the evapotranspiration model, the FAO-56 PenmanMonteith equation and theSIMULINK protocol tool in the software program MATLAB were utilized. The model was validated through contrasting everyday evapotranspiration estimates against Class A pan as well as evapotranspiration measurements in the United States of America. Each day's ETo computed by the model and that measured by the Class A pan and evapotranspiration gauge fit each other well, according to the data.

Tarate (2017) focused on estimating reference evapotranspiration (ETo) with CROPWAT software and 32 years of meteorological data. FAO-56 Penman-Monteith is the recommended standard method for assessing the reference evapotranspiration (ET0).

2.4 Irrigation Scheduling

Irrigation scheduling entails determining when and what quantity of water to deliver to a soil. Water should be applied at the proper time as well as in the appropriate amount to increase production while decreasing negative environmental impacts. Due to poor scheduling, either excessive water was consumed or it was delivered too rapidly, resulting in excess watering, or inadequate moisture was supplied or it was supplied at an incorrect moment, leading in underwatering. Irrigation too little or too much might result in decreased production, poor quality, and inadequate fertilizer use. Production of crops and water consumption efficiency is often low. The plants use 40 to 60 percent of the water efficiently; the remainder is lost through runoff, evaporation or percolation onto the farm's groundwater. When done correctly, the scheduling of irrigation can be a wise technique for increasing farm water effectiveness. Irrigation scheduling ensures that water is continuously given to plants while also distributing it in proportion to the crop's needs. Consider irrigation scheduling, watering at 100% critical depletion, irrigation over predetermined intervals for each stage, and irrigation application type when using CROPWAT. Fill the field to the brim with soil moisture. Irrigation Scheduling Benefits

- Allow farmers to schedule irrigation in order to bring down crop water stress and boost yields.
- By applying a smaller irrigation, farmers can reduce labor and water costs while increasing the quantity of moisture held in the soil.
- Lower fertilizer costs by minimizing surface runoff and deep percolation (leaching).
- Improving crop yields and quality to boost net returns.
- Cut down on drainage needed to avoid the accumulation of water problems.

The signs used to determine if irrigation is required are irrigation criteria and irrigation scheduling. Both soil moisture content and soil moisture tension are common irrigation requirements. The amount of soil moisture needed to start irrigation depends on the irrigator's plan and objectives. Maximizing yield is the objective here. As a result, the irrigation system will work to maintain soil moisture levels above the point at which plants begin to wilt. The yield can be less than the highest possible yield if soil moisture goes below this mark. As a result, irrigation is used whenever the essential level of soil water content is reached. By avoiding crucial soil water deficiencies that lower crop yield or by providing both water and nutrients needed by the crop at a more "optimum" time for that crop, irrigation scheduling may in some situations actually increase irrigation water use while simultaneously boosting crop production. In fact, breaking down ET into its constituent parts and expressing the seasonal irrigation needs is more illuminating. According to El-Tantawy et al. (2007), irrigation scheduling is a strategy used to precisely and timely provide water to a crop. Crop monitoring and soil data are the foundations of irrigation scheduling techniques (Hoffman et al., 1990). However, employing more effective technologytypically leads to an increase in water consumption. rather than a decrease (Whittlesey 2003). Improved irrigation planning can boost crop quality while decreasing irrigation expenses. Because crops respond to each of the soil and airborne environments, scheduling irrigation based on crop water status is more advantageous (Yazar et al., 1999).

CHAPTER III

THE STUDY AREA

3.1 Study Area Location

Lake Tanas upper basin ,Shine River as well as the watershed of Rib are both in the South Gondar Zone of Ethiopia's Amhara region. The study area (36 km2) was conducted on these two rivers. It is located 67 kilometers to the northwest of Debre Tabor and 747 kilometers north of Addis Abeba, the country's capital. The location of the area, which is on average 1975 meters above sea level, is 36° 63'41.44"Eand 13° 38'24.84"N, respectively. The average mean daily minimumandmaximum rainfall in this area, according to the Ethiopian Meteorology Agency, are approximately5mmand 150mm, respectively. The average minimum and maximum temperatures in the research region are 14° C and26° C respectively, with an overall average temperature of 20° C. The scarcity of water is one of the barriers to this region's economic growth and agricultural productivity. The research region natural land use and cover is a plain, unpolluted environment that is appropriate for irrigation activities in agriculture. In this aspect, water management has become a crucial step that must be taken.

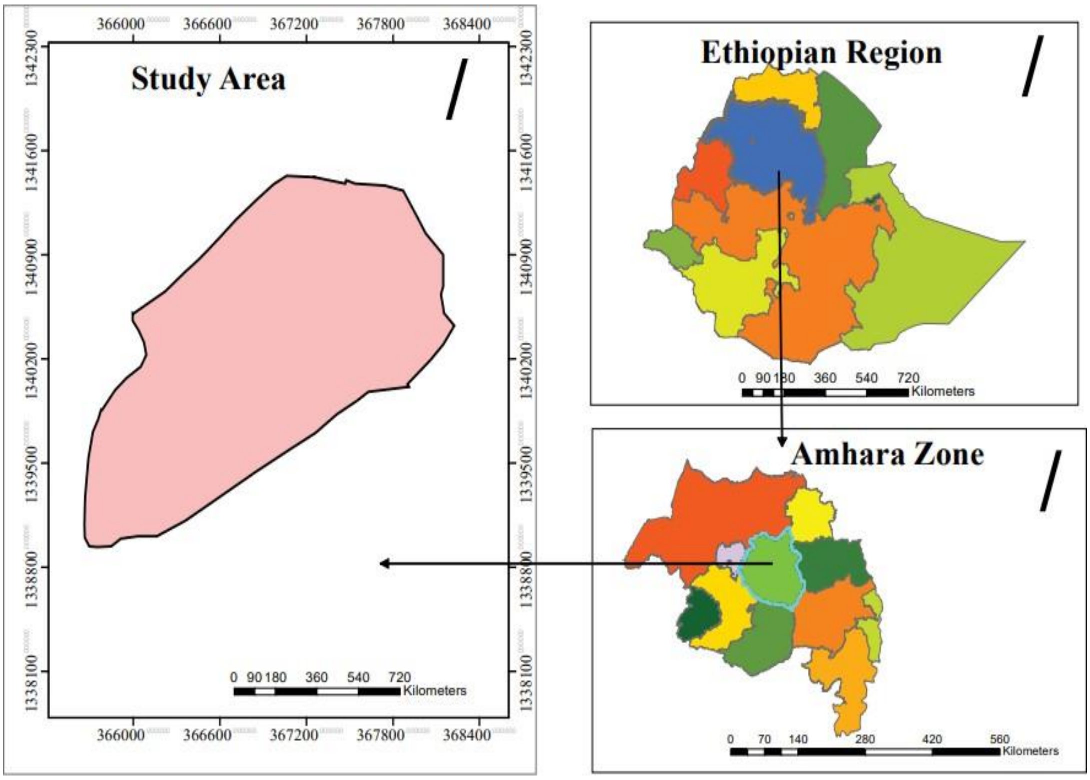


Fig3.1 Study areaLocation

3.2 Water resource

The topography, climate, and water resources of Ethiopia are all complex. Rainfall patterns in the country define the temporal and spatial variation of the country's water resource. During the three major wet seasons (June-August), the majority of streams flood to full and overflow the surrounding land. West direction flowing rivers (Baro-Akobo, Abay, Tekeze, and Omo-Gibe) get much more precipitation than northeast- and east-flowing rivers (Awash and Wabishebele, respectively). Although further research is needed, the country contains roughly 124.4 billion cubic meters (BCM) of river water, 70 BCM of lake water, and 30 BCM of groundwater resources. It is capable of producing 45,000 MW of energy as well as irrigate 3.8 million acres.

3.2.1 Water resources from the surface

Ethiopia comprises 99.3 percent mainland, with bodies of water accounting for the remaining 0.7% (MOWE 2013). There are 12 enormous lakes, 12 main basins, with several smaller bodies of water in the country (Fig. 6.5). Nonetheless, 3 of the major basins have no stream flow. Ethiopia has a surface water potential of 124.4 billion cubic meters (BCM), as discovered and predicted in various comprehensive basin of river strategic plans (Table 3.1), although this has to be updated and carefully assessed. Considering nearly all of the nation's rivers are transboundary, Ethiopia only receives 3% of the nation's expected yearly flow of streams, with the rest, or 97%, flowing into countries adjacent to it. Surface water, like rain, varies in space and time. Geographically, Ethiopia's major rivers flow in one of two directions, depending on their location relative to the Great Rift Valley, which divides the entire nation into two distinct regions: east and west.

The streams that flow west and enter the Nile basin emerge from Ethiopia's central mountains and western plateaus. These basins, which occupy 39% of the country's geographical mass, consist of the Mereb, Baro-Akobo, Abbay and Tekeze basins. This region contains the majority of the nation's surface water. It is estimated that it makes up more than 70% of total water flows in the entire area. The following segment comprises basins that flow east from the Eastern Highlands. It encompasses nearly 33% of the country's land area although possessing only 8% of the country's water on the surface. The basins along the southern portion of the Great Rift Valley are included in the remaining two segments. And rivers flow away from Meki, which is located in the heart of the Great Rift Valley, to the north and south respectively. The sole river basin in the nation with water flowing in a northeasterly direction is Awash, which has a land area of 10% and accounts for 4% of all surface water flow. It is the most frequently used basin in the nation. The southern flow portion is made up of two basins: the Rift Valley Lake plus the Omo-Gibe river. They comprise 5 percent for the land's surface and 18 percent of surface flow.

The country provides approximately 85 percent of the entire Nile water, primarily from June to September during the rainy season. The pattern of the nation's surface water's temporal variation mirrors the trend of its precipitation. River basins with two seasons of precipitation see distinct peak flows based on the changing seasons of the annual rainfall. Western basins, on the other hand, usually have a single rainy season and a single high flow month. Although the western lakes and rivers only receive rain for a single season, they're given the most and discharge it in three to four months. The majority of river basin master plan studies ignore the nation's open water systems' surface water resources (lakes, marshes, and flood plains). These devices can hold a lot of water. In the Awash River basin, for example, the Water Auditing Model Study (MoWE and FAO 2012) showes 5.7 BCM of water is held in the basin's lake and susceptible to evaporation, marshes, and flooding-prone areas. It is an indication that our surface water accounting technique has to be updated in order to fully understand the nation's surface water potential. According to our estimate of the country's greatest lakes, Ethiopia has 12 major lakes. They have a surface area of 7,300 km2 and a capacity of 70 BCM.

Table 3.1 shows the physical features and the mean annual flow from the surface at river basin outflows (source: individual basin master plans). The MoWE (2013) collated studies

No.	Basin name	Type	Source	Terminal	Water resource Billion m^3
1	Abbay	R	Sekela west Gojjam	Border ofSudan	54.4
2	Awash	R	Ginchi	Terminal lakes	4.9
3	Aysha	D	-------------	Djibouti borde	0.00
4	Baroo akoboo	R	Illubabbor	Border of Sudan	23.2
5	Dinakle	D	---------------	Kobar sink	0.9
6	Genaledawa	R	Bale mountains	Somali border	6.0
7	Mereb	R	Zalanbesa	Eritrean border	0.7
8	Ogaden	D	-------------	Somalia border	0
9	Omoo gibe	R	Amboo	lake Rudolph	6.6
10	The Rift valley lakes	L	The Arsi mountain	Border of Sudanese	3.4
11	Tekezze	R	Lasta or Gidan	Chew bahir	3.2
12	Wabishebele	R	The Bale mountains	Somalia border	0.5

3.3 Present situation in agriculture

3.3.1 System of Farming

Agriculture and related industries provide practically all of the livelihood for rural inhabitants in the project area and its surrounds. Kolla mixed farming, which is practiced by nearly all of the farming community in the project area, is a widespread agricultural method where animal production is carried out in addition to crop production (i.e., crop and livestock productions run side by side). In general, mixed-farming of field crops and livestock husbandry—particularly the rearing of cattle, goats, sheep, equines (donkeys), and camels—makes up the area's core agro-economic foundation.

Subsistence farming, with its usual attribute of low input-poor output productivity, characterizes the farming system, which produces the majority of the food in the region. The majority of crop production takes place in rainfed environments, making it regularly susceptible to natural whims and occurrences including unpredictable/erratic and uneven rainfall distributions, recurring droughts, and crop pest attacks. Production of irrigated agriculture in the region has not begun recently.

Currently, only smallholder farmers are cultivating the command area. The vast majority of the primary foods produced by farmers are produced on their land using the rainfed subsistence cropping approach. In the project region, irrigation farming is not a new practice; it is done on modest scales mostly by using water from river diversions and perennial springs.

3.3.2 Cropping System

One of the key determinants of the types of crops planted is the state of the market. Another is the physical environment, which drives farmers to grow similar combinations of crops. The following cropping systems are used when we visit the project area.

3.3.2.1 Mono-cropping

This method, in which cereals are rotated with other cereals and so on, is not ideal from a scientific standpoint. After sorghum is cultivated in the area, some farmers also use mono-cropping, which involves growing only one type of crop, like sorghum.

This system has historically been run utilizing low input and inadequate management techniques, such as weed control and land preparation.

3.3.2.2 Intercropping

For rainfed crops, there is no intercropping practice used in the project area.

3.3.2.3 Crop rotation

Crop rotation: Farmers in the project region typically rotate cereals with cereals (such as sorghum with teff and vice versa); however, as long as the only pulse crop farmed there is chick pea, cereals with pulses rotation methods are uncommon. However, farmers occasionally alternate deep-rooted crops with shallow-rooted ones. Table 3.2 provides an illustration of the project area's normal crop rotation trend.

Table 3.2:The project area's current crop rotation practices (source: District agricultural development office)

Meher/Wet Season (1st)	Meher/Wet Season (2nd)
Sorghum	Sorghum/teff
Teff	Sorghum/chick pea
Chick pea	Teff/sorghum
Maize	Teff/chick pea/sorghum
Meher/Wet Season (1st)	Irrigated/Dry Season
All crops	Vegetables(onion), maize, teff

3.3.3 Irrigated Agriculture and Current Practices

Farmers were forced to adopt conventional irrigation systems throughout the course of the project region due to the existing low crop productivity or production capacity (i.e., mostly because of the unpredictable/unreliable nature of rainfall, uneven rainfall distribution, crop pest attacks, and population pressure). As a result of irregular rainfall patterns and a lack of cropland, irrigated agriculture has been progressively growing. By building traditional Intake structures, irrigation agricultural production has been established using water from the wadi Gobu in the project area. As a result, the project area uses a two-season agricultural production system. The first is rainfed crop production, which accounts for about 93% of the annual cultivated land and approximately 66% of the annual income. The second is traditional irrigated crop production, It provides for around 7% of total cultivated land surface and 34% of yearly gross output.

3.3.4 Production and Yields of Crops

The Jarota (04) Kebele Agricultural Development Office provided data on the 2020 annual irrigated crops area and yield estimation, which showed that a total of 153.5 hectares of land were covered by irrigated crops and that the kebele produced roughly 29,282 quintals. It accounts for around 1.8% of the woreda's total irrigated land area (see Table 3.3). However, due to several technical and societal factors, conventional irrigation as it currently exists is not diverse. As a result of conventional management techniques and limited input usage, crop productivity is thus relatively low (see Table 3.3). Furrow irrigation and flooding are the two most popular irrigation techniques in the project area for practically all crops.

Table 3.3: Traditional irrigated agricultural output yield data currently available for the year 2020 (sour1ce: District agricultural development office)

No.	Crop type	Cropped area (ha)	Productivity (qt/ha)
1	Onion	3309.5	220
2	Pepper	320	15
3	Cabbage	442.2	150
4	Tomato	504.6	200
5	Carrot	79.35	8
6	Lettuce	79.35	90
7	Barley	11	25
8	Wheat	14.5	20
9	Maize	406.5	80
10	Teff	2601	14
11	Chick pea	397	16
12	Lentil	29	9
13	Field pea	11	11
14	Avocado	3	150
15	Papaya	12	250

16	Orange	10	150
17	Mango	94	200
18	Banana	35	350
19	Sugarcane	158	1250
20	Hops	5	150
	Total	8,522	3358

In terms of irrigation development support services, Raya Kobo Woreda Agriculture Development Office, like other woredas in the area, has already implemented irrigation and drainage work processes.

CHAPTER IV
MATERIALS AND METHODOLOGY

4.1 Materials

4.1.1 Metrological data

Climate has a significant impact on the nature of natural flora, soil properties, crops that may be cultivated, and the sort of farming that can be conducted in every place. The climate of a region is closely tied to its vegetation and, as a result, the sort of crop that may be grown there. The key climate factors are as follows

4.1.1.1 Rainfall pattern

The rainfall pattern in the project region is unpredictable and partially bimodal. The primary rain season (called locally as Meher or Kiremt) lasts from late June to late September, with an average annual rainfall of 228.25mm. Approximately 34.6% of the yearly rainfall falls between October and May (Belg). During the wet season of June to September, dependable rainfall varies between from 110 mm (June) to 355 mm (July) low and high respectively. The fact of unreliable/erratic and irregular distribution of rainfall is the key bottleneck for productive crop growth in the project region. The heaviest rainfall occurs in August and July, with greater intensity and regional spread. If rainfall had been uniformly distributed throughout the wet seasons, a year's worth of precipitation would be considered enough for crops that are grown during the rainy seasons where Maher crops are grown. In general, the region is distinguished by variable and unequal rainfall distribution. The current unreliable rainfall and uneven distribution makes traditional rainfed crops production difficult. As a rule of thumb, the amount and duration of rainfall affects the moisture content and nutrient status of soil, which in turn determine the growing periods and type of crops to be cultivated in wet seasons. Addis Zemen meteorological station rainfall data has taken to represent the project area.

Table 4.1 Monthly rainfall data (Source CROPWAT)

	Rain Mm
January	6.0
February	2.0
March	0.0
April	11.0
May	32.0
June	110.0
July	355.0
August	319.0
September	129.0
October	51.0
November	13.0
December	4.0
Total	1032.0

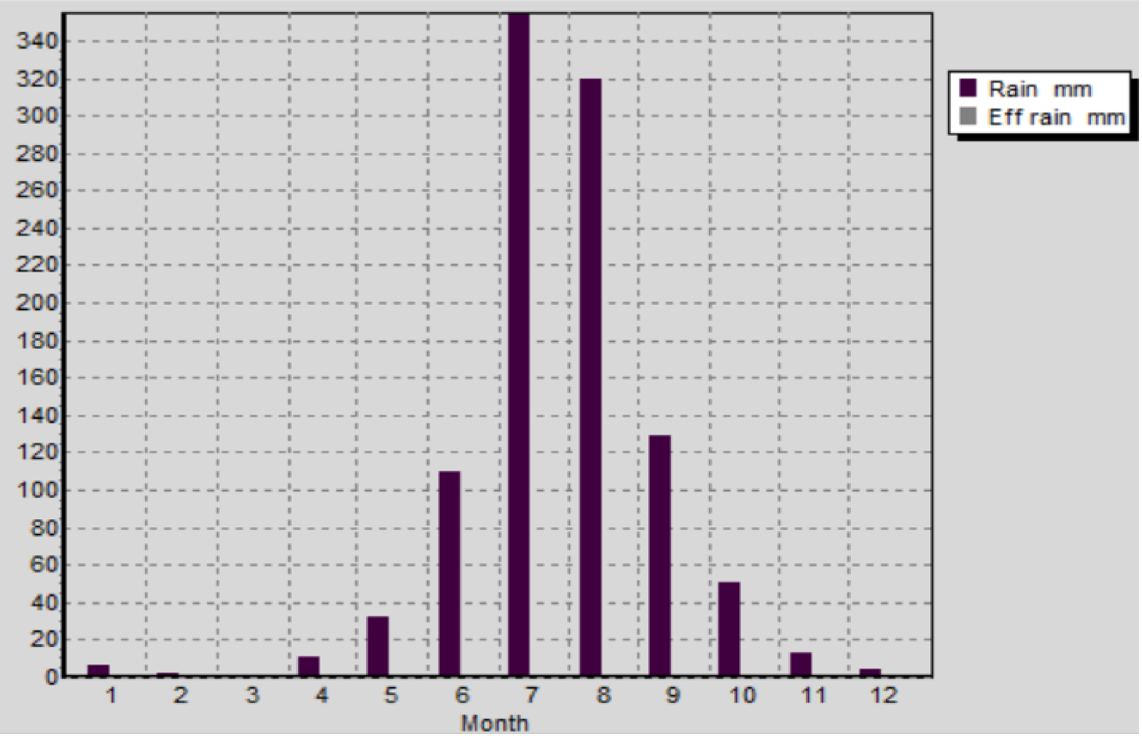
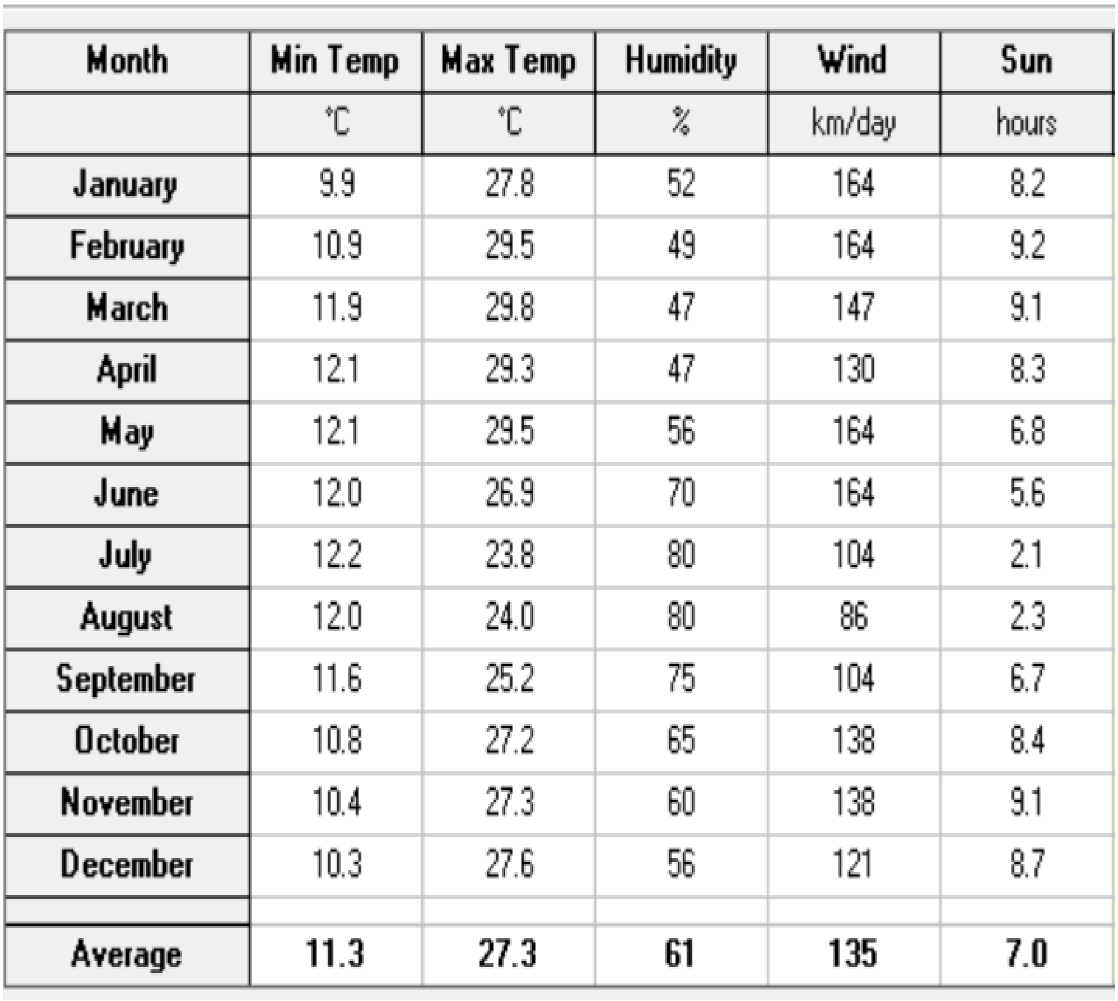


Fig 4.1: Rainfall chart (source: CROPWAT)

4.1.1.2 Temperature, Relative Humidity, Wind Speed & Sunshine Hour

The minimum temperature variations throughout the year are somewhat wider (9.9 °C in January to 12.2°C in July), whereas humidity values vary from 47% in March and April to 80% in July and August. Maximum temperatures over the year vary within a range of 23.8°C (July) to 29.8°C (march) and Wind speeds are relatively high and varies from 86km/day (in August) to 164km/day (in January, February, May and June). Sunshine duration is reduced due to cloud cover; and values vary from 2.1hours (in July) to 9.2hours (in February) during over the year.

Table 4.2 Temperature, Relative Humidity, Wind Speed & Sunshine Hour (source: CROPWAT)



Month	Min Temp	Max Temp	Humidity	Wind	Sun
	°C	°C	%	km/day	hours
January	9.9	27.8	52	164	8.2
February	10.9	29.5	49	164	9.2
March	11.9	29.8	47	147	9.1
April	12.1	29.3	47	130	8.3
May	12.1	29.5	56	164	6.8
June	12.0	26.9	70	164	5.6
July	12.2	23.8	80	104	2.1
August	12.0	24.0	80	86	2.3
September	11.6	25.2	75	104	6.7
October	10.8	27.2	65	138	8.4
November	10.4	27.3	60	138	9.1
December	10.3	27.6	56	121	8.7
Average	**11.3**	**27.3**	**61**	**135**	**7.0**

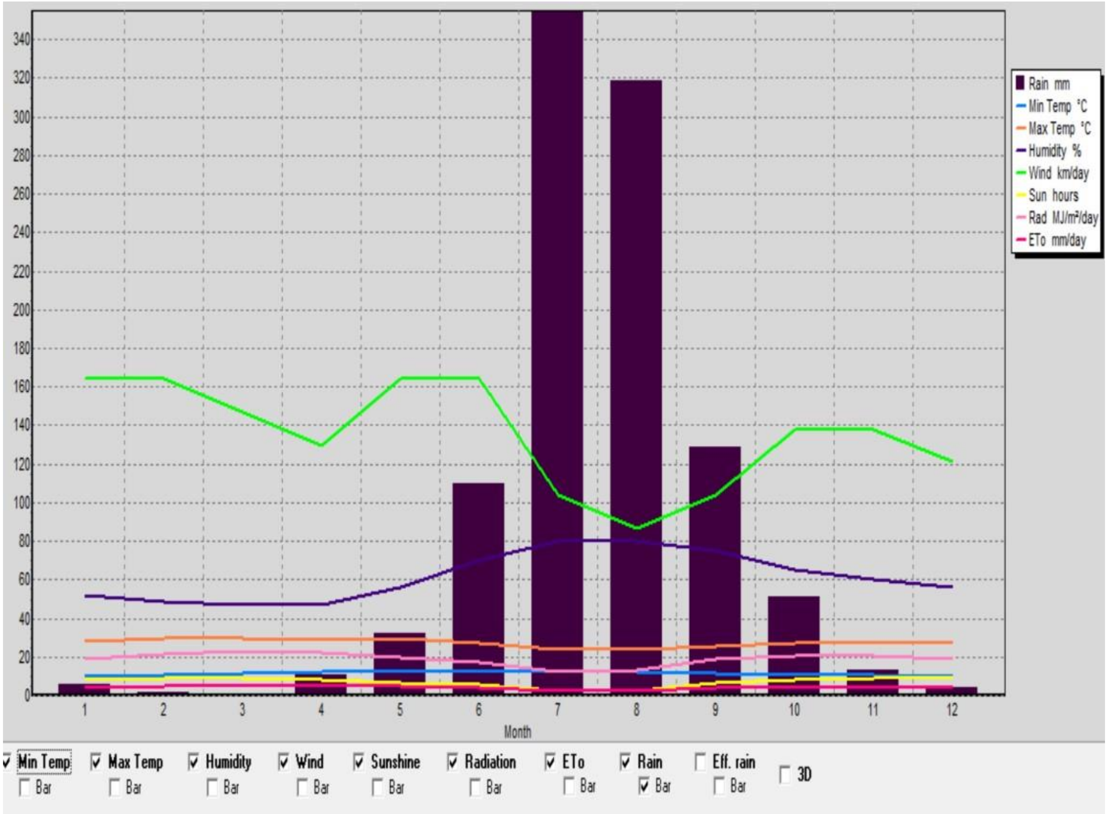


Fig 4.2 chart presentation ofTemperature, Relative Humidity, Wind Speed & Sunshine Hour (source: CROPWAT)

4.1.2 Soil data

Physical, chemical, and other aspects of the soil have a big impact on how well crops grow and produce. According to estimates, the command area's soils have a red loam texture in around 85% of cases.

4.1.2.1 Soil physical properties

a) Texture

The silt, sand, and salt proportions in a mass of soil refer to the texture of soil. The texture is required when assessing the soil's ability to hold moisture & air, which are both required for the development of plants. Higher particle content soils generally make it easier for water to travel faster throughout the soiland are considered to be wellaerated. Based onthe soil samplestested in the ADSWE lab, the findings suggested that this command area consists mostly of loam textured soil, which may be classified as well drained soil.

b) Effective soil depth

According to FAO, soil depth is categorized as follows:

Very shallow	< 30 cm
Shallow	30 – 50 cm
Moderately deep	50 – 100 cm
Deep	100 – 150 cm
Very deep	> 150

All of the soils in the research area are classified as extremely deep soils (>1.5 meters) because during the field operating period, the actual soil depth for the command region was measured.

4.1.2.2 Chemical Characteristics of Soil

a) Soil (PH)

PH of a soil generally gives an image of the quality of the soil, when it comes to crop selection and for crop growth as well.

Table 4.3 PH class for soil in general

Class	pH	Interpretation in General
Very high	>8.5	magnesium and calcium are scarce, and there is a possibility of excessive Na as well as B toxicity.
High	7.0-8.5	Decreased access to B and P above 7.0 increases the risk of Fe, Cu, Mn, Co and Zn deficiencies.
Medium	5.5 –7.0	Choosed by most crops' range
Low	<5.5	A Soil that is acidic. Potential toxic effects of aluminum as well as excess Co, Fe, Cu, Mn, as well as Zn. K, Ca, N, P, Mo,S deficit.

The command area's soils have PH values that vary from 6 to 7.1. According to Table 4.3's PH rating, the soil of the command has a medium PH level. As a result, the majority of the chosen crops can be cultivated on the command area's soil. Therefore, it must cultivate foods that can withstand high pH.High concentrations of salt are typically seen in pH value of 8.3 and above soil types. Soils having a pH under 5.5, on the opposite hand, are severely acidic and limit the accessibility of important nutrients (P and N).

c) Electrical conductivity (ECe)

The electricalconductivity (Ece) measurement of a soaked extract of soil (saturated), is the primary indicator to determine the soil’s salinity.Table 4.4 depicts the effects of salinity on crops measured by Ece of the saturated (soaked)soil extract. electrical conductivity (ECe) is expressed in dS/m (decisiemens per meter).

Table 4.4: Based on Fundamentals of Soil Science, 8th Edition, Ece in (dS/m).

Rating	EC (dS/m)	Crop Reaction
Non-saline	Less than 2	The effect of salinity are frequently minor.
Slightly saline	Between 2- 4	The Yields of crops that are very salt-sensitive may be limited.
Moderately saline	Between 4 – 8	Various crops have limited yields.
Strongly saline	Between 8 – 16	Only crops that can withstand salt can produce effectively.
Very strongly saline	Greater than 16	There are only minor crops that thrive when exposed to salt.

The main indirect impact of salts on plants is its impact on the osmotic water potential. Salt diminishes water potential, which lowers the pace at which roots and germination of seeds take up water. According to the results of the soil laboratory (ADSWE, 2014), the command area's soils have their ECe value that is ranging from 0.122 to 0.179 dS/m.

d) Total Nitrogen

According to Kieldahl's technique, Table 4.5 shows the overall grade for total nitrogen.

Table 4.5: General total Nitrogen Interpretation

N (%)	Class
> 1.0	Very high
0.5 - 1.0	High
0.2 - 0.5	Medium
0.1 - 0.2	Low
< 0.1	Very low

The top 0–60 cm of the command area soils have total nitrogen values ranging from 0.07 to 0.09%, indicating very low levels of Nitrogen(N) in the profile of the soil. Therefore, fertilizers of N soil respond quite well.

Available phosphorus

The Olsen method of bicarbonate extraction has been used to estimate the amount of available phosphorus (P). The command area's soils therefore displayed high available P values. The command soil has a range of accessible P from 1.51 to 6.74 mg/kg or PPM in the top 0–60 cm of soil.

Table 4.6: Olsen's method Interpretation of phosphorus

Available P (parts per million)	Value	Additional Comment
>15	High	Fertilizer is unlikely to be effective.
5–15	Medium	Potential fertilizer response
< 5	Low	anticipated fertilizer response

4.1.3 Crop data

4.1.3.1 Crop Basket Determination

The crop basket or list of crops growing in the project region has been produced and is given in Table 20 prior to the selection of potential crops for the proposed irrigation project. The crop basket is determined by the agro-climatic and soil conditions rather than just the list of crops that are currently growing in the project region. Because there are potential and acceptable crops that are not already found in the cropping patterns of the project area and that need to be taken into account in future development interventions, all feasible crops are included in the crop lists.

Table 4.7: The potential crop list for irrigation agriculture

Crop group	Type of crops
Cereals	Sorghum, maize, millet, teff
Pulses	Soybean, haricot bean, mung bean, chick pea
Oil crops	Sunflower, safflower, noug , ground nut
Vegetables	Onion, cabbage, tomato
Spices	Pepper, fenugreek
Fruits	Mango, avocado, banana, papaya, guava
Other perennial crops	Sugarcane
Fiber crops	Cotton
Stimulant crop	Coffee

4.1.3.2 Crops Selection Criteria

The smallholder farmers in the project region have two main goals when using irrigation agriculture on their plots of land: the first is to meet the family's food needs, and the second is to plant cash crops to supplement household income. The choice of crops for small-scale irrigation should take into account the best possible use of water, land, and labor to achieve the project's goals. Because the ultimate objectives of irrigation projects are connected to the enhancement of crop yields, crop selection is a key and determining procedure to assure the sustainable development of irrigation projects.

To address a variety of difficulties, the selection criteria for suitable crops should use a multifaceted approach. To make determining the selection criteria easier, the criteria or requirement could be divided into social, cultural, business, agronomic, and environmental sectors. Increased agricultural yield, high revenue generation, and soil fertility restoration are the three main objectives of the criteria.

The following factors are taken into consideration when choosing or selecting crops:

- The preferred crops grown by farmers and their prior cropping experience on commercial farms (including their familiarity with and past experiences with irrigated agriculture);
- Compatibility with irrigation technology and the specificagroclimate and soils (agro-ecology)
- Crop productivity and the potential yield.
- Market potential in domestic and international markets
- Crop potential for irrigated agriculture (crop irrigation features).
- LGP (length of growing period) of crops and the early maturing type.
- The potential of the water source for irrigation.
- Farmers' attitudes toward the adoption of new crops
- Availability of improved inputs and other adequate supplies of high yielding varieties.
- Marketability (Potential export market and high market value).
- The potential of the soil for maintaining it'sfertility;
- The intensity of cropping;
- Recurring prevalence of pest infestation;
- Community consumption patterns;
- Government policy and development strategies

4.1.3.3 Proposed Crops

Based on the above mentioned criteria for the selection of soil, the proposed crops for this study are;sorghum, maize (grain), Tomato, Soybean, Potato, Sunflower, Cotton, Barley, Pulses, Sweet Peppers, Cabbage, Tobacco, Green beans&Dry beans. The texture of the command soil is predominantly loam textured. Therefore, for specific crops, the starting point to find the cropping pattern of small scale farms is the sustainability or endurance of this loam-textured soil type.

4.2 Methodology

The decision-support tool CROPWAT 8.0 with CLIMWAT 2 is used for this study. The CROPWAT 8.0 software which is created by FAO to calculate crop water requirements (CWR) by using climate data, rainfall, crop andsoil data. Irrigation water requirement (IR), Reference evapotranspiration (ETo) and irrigation scheduling can also be calculated using the software. This program incorporates generic data for diverse crop characteristics, climate of the local area, and characteristics of soil to enhance schedules for irrigation and computing water supply for the entire schemeof varied patterns of crop in the cases of irrigationaswell as in the case of rain-fed. The CROPWAT software requires climate, rainfall, crop, and soil data.

The CROPWAT program makes use of the CLIMWAT 2.0 meteorological database to calculate irrigation water requirements for diverse crops at a variety of weather stations throughout worldwide. CLIMWAT contains monthly highest and lowest temperatures (in degrees Celsius), wind velocity (in kilometers per hour), sunshine hours (in hours),mean relative humidity (in percentage), rainfall information (in millimetres), and effective rainfall (mm). Some of the crop statistics integrated into the CROPWAT program from the FAO Manual 56 includes the response of yield factor, the depth of the root, the crop coefficient, the critical depletion, and the duration of stages for the growth of the plant as well. The Ethiopian Metrological Agency's handbook, which divides the year into wet and dry seasons, is used to establish planting dates. The information in the FAO CROPWAT model 8.0 presents soil parameters and provide specific information on the soil close to the climate station, such as the maximum rate of rainwater infiltration and rooting depth. This study employes the soil conservation (S. C.) method developed by the United States Department of Agriculture (USID).

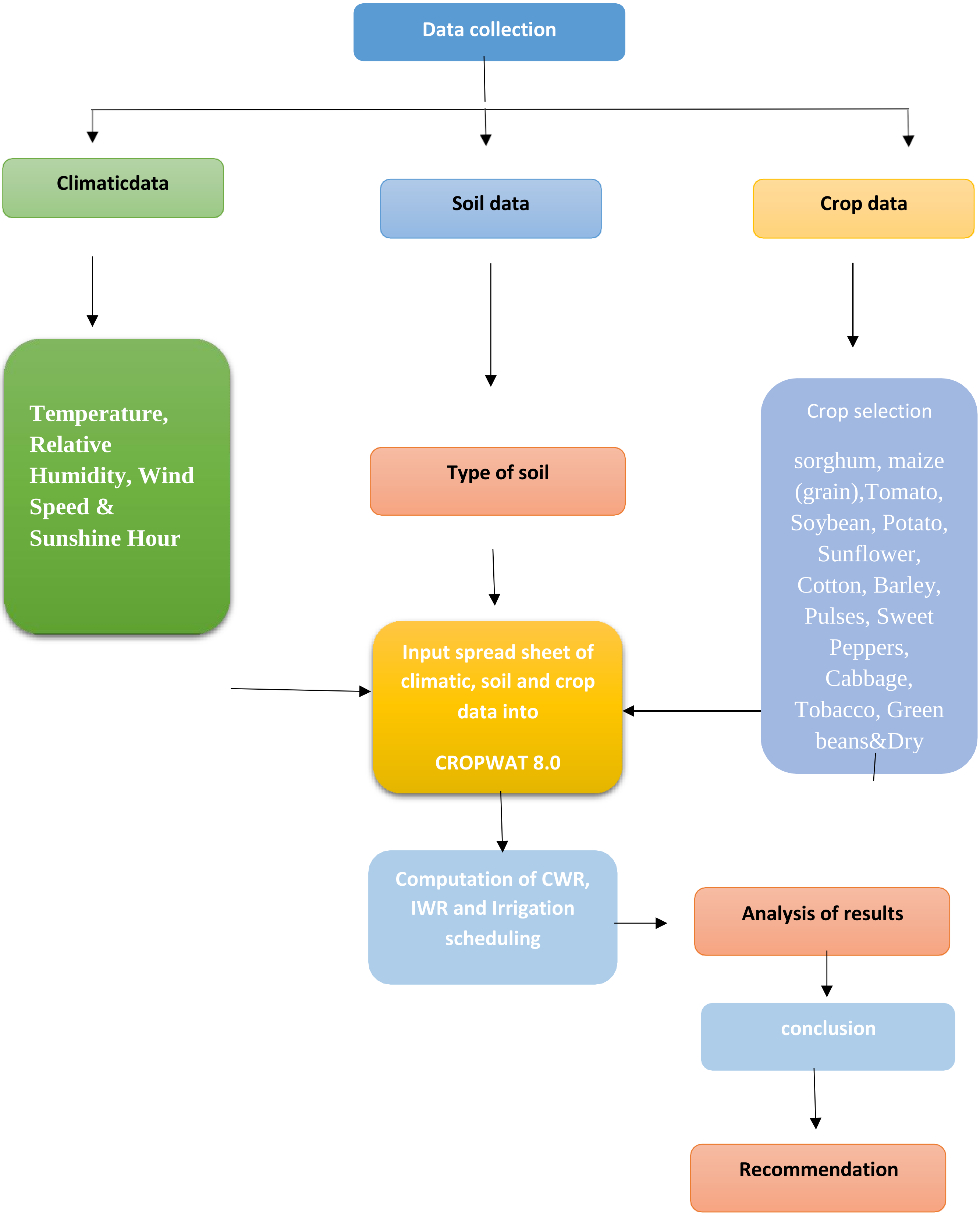


Fig 4.3 Graphical Representation of Methodology

4.2.1 CROPWAT

The FAO's Land and Water Development Division created the decision support tool CROPWAT to help in irrigation planning and management. In order to do conventional calculation on the requirements of crop irrigation, reference evapotranspiration, and more importantly, the management and design of the schemes of irrigation,CROPWAT is intended to be used as a practical tool. It enables the creation of suggestions for better irrigation techniques, the scheduling of irrigation operations under various water supply situations, and the evaluation of crop output under rain-fed or deficit irrigation.

In order to determine Etc (requirements of cropwater), the schedule of irrigation, and Eto (reference evapotranspiration), the FAOPenman-Monteith method is used by the computer application CROPWAT (FAO 1992). The application enables the creation of irrigation schedules under different management and water supply scenarios, as well as the assessment of rain-fed productivity, the consequences of drought, and the effectiveness of irrigation techniques (FAO 2002). Water resources engineers, agroscientists, and academics can all benefit from using CROPWAT as a practical tool to perform common evapotranspiration calculations and manage irrigation plans. Weather circumstances are what motivate this process, which involves using water to chill down plants. varying crops require varying amounts of water under the same climate and environment.

The application makes use of the aforementioned data, including the rainfall files, the CLIMWAT climate, and the same approach which is the Penman Moneith, as used in 5.7 & 7.0 versions of CROPWAT. The application makes heavy use of visuals, a configurable menu system, and file processing. It is simple to generate and print graphs showing the input data (climate, cropping pattern), as well as the outcomes (crop water requirements, soil moisture deficit). Multiple crops with staggered planting dates can be used to create complex cropping patterns.

The MPMAS model's application of the model of the crop growth under a deficit of water is summarized in this documentation. Henceforth, it heavily expands on its database of CLIMWAT and the model of FAO CROPWAT.The information on these databases provide reliable predictions for agricultural yield responses to water deficits with respectable global accuracy. It is crucial for an MPMAS application to have complete crop coefficient coverage for all economically relevant crops, and these crops should exhibit consistent and coherent behavior. We are aware that there may be more accurate models for specialized purposes. The software utilizes the same CLIMWAT climate and rain fall datasets as used in CROPWAT versions 5.7 and 7.0, as well as the same Penman Moneith approach. The application makes heavy use of visuals, a configurable menu system, and file processing. It is simple to construct and print graphical representations of the cropping pattern and climate (the input data), and the deficiency of moisture of soil, and CWR (the outcomes). With many crops and staggered planting dates, complex cropping patterns can be created. The equations used by CROPWAT for windows are the same as those used by CROPWAT 7.0, however there are some variations in the menu structure and the types of calculations that can be performed. Because the insinuating techniques that were utilized may be marginally not similar with those used in 7.0 version CROPWAT, there may occasionally be up to 2% differences in calculations. Therefore, if one alters or changes the insinuation (interpolation) methods from the default settings,the differences will be more noticeable.

The following capabilities are present in CROPWAT. Climate data are entered daily, monthly, and over a decade. Climate data estimation is possible even in the absence of measurements.

- Decade and daily calculations of crop water requirements based on updated calculation algorithms with crop-coefficient value adjustments.
- Dry crop calculations, as well as those for upland and paddy rice
- Soil water balance output Tables for the daily.
- User-defined irrigation schedule, as well as simple sessions storage and retrieval.
- A graphic display of the input data and computation outcomes.
- Simple clipboard or ASCII text file import/export of data and graphics.
- Comprehensive printing processes.
- Context-sensitive assistance system

4.2.2 Penman-Monteith Approach

Penman coupled the energy balance with the mass transfer approach in 1948 to develop an equation for calculating evaporation from an uncovered surface of water using traditional climatological observations of sunshine, humidity, temperature, and wind speed. Other investigators enhanced this so-called combined approach through including resistance factors and expanding it to crop surfaces. Given the atmosphere and conditions on the surface, the equation can be regarded as the maximum amount of water which might evaporate owing to the system's wind and solar power. The resistivity factor terminology differentiates between aerodynamic resistant and resistivity at the surface variables. The overall resistance of the surface parameter, which works in line alongside the aerodynamics resistance, is a prominent resistivity of the surface parameter pairing. Surfaces resistance (rs), is a barrier to vapor flow through openings of stomata,the soil and the entire leaf surface. The term "ra," or "aerodynamic resistance," refers to the upwards resistance generated by plants that encompasses airflow friction on vegetation surfaces. Despite the two resistance factors cannot completely describe the exchange process in a vegetation layer, there are good relationships among measured and calculated evapotranspiration rates, especially for a uniform grass reference surface.

A crucial hydrological cycle parameter that must be used in the study is evapotranspiration. Using the CROPWAT 8.0 program and the FAO 56 Penman Monteith method, reference evapotranspiration may be estimated for the entire research region. The daily reference evapotranspiration is calculated using the Penman-Monteith equation. Equation represents the mathematical formulation of the Penman-Monteith equation.

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \tag{1}$$

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].

4.2.3 Crop Coefficient (Kc)

Jensen (1968) pioneered the concept of Kc, which was built upon by other researchers (Doorenbos and Pruitt, 1975, 1977; Burman et al., 1980a, Burman et al., 1980b; Allen et al., 1998). The crop coefficient takes into account the effects of features that differentiate field crops from grass, such as ground cover, canopy quality, and aerodynamic resistance. It is the difference between real crop evapotranspiration (ETc) and reference crop evapotranspiration (ETo). To estimate ETc, the so-called two-step approach is utilized, in which ETo is first estimated, and ETc is then calculated as the sum of ETo and the Kc for the same day. Reference evapotranspiration is a measure of evaporative demand, whereas crop coefficient considers crop characteristics and management approaches (such as how often the soil is moist). It is unique to each vegetative surface and varies based on the crop's stage of development. Evapotranspiration varies during the season due to changes in the crop's morphological and ecophysiological features.

The Crop coefficient (Kc) integrates the effect of features that distinguish one crop from another. In the Crop coefficient approach, the Reference evapotranspiration (ETo) is multiplied by the appropriate Kc to determine Crop evapotranspiration under standard conditions (ETc).

$$ETc = Kc \times ETo \tag{2}$$

Crop type has the biggest impact on Kc, with the climate and soil evaporation having less of an impact. Additionally, the Kc for a certain crop changes as the crop grows. stages, as crop development affects crop height,ground coverand leaf area.Any cropKc value is most likely to be lower during planting and reach its peak during the middle of the growing season..

4.2.4 Crop Coefficient Curve

This evolution has been compiled by WMO (World Meteorological Organization) and FAO experts into a "crop coefficient curve" for determining the Kc value associated with the different phases of crop growth and development (early, mid, as well as late, thus Kc in, Kc mid, and Kc end) (Tarantino and Spano, 2001). For the vast majority of agricultural crops, Kc values grow from a low at planting to a high at about complete canopy cover. Following the crop season's total cover is reached, the Kc frequently begins to decline. The primary determinants of extent to the declination are characteristics of the growth of crop(Jensen et al, 1990), and irrigation administration during the growing season’s end-period (Allen et al., 1998).Seasonal distribution value of Kc is represented by a Kc curve, which is typically a smooth continuous function.

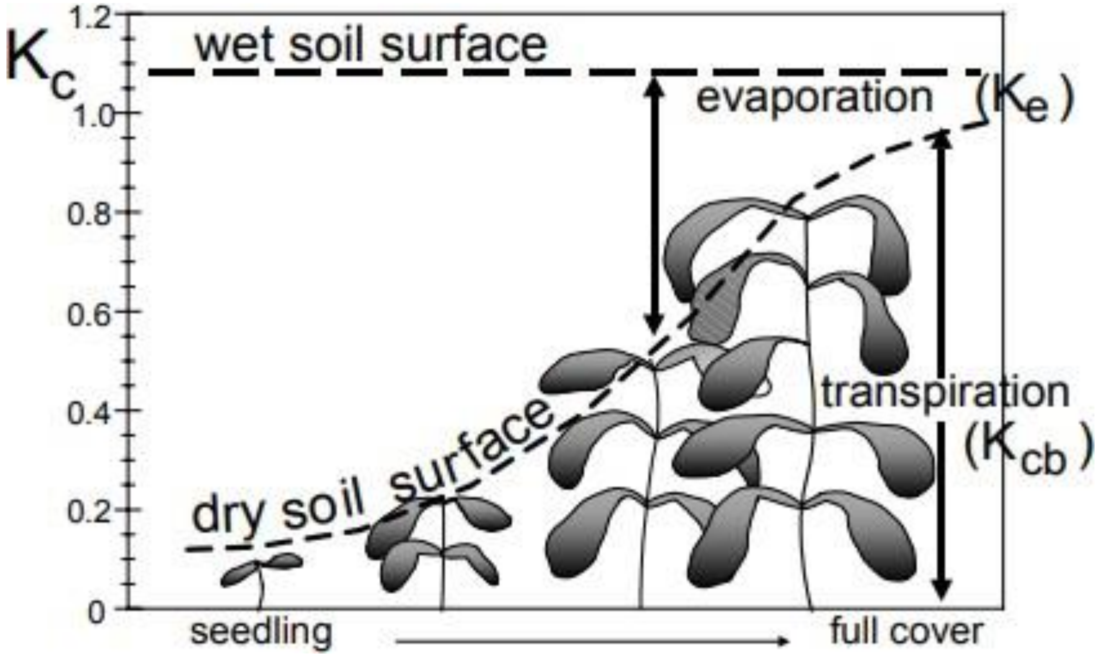


Fig 4.4 Kc is affected by evaporation. When the surface of the soil is kept consistently moist, Kc is shown by the horizontal line. While the soil surface remains dry, yet the crop getsadequate water to support transpiration, the curved line corresponds to Kc. With regard to seasonal crops, a crop's overall development lifetime can be sub-divided into 4 separate developmental stages:-

The intial phase: This phase lasts about 10% ground cover from plating point.

Development phase: This phase usually occurs when blooming starts and it lasts from 10% ground cover to a complete and effective total cover.

Mid-season phase: This period extends from effective full cover to the commencement of maturity, which is commonly characterized by the onset of ageing, leaf drop, fruit browning and yellowing or senescence of leaves.

Late season phase: This stage lasts from the beginning of maturation until harvesting or full senescence.

4.2.5 Crop Evapotranspiration (ETc)

The crop evapotranspiration is calculated by multiplying ETo by Kc, a coefficient which reflects the variation in evapotranspiration that exists between crop and benchmark grass surfaces.

The crop coefficient approach, which converts crop attributes into the Crop coefficient and incorporates the impact of various meteorological conditions into ETo, is used to calculate ETc.

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

A single crop coefficient incorporates the impact of both soil evaporation and crop transpiration.CWR (Crop water requirement) is the term used for describing the water amount which is needed by crops over the entire season.

4.2.6 Irrigation Scheduling

When the available rainfall is inadequate for the make up of the water that is lost through evapotranspiration, application of irrigation is necessary. Water application at the proper time and in the proper amount is the main goal of irrigation. The depth and time of upcoming irrigations can be planned by daily estimating the root zone soil water balance. The irrigation demand is calculated during a specific time period and represented in millimeters (mm) as the variation in theETc(evapotranspiration) of the crop during normal conditions and an effective contribution of rainfall in a similar timeframe.

The irrigation demand is the percentage of the crop's water requirement that has to be fulfilled in part by irrigation contribution to be able to assure the crop's optimal state for growth. However, it should be cautiously addressed because this metric fails to account to the crop's soil water input.

Calculations in the Schedule module generally result in a Soil Water Balance on a daily basis. This allows to:

- ✓ Develop indicative irrigation schedules to improve water management;
- ✓ Assess the efficacy of supplementary irrigation;
- ✓ Assess crop water productivity associated with current irrigation practices;
- ✓ Assess crop production under ram-fed conditions;

- ✓ Develop alternate water delivery schedules under limited water supply conditions.

Irrigation Scheduling can be carried out using following scenarios.

1. Irrigation at the point of critical depletion,
2. Irrigation at the point of fixed depletion,
3. Irrigation at the point of user defined intervals.
4. Irrigation atthe point of fixed interval per stage

In this study Irrigation at fixed interval per stage is used for the irrigation scheduling of the crops.

CHAPTER V
RESULTS AND DISCUSSION

5.1 Reference evapotranspiration (ETo)

Thevalues of ETo(potential evapotranspiration) are provided in Table 5.1 based on the calculations made using the Penman-Monteith Approach on CROPWAT 8.0. Maximum daily evapotranspirationpotential rate of 5.23mm occurred in March. If an evapotranspiration value is high, the crop water amount that's required will increase, because a lot of evapotranspiration implies high evaporation. On the other hand, if the value of evapotranspiration is minimum, the water requirement of crop's will also be minimal.

Temperature, relative humidity, and wind are the key elements influencing evapotranspiration. In general, evapotranspiration increases when temperature, humidity, solar thermal radiation and speed of wind rises. Photosynthesis is the mechanism through which solar thermal radiation impacts evapotranspiration. To manage the plant's life, water must flow by means of the system of root-stem-leaf. On an affected vegetation, a solar thermal radiation increase will speed up the water's movement from the root to the leaves (bottom to top movement).

Table 5.1: Long term monthly average climatic data of the study district

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	km/day hours	MJ/m²/day	mm/day
January	9.9	27.8	52.2	164.2	8.2	19.0	4.28
February	10.9	29.5	49.0	164.2	9.2	21.8	4.96
March	11.9	29.8	46.9	146.9	9.1	23.0	5.23
April	12.1	29.3	47.1	129.6	8.3	22.4	5.06
May	12.1	29.5	56.2	164.2	6.8	19.8	4.86
June	12.0	26.9	70.2	164.2	5.6	17.7	4.03
July	12.2	23.8	80.0	103.7	2.1	12.5	2.73
August	12.0	24.0	80.0	86.4	2.3	12.9	2.72
September	11.6	25.2	75.1	103.7	6.7	19.4	3.74
October	10.8	27.2	65.1	138.2	8.4	20.9	4.26
November	10.4	27.3	60.0	138.2	9.1	20.4	4.14
December	10.3	27.6	56.0	121.0	8.7	19.1	3.88
Average	11.3	27.3	61	135	7.0	19.1	4.16

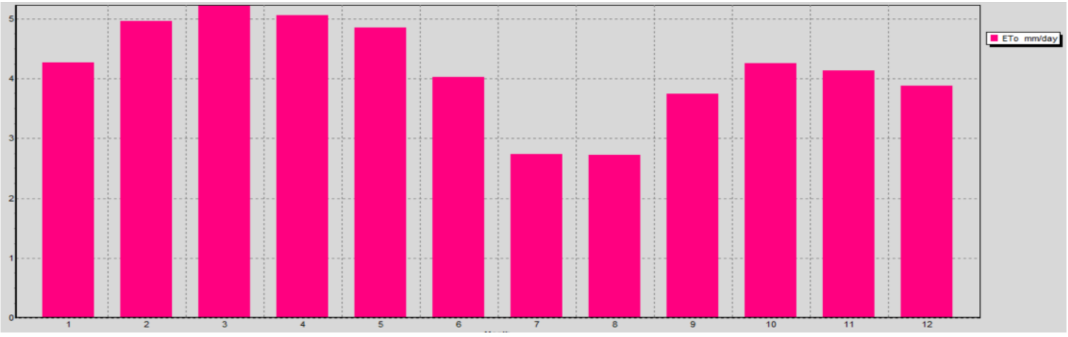


Fig 5.1 Graphical presentation ofmonthly average climatic data

The length and intensity of solar radiation are thought to be directly correlated with the impact of temperature on evapotranspiration. The drier and hotter climate shift, which results in rainfall reduction and also includes a rise in the mean of the temperature of air, generally leads to a greater decline of yield. For instance, it has been observed that photosynthesis is more efficient within the ideal range, however maintenance respiration rises with temperature, which may inhibit plant development by reducing the supply of assimilates. However, more research is required to determine whether the temperature of the leaves themselves, rather than the air around them, will have an impact on evapotranspiration.

By using the process of removing the water vapor that emerges from the leaves pores, the wind influences evapotranspiration, and the greater the power of the wind, the greater potential for evapotranspiration. In comparison to the radiation of solar thermal, the wind less affects the rate of evapotranspiration. Evapotranspiration is influenced by soil moisture, among other factors. When the vegetation has access to enough water, evapotranspiration occurs. Alternatively put. When soil moisture levels are between the wilting point and the field capacity, potential evapotranspiration occurs.

5.2 Crop Coefficient (K_c)

Crop coefficients (Kc) data were required in order to calculate the crop water requirement. Each type of crop has a different Kc value. The Kc values utilized in this investigation were fromFAO Irrigation and Drainage Paper No. 56 of Table 12 of. The four phases growth stage in general are initial stage, development, mid-season, and the late phase. While only three phases which are initial, mid-season, and late stages are known to be the value of Kc in the FAO book. In Table 5.2, the Kc values for each crop are listed.

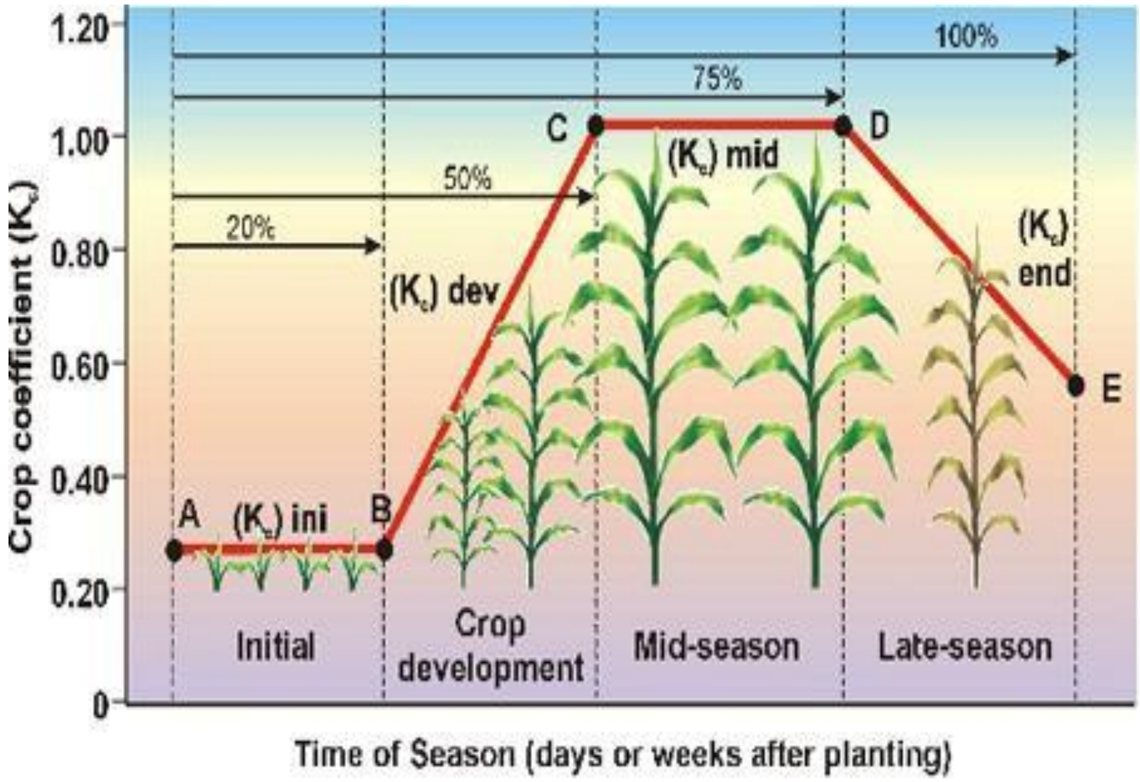
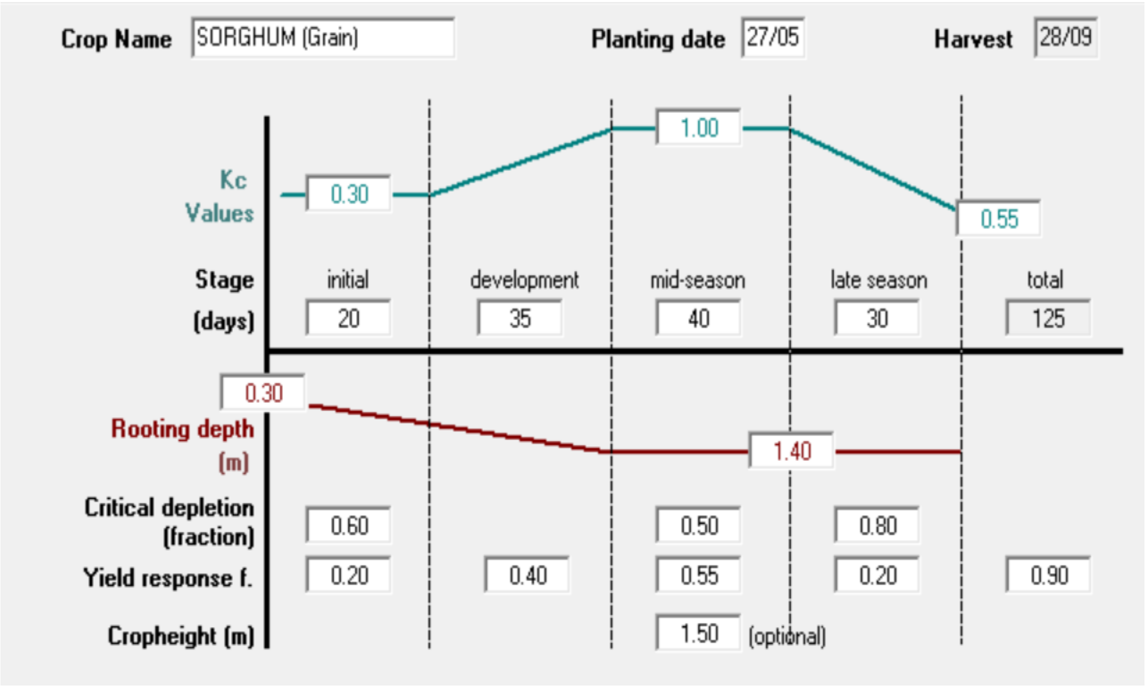


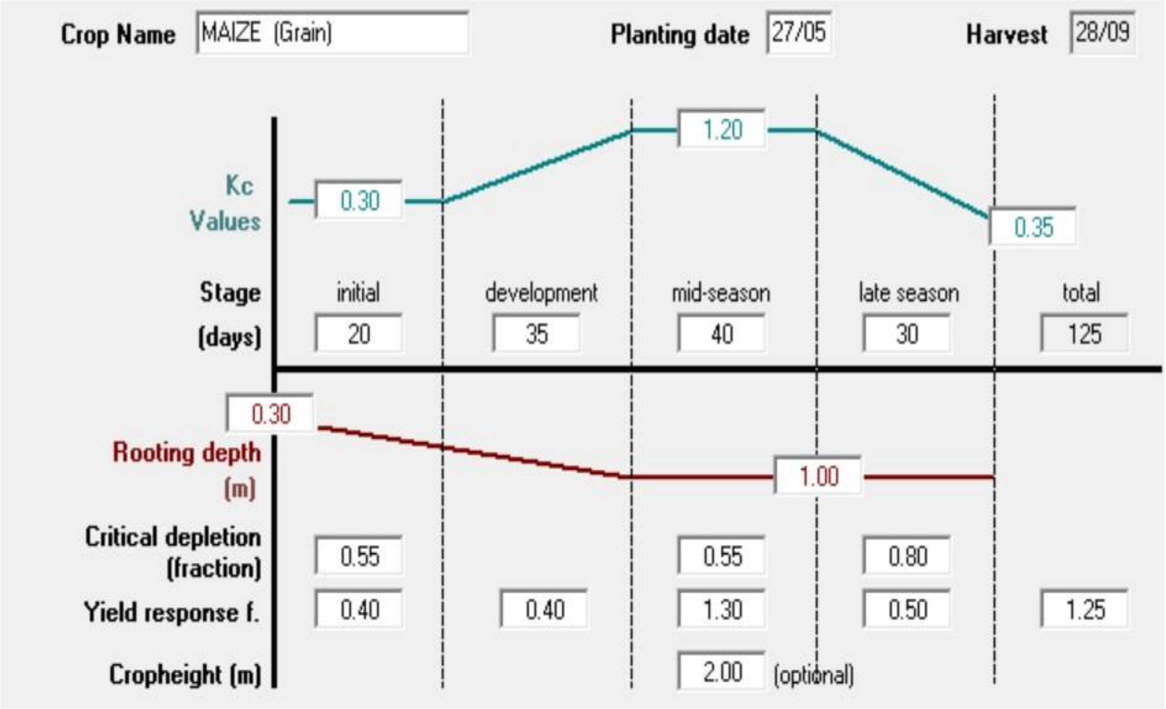
Fig 5.2 K$_c$ curve pictorial description



Crop Name: SORGHUM (Grain)
Planting date: 27/05
Harvest: 28/09

	initial	development	mid-season	late season	total
Kc Values	0.30		1.00	0.55	
Stage (days)	20	35	40	30	125
Rooting depth (m)	0.30		1.40		
Critical depletion (fraction)	0.60		0.50	0.80	
Yield response f.	0.20	0.40	0.55	0.20	0.90
Cropheight (m)			1.50 (optional)		

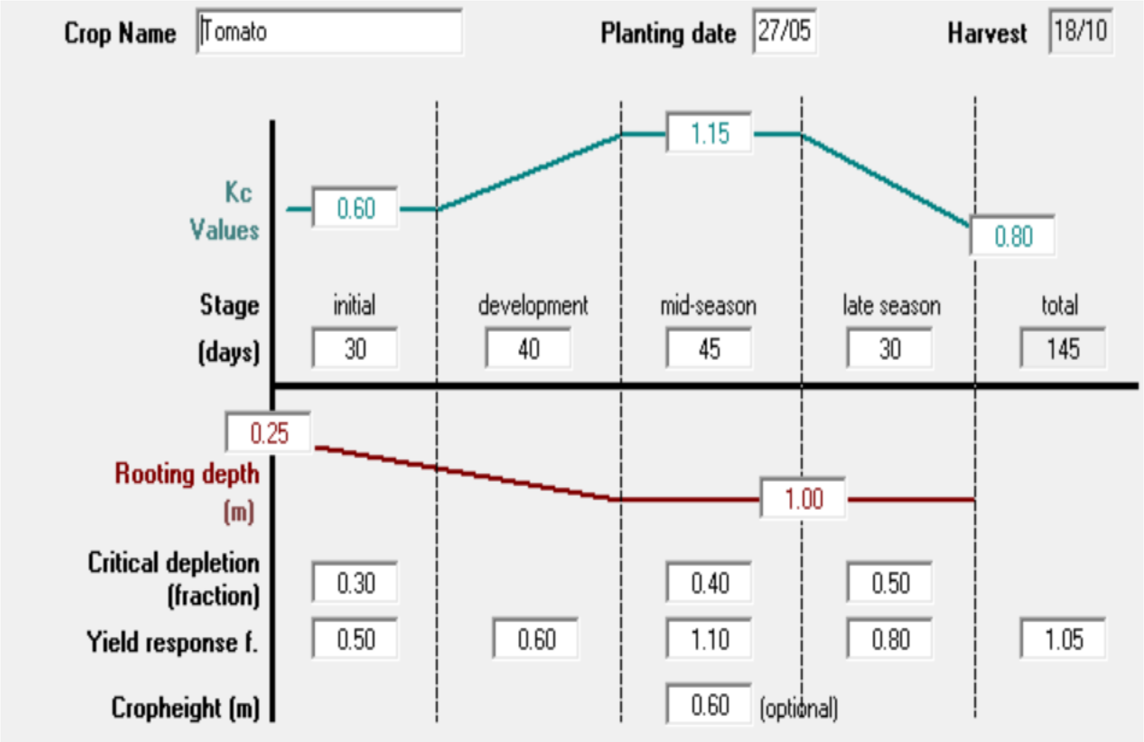
Fig 5.3: Sorghum K$_c$



Crop Name: MAIZE (Grain)
Planting date: 27/05
Harvest: 28/09

	initial	development	mid-season	late season	total
Kc Values	0.30		1.20	0.35	
Stage (days)	20	35	40	30	125
Rooting depth (m)	0.30		1.00		
Critical depletion (fraction)	0.55		0.55	0.80	
Yield response f.	0.40	0.40	1.30	0.50	1.25
Cropheight (m)			2.00 (optional)		

Fig 5.4: Maize K_c



Crop Name: Tomato
Planting date: 27/05
Harvest: 18/10

	initial	development	mid-season	late season	total
Kc Values	0.60		1.15	0.80	
Stage (days)	30	40	45	30	145
Rooting depth (m)	0.25		1.00		
Critical depletion (fraction)	0.30		0.40	0.50	
Yield response f.	0.50	0.60	1.10	0.80	1.05
Cropheight (m)			0.60 (optional)		

Fig 5.5: Tomato k_c

Table 5.2: Values of K_c for Different Crop

Crop type	Total stage date (Days)	K_c Values		
		Initial	Mid	Late
Sorgum	125	0.30	1.00	0.55
Maize	125	0.30	1.20	0.35
Tomato	145	0.60	1.15	0.80
Soybean	85	0.40	1.15	0.50
Potato	130	0.50	1.15	0.75
Sunflower	130	0.35	1.15	0.35
Cotton	195	0.35	1.20	0.60
Barley	120	0.30	1.15	0.25
Pulses	110	0.40	1.15	0.35
Sweet Peppers	125	0.60	1.05	0.90
Cabbage	165	0.70	1.05	0.95
Tobacco	110	0.50	1.15	0.80
Green beans	90	0.50	1.05	0.90
Dry beans	110	0.40	1.15	0.35

The value of Kc in the phase of development is believed to have the same value of Kc in the stage of mid-season because this phase's Kc value falls in between initial stage and the mid-season stage, with midseason having greatest value of Kc. Kc values are essentially consistent at 1.15 for all crops during the mid-season period. It demonstrates that when the value of Kc decreases from the mid season stage termination to the planting period's ending, the requirement for the amount of crop water in the stage of late season up to the growing season's end, decreases. When harvesting, the Kc value was at its lowest point of 0.25.

Yield response factor

In the late 1970s, FAO addressed the issue of crop output and water use and proposed a straightforward equation whereby a relative decrease in yield is correlated with a similar relative decrease in evapotranspiration (ET). The yield response to ET is specifically described as:

$$\left(1-\frac{Y_a}{Y_x}\right)=K_y\left(1-\frac{ET_a}{ET_x}\right)$$

equation (3)

In the above equation the maximum and real yields are represented by Yx and Ya, the maximum and actual evapotranspiration by ETx and ETa, and the yield response factor Ky is a measure of how yield losses are impacted by changes in evapotranspiration.

For all agricultural crops, Equation 1 can be used as a water production function. The intricate relationships between a crop's output and water use, where numerous biological, physical, and chemical processes are involved, are best summarized by the yield response factor (Ky). The relationship has demonstrated amazing validity and made it possible to quantify how water shortages affect yield.

According to growth stages, the Ky values are crop-specific and change over the growing season with:

Ky >1: When water use is decreased due to stress, the crop's response to the decrease in water availability results in proportionately greater production decreases.

Ky-1: Crop shows less than proportional production declines with reduced water use. Crop is more resistant to water deficit and partially recovers from stress.

Ky=1: A decrease in yield is inversely related to a decrease in water use.

Table 5.3: Yield response factor

Crop Type	Crop height (m)	Yield response factor				
		Initial	Development	Mid	Late	total
Sorghum	1.50	0.20	0.40	0.55	0.20	0.90
Maize	2.00	0.4	0.40	1.30	0.50	1.25
Tomato	0.6	0.5	0.6	1.10	0.80	1.05
Soybean	0.6	0.4	0.8	1.00	0.40	0.85
Potato	0.6	0.45	0.8	0.80	0.30	1.10
Sunflower	2.00	0.4	0.6	0.80	0.80	0.95
Cotton	1.3	0.20	0.50	0.50	0.25	0.85
Barley	1.00	0.20	0.60	0.50	0.40	1.00
Pulses	0.40	0.4	0.60	0.80	0.60	0.80
Sweet Peppers	0.70	1.40	0.60	1.20	0.60	1.10
Cabbage	0.4	0.20	0.40	0.45	0.60	0.95
Tobacco	1.2	0.40	1.00	1.00	0.50	0.90
Green beans	0.4	0.20	1.10	0.75	0.40	1.15
Dry beans	0.40	0.20	0.60	1.00	0.20	1.15

Table 5.4: Rooting depth at different stages

Crop Name	Rooting depth for different crops		
	Initial	Mid	Late
Sorghum	0.30	1.40	1.40
Maize	0.30	1.00	1.00
Tomato	0.25	1.00	1.00
Soybean	0.30	1.00	1.00
Potato	0.30	0.60	0.60
Sunflower	0.3	1.30	1.30
Cotton	0.30	1.40	1.40
Barley	0.30	1.10	1.10
Pulses	0.30	1.00	1.00
Sweet Peppers	0.25	0.80	0.80
Cabbage	0.25	0.50	0.50
Tobacco	0.25	0.80	0.80
Green beans	0.30	0.70	0.70
Dry beans	0.30	0.90	0.90

5.3 Crop Water Requirement (CWR)

Crops loose the same quantity of water as they require through evapotranspiration (ETc). In simple terms, crop water requirements are equal to the plant’s evapotranspiration.

The cropwater requirement for sorghum

Results from the data processed using Cropwat 8.0 reveal that the Kc value varies by decade. HighestKc values wererecorded from the mid-season stageduring the third decade of July until the late stage in August of the third decade.

The largest requirement of cropwater for the crop sorghum happens when it’s in its midseason stage and continues until the second decade of Sept (late season). On ht other hand, the lowest requirement of cropwater is in the first stage (Initial phase). When the crops are in the stages of producing fruit, they require the most amount of water because in the final stages of the season, it takes more energy in order to produce fruits. After that, the water requirement value reduces as fruit ripening process starts. The crop then enters into the harvesting stage where it’s growth has been optimized and no longer developing, and the crop is going to wilt.

Table 5.5: Crop water requirement of Sorghum

Month	Decade	Stage	K_c	ET_C mm/day
May	3	Init	0.3	1.37
Jun	1	Init	0.3	1.29
Jun	2	Deve	0.33	1.32
Jun	3	Deve	0.50	1.79
Jul	1	Deve	0.69	2.13
Jul	2	Deve	0.88	2.31
Jul	3	Mid	0.96	2.56
Aug	1	Mid	0.96	2.56
Aug	2	Mid	0.96	2.52
Aug	3	Late	0.96	2.87
Sep	1	Late	0.85	2.90
Sep	2	Late	0.71	2.66
Sep	3	Late	0.58	2.27
Total				28.55

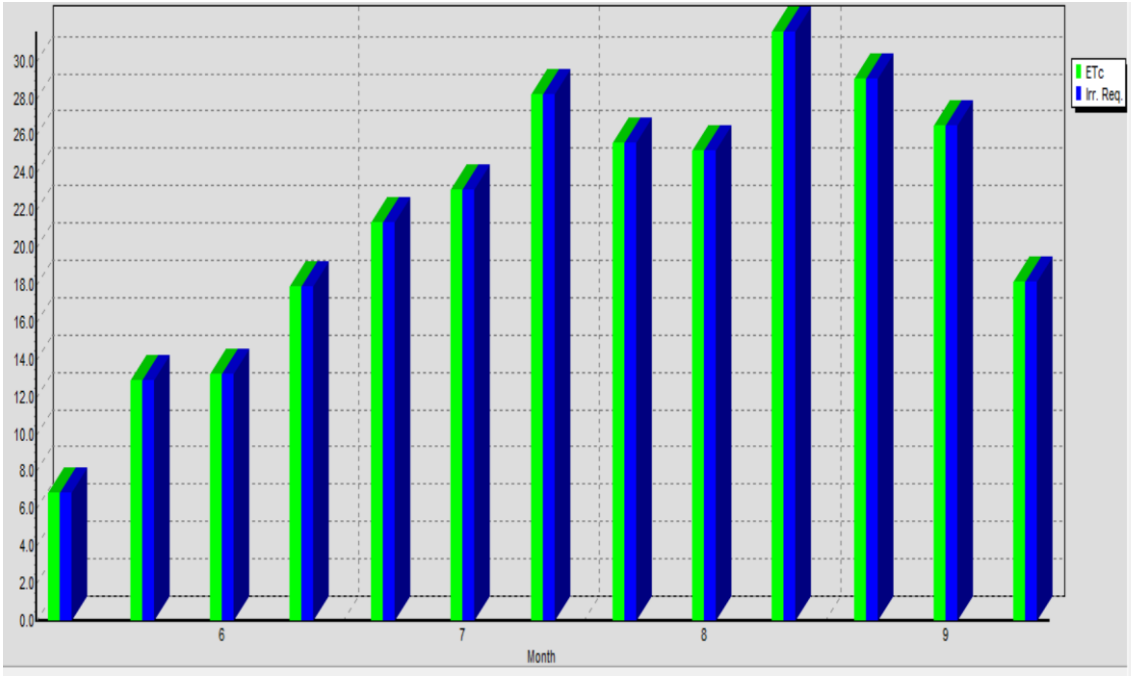


Fig 5.6: graphical presentation of crop water requirement of Sorghum

The above graph shows that the requirement of crop water needed in a period of 10 years (each decade) fluctuates due to the varying in the decadal potential evapotranspiration value. The value of crop water need increases continuously from the beginning to the final stages of the development phase. The requirement of cropwater in the mid stage stays largely constant, at about 2.56 mm/day. The requirement of cropwater continue slightly fluctuating from the mid-season stage until the late stage's ending. As the harvest approaches, crop water requirements drop in the late stage, beginning in the second decade of September.

During the flowering phase, the value of water requirements grows dramatically. Water is essential during the vegetative and reproductive stages. While the time leading up to harvest requires very little water. Then it correlates to the plant's increasing coefficient over the growing season, which decreases towards the end. The storage of more soil moisture in the profile in the red loamy soil, as well as the crop's lower water requirement during the maturity phase due to less green leaves, can explain the decreased water demand during the reproductive period. Cropwat 8.0 was used to establish the outcome of this crop water need calculation. The overall crop water demand was estimated to be 28.55 mm/day. In the short run, crops grown during the dry season require more water than crops grown during the wet season. Total water requirements for crops vary, but excellent productivity can be achieved with the optimum amount of water if all other agronomic rules are followed.

Cropwater requirement of maize

Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop.

The Maize growth to harvest phase lasts 125 days, beginning in May of the third decade, and ending in September of the third decade. The maize stage of growth lasts from the beginning to the end of the growing season. The starting stage lasts 20 days, the development stage 40 days, the mid-season stage 30 days, and the late-season stage 30 days. The crop water need for maize will vary depending on the Kc value and the total number of days in each development phase. Table 5.6 shows an estimate of crop water requirements for maize in every development stage. The largest crop water need comes during the midseason (third decade of July) and late stage (first decade of September), ranging from 3.08 mm/day to 3.25 mm/day. Whereas the least water demand throughout the growth stages occurred in the first decade of June, at 1.29 mm/day. Because the plant had not grown at this point, its water requirements were minimal.

Table 5.6: Crop water requirement of Maize

Month	Decade	Stage	K_c	ET_C mm/day
May	3	Init	0.3	1.37
Jun	1	Init	0.3	1.29
Jun	2	Deve	0.34	1.36
Jun	3	Deve	0.56	2.01
Jul	1	Deve	0.80	2.49
Jul	2	Deve	1.05	2.76
Jul	3	Mid	1.16	3.08
Aug	1	Mid	1.16	3.08
Aug	2	Mid	1.16	3.04
Aug	3	Late	1.15	3.45
Sep	1	Late	0.96	3.25
Sep	2	Late	0.69	2.57
Sep	3	Late	0.44	1.74
Total				31.49

During the growing season, the maize crop requires 31.49 mm/day of water. The figure is regarded normal because maize's water requirement ranges from 10mm/day to 40mm/day. Because no rainfall is considered in the computation of effective rainfall, the value obtained is the maximum required. During the first decade of June, eventhough there is a decrese in the requirement of cropwater, the demand of water in from the early to the mid season phase keeps growing. Between the mid-season and late-season stages, crop water requirements were roughly comparable. During harvest, water demand is at its lowest.

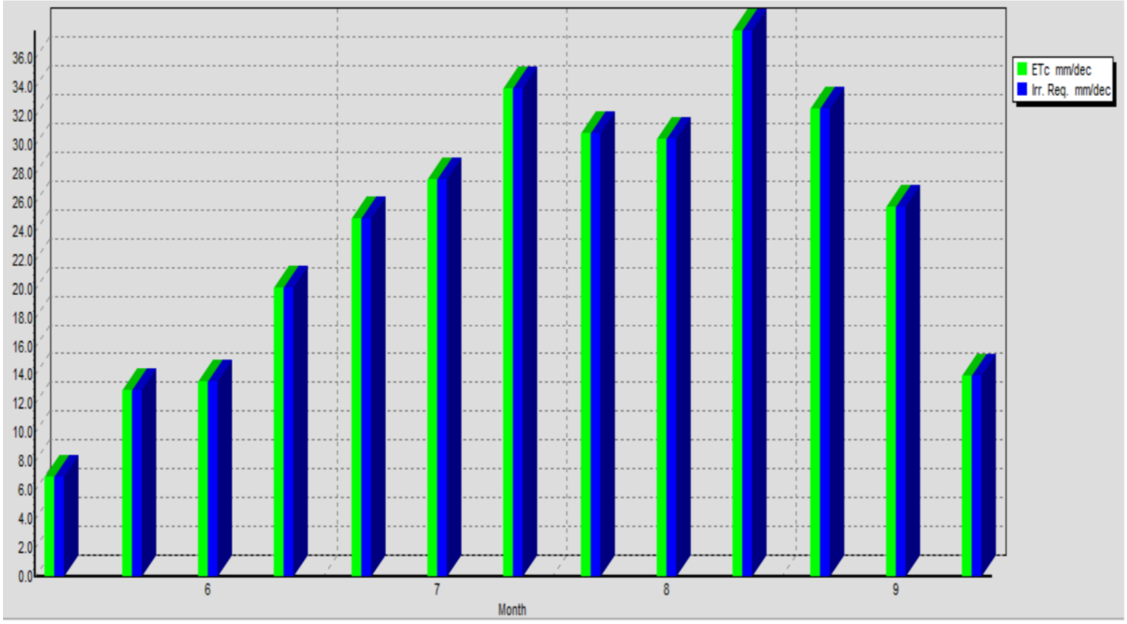


Fig 5.7: Graphical presentation of crop water requirement of maize

The Maize crop demands the most water during the fruit formation activity because the structure of the plant grows larger and demands additional energy for the purpose of producing the grain of Maize. We're approaching the end of the season. The water need is lowered because the fruit/grain is maturing at this time. Table 5.7 displays the crop water requirements for each crop in millimeters per day.

Table 5.7: Crop water requirement of each crop

Crop Name	Planting date	Harvest date	ETc mm/day
Sorghum	27/05	28/09	28.55
Maize	27/05	28/09	31.49
Tomato	27/05	18/10	46.08
Soybean	27/05	19/08	24.02
Potato	13/04	03/10	39.83
Sunflower	13/04	03/10	33.70
Cotton	13/04	07/12	61.27
Barley	13/04	23/09	31.19
Pulses	13/04	13/09	28.96
Sweet Peppers	13/04	28/09	36.16
Cabbage	13/04	07/11	54.52
Tobacco	13/04	13/09	32.45
Green beans	13/04	24/08	25.08
Dry beans	13/04	13/09	28.96

Of the above crops, cotton has the highest crop water requirement. The growing season's water demand for Cotton crop is 61.27 mm/day. Cotton's crop water requirements rise from the early to the late stages of development; they begin to decline from the mid to the late stages; they rise again during the first three decades of the late season in September; and they reach their lowest point at harvest in the final two decades of the late stages in October. For cotton crop at the late phase, which begins in the second decade of October, is when crops require the most water (4.9mm/day), while the late phase that has the lowest water demand had a requirement of 18.0 mm/day.

Table 5.8: Crop water requirement of Cotton

Month	Decade	Stage	K_c	ET_C mm/day
May	3	Init	0.35	1.60
Jun	1	Init	0.35	1.51
Jun	2	Init	0.35	1.41
Jun	3	Deve	0.38	1.35
Jul	1	Deve	0.53	1.63
Jul	2	Deve	0.69	1.82
Jul	3	Deve	0.87	2.31
Aug	1	Deve	1.04	2.77
Aug	2	Mid	1.17	3.08
Aug	3	Mid	1.18	3.55
Sep	1	Mid	1.18	4.03
Sep	2	Mid	1.18	4.43
Sep	3	Mid	1.18	4.63
Oct	1	Mid	1.18	4.84
Oct	2	Late	1.16	4.92
Oct	3	Late	1.05	4.43
Nov	1	Late	0.94	3.94
Nov	2	Late	0.84	3.47
Nov	3	Late	0.74	2.98
Dec	1	Late	0.65	2.57
Total				61.27

For the majority of crops, the third decade of June which is the midseason phase, is the period that requires the greatest amount of crop water. The phase of the growing season leading up to the late season is when the plants demand the most water since fruit development requires the most energy.Although the initial and late-season stages possess the lowest demand for water because the crops are just planted at the initial stage and the plants are mature and require less water at the late stage, the amount of water requirement is reduced due to the mechanism of the ripening of fruit. The crop's growth has already been maxed, and there will be no further development as the crops near harvesting.

5.4 Irrigation scheduling

Irrigation scheduling specifies the amount of water to be used for irrigation as well as the timing of the irrigation. Different agronomic practices and irrigation scheduling have a considerable impact on yield under varied geographical and climatic situations (Mehrabi &Sepaskhah 2018; Solgi et al. 2022; Ahmadi et al. 2022). Irrigation and water supply schedules are created when ETo, CWR, and IWR are computed using the CROPWAT model (Allen et al. 2005).

Scheduling irrigation is a straightforward method for determining how much water to supply crops and when to deliver it. Each crop has different stages, such as early, developmental, medium, and late. Because irrigation requirements vary at each stage, irrigation must be efficiently controlled for optimal water usage (Solangi et al. 2022). This study discovered that the irrigation requirement for each crop was reduced in the early stage and then increased in the developmental stage. Furthermore, it was generally consistent, with a high in the middle period and a decline in the late period due to the fact that harvesting requires the soil to be dry.

Irrigation Scheduling is carried out using the following scenarios:

I) Irrigation at critical depletion
II) Irrigation at fixed depletion
III) Irrigation at user defined intervals
IV) Irrigation at fixed interval per stage

Irrigation at set intervals per stage is employed in this study for crop irrigation scheduling. This is because this strategy works well in gravity systems with rotational water distribution, which are common in most irrigation schemes. Although it may result in some over irrigation in the early stages and under watering during peak season, fixed irrigation turns have significant operational benefits.

Table 5.9 – 5.11and Fig 5.8-5.10 illustrate irrigation schedules for sorghum and maize.

Table 5.9: Irrigation scheduling of sorghum

Day	Date	Stage	Net irrigation Mm	Gross irrigation Mm
5 Jun	10	Init	3.9	5.5
15 Jun	20	Init	4.0	5.7
25 Jun	30	Dev	5.4	7.7
5 Jul	40	Dev	6.4	9.1
15 Jul	50	Dev	6.9	9.9
25 Jul	60	Mid	7.7	11.0
4 Aug	70	Mid	5.1	7.3
14 Aug	80	Mid	5.0	7.2
24 Aug	90	Mid	5.7	8.2
3 Sep	100	End	2.9	4.1
13 Sep	110	End	2.7	3.8
23 Sep	12O	End	2.3	3.2
Total			58	82.8

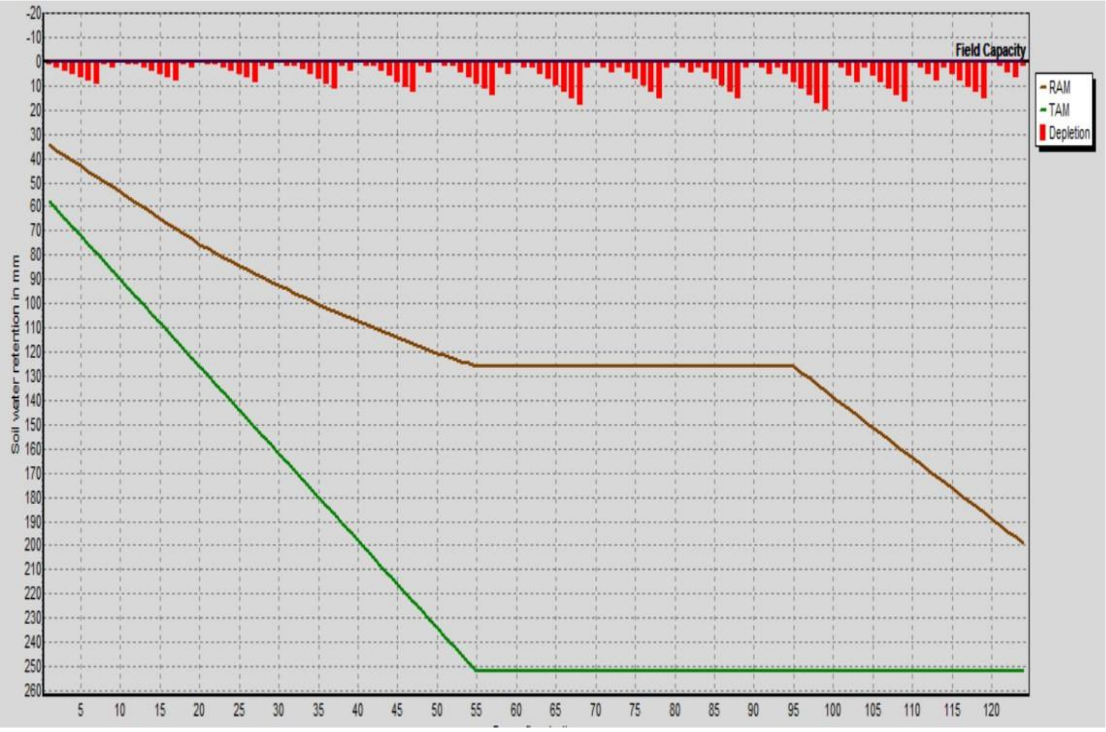


Fig 5.8: chart presentation of Irrigation scheduling of sorghum

Table 5.10: Irrigation scheduling of Maize

Day	Date	Stage	Net irrigation Mm	Gross irrigation Mm
5 Jun	10	Init	3.9	5.5
15 Jun	20	Init	4.1	5.8
25 Jun	30	Dev	6.0	8.6
5 Jul	40	Dev	7.5	10.7
15 Jul	50	Dev	8.3	11.8
25 Jul	60	Mid	9.3	13.2
4 Aug	70	Mid	6.2	8.8
14 Aug	80	Mid	6.1	8.7
24 Aug	90	Mid	6.9	9.8
3 Sep	100	End	3.3	4.6
13 Sep	110	End	2.6	3.7
23 Sep	12O	End	1.7	2.5
Total			65.7	93.8

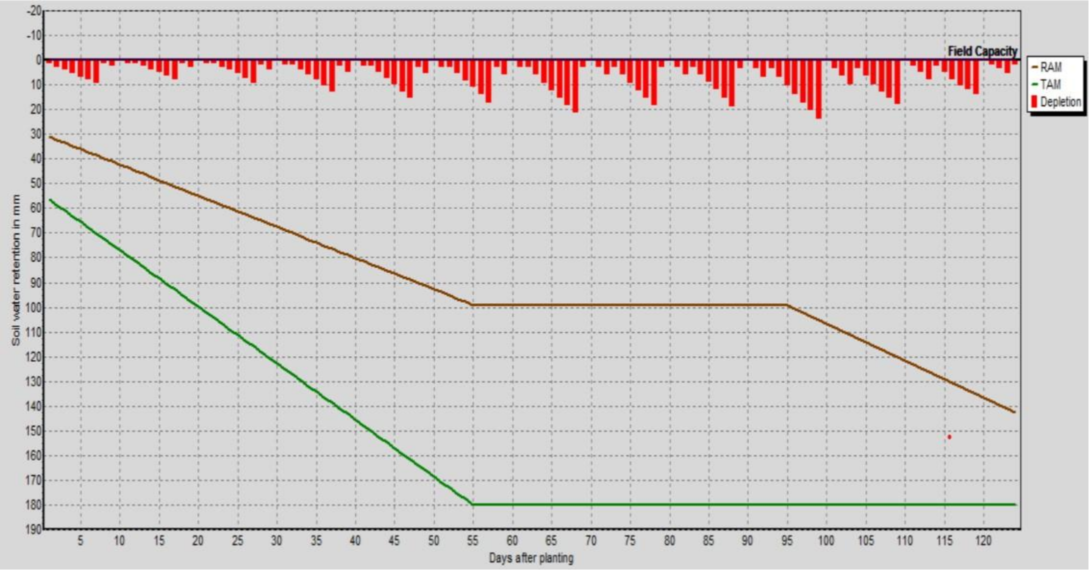


Fig 5.9: chart presentation of Irrigation scheduling of Maize

Table 5.11: Irrigation scheduling of cotton

Day	Date	Stage	Net irrigation Mm	Gross irrigation Mm
5 Jun	10	Init	4.5	6.5
15 Jun	20	Init	4.2	6.0
25 Jun	30	Init	4.0	5.8
5 Jul	40	Dev	4.9	7.0
15 Jul	50	Dev	5.5	7.8
25 Jul	60	Dev	6.9	9.9
4 Aug	70	Dev	5.5	7.9
14 Aug	80	Dev	6.2	8.8
24 Aug	90	Mid	7.1	10.1
3 Sep	100	Mid	4.0	5.8
13 Sep	110	Mid	10.6	15.1
23 Sep	12O	Mid	16.2	23.2
3 Oct	130	Mid	20.8	29.8
13 Oct	140	Mid	28.8	42.2
23 Oct	150	End	34.4	49.1
2 Nov	160	End	37.5	53.6
12 Nov	170	End	34.6	49.4
22 Nov	180	End	32.3	46.1
2 Dec	190	End	27.8	39.7
Total			295.9	422.7

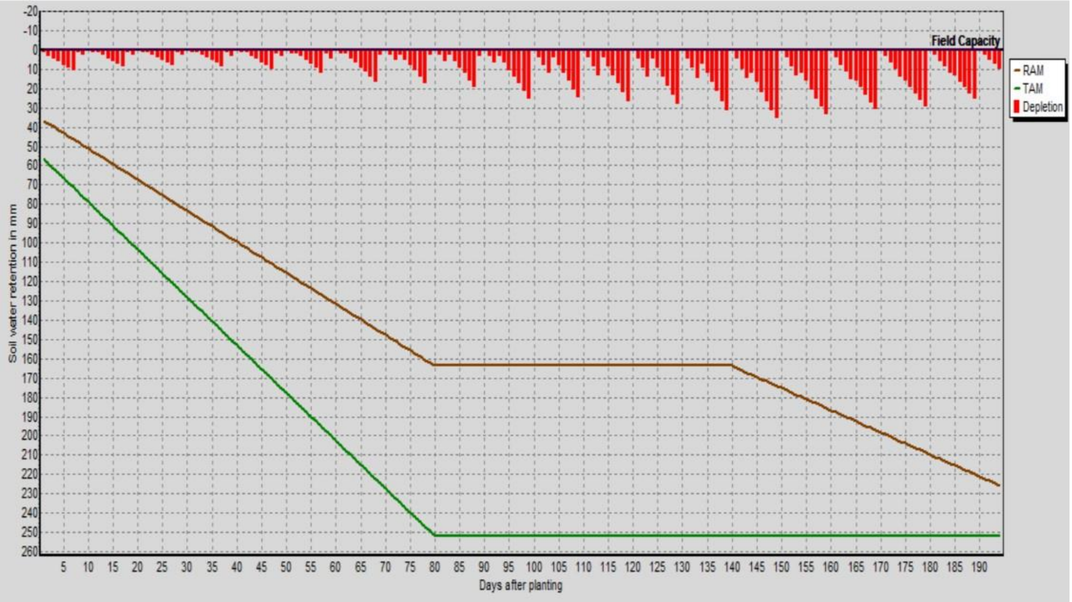
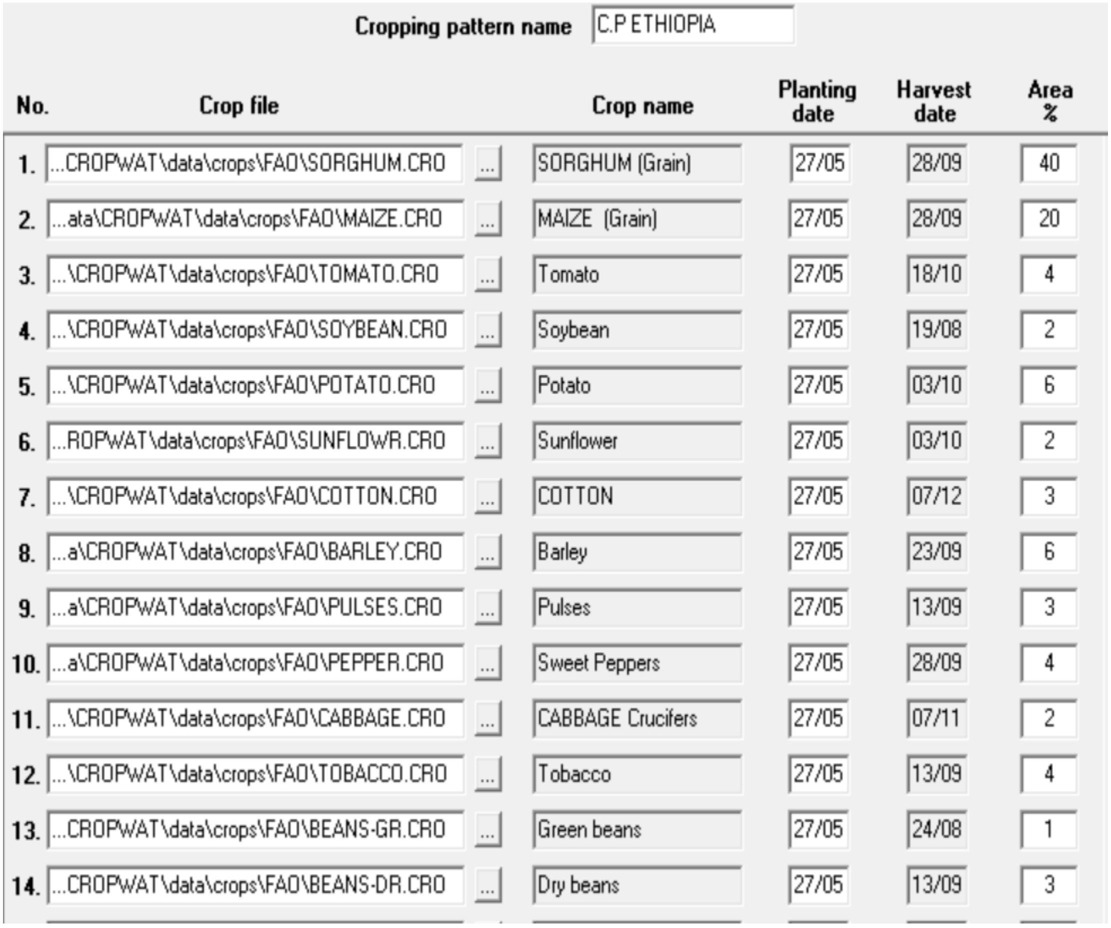


Fig 5.10: chart presentation of Irrigation scheduling of Cotton

5.5 Crop pattern

Crop pattern is used for calculating irrigation requirement for all the crops (scheme). the total area of 300 ha is going to be covered with the selected 14 crops. from this crops Sorghum and Maize are the most popular crops grown in the study area and they will cover 60% of the total area in which Sorghum will cover 40% & Maize 20%.

The allocated area percentage of each crop is shown in the figure below.



Cropping pattern name C.P ETHIOPIA

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1.	...CROPWAT\data\crops\FAO\SORGHUM.CRO	SORGHUM (Grain)	27/05	28/09	40
2.	...ata\CROPWAT\data\crops\FAO\MAIZE.CRO	MAIZE (Grain)	27/05	28/09	20
3.	...\CROPWAT\data\crops\FAO\TOMATO.CRO	Tomato	27/05	18/10	4
4.	...\CROPWAT\data\crops\FAO\SOYBEAN.CRO	Soybean	27/05	19/08	2
5.	...\CROPWAT\data\crops\FAO\POTATO.CRO	Potato	27/05	03/10	6
6.	...ROPWAT\data\crops\FAO\SUNFLOWR.CRO	Sunflower	27/05	03/10	2
7.	...\CROPWAT\data\crops\FAO\COTTON.CRO	COTTON	27/05	07/12	3
8.	...a\CROPWAT\data\crops\FAO\BARLEY.CRO	Barley	27/05	23/09	6
9.	...a\CROPWAT\data\crops\FAO\PULSES.CRO	Pulses	27/05	13/09	3
10.	...a\CROPWAT\data\crops\FAO\PEPPER.CRO	Sweet Peppers	27/05	28/09	4
11.	...\CROPWAT\data\crops\FAO\CABBAGE.CRO	CABBAGE Crucifers	27/05	07/11	2
12.	...\CROPWAT\data\crops\FAO\TOBACCO.CRO	Tobacco	27/05	13/09	4
13.	...CROPWAT\data\crops\FAO\BEANS-GR.CRO	Green beans	27/05	24/08	1
14.	...CROPWAT\data\crops\FAO\BEANS-DR.CRO	Dry beans	27/05	13/09	3

Fig 5.11: allocated area in % for each crop out of the whole command area

5.6 Irrigation scheme

From the results of irrigation scheme gathered from cropwat 8.0 important results have been gathered. Table 5.12 shows the irrigation scheme of the whole area. The net scheme irrigation requirement during the early stage when all the crops were planted was 0.3 mm/day. The highest net scheme irrigation requirement will be in the month of August this implies that most of the crops will be in the development stage where they will start to produce fruits. During such stage the plants require most of the energy they can have so the irrigation water requirement becomes so high.

Table 5.12: irrigation scheme of crops

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. SORGHUM (Grain)	0	0	0	0	6.9	44.1	72.6	82.4	73.8	0	0	0
2. MAIZE (Grain)	0	0	0	0	6.9	46.6	86.4	99.1	72.1	0	0	0
3. Tomato	0	0	0	0	13.7	72.3	75.3	96.4	121.3	66.9	0	0
4. Soybean	0	0	0	0	9.2	82.9	97.6	42.8	0	0	0	0
5. Potato	0	0	0	0	11.5	63.8	85.4	96.2	105.6	9.2	0	0
6. Sunflower	0	0	0	0	8	46.1	77.1	95.4	93.2	4.7	0	0
7. COTTON	0	0	0	0	8	42.7	59.9	97.5	130.9	146.3	103.9	18
8. Barley	0	0	0	0	6.9	61.3	95.7	93.4	46.4	0	0	0
9. Pulses	0	0	0	0	9.2	58.3	89.7	93.2	26.1	0	0	0
10. Sweet Peppers	0	0	0	0	13.7	72.3	73.3	87.7	99.5	0	0	0
11. CABBAGE Crucifers	0	0	0	0	16	83.6	66.1	81.2	115.9	135.3	28.6	0
12. Tobacco	0	0	0	0	11.5	68.7	90	90.5	38	0	0	0
13. Green beans	0	0	0	0	11.5	67.4	83.2	64	0	0	0	0
14. Dry beans	0	0	0	0	9.2	58.3	89.7	93.2	26.1	0	0	0
Net scheme irr.req.												
in mm/day	0	0	0	0	0.3	1.8	2.6	2.9	2.4	0.3	0.1	0
in mm/month	0	0	0	0	8.3	52.7	79.6	88.7	73.1	10.4	3.7	0.5
in l/s/h	0	0	0	0	0.03	0.2	0.3	0.33	0.28	0.04	0.01	0
Irrigated area (% of total area)	0	0	0	0	100	100	100	100	97	17	5	3
Irr.req. for actual area (l/s/h)	0	0	0	0	0.03	0.2	0.3	0.33	0.29	0.23	0.28	0.07

The net irrigation requirement of each crop throughout their growth period is provided in the table above. Sorghum will have its highest net irrigation requirement in the month of August which is82.4 mm/dec while cotton will have the highest net irrigation requirement of 130.9 mm/dec in the month of September.

The irrigated area from the total area was 100% until the month of august. The percentage of total irrigated area starts to decline as some crops reach there harvesting stage and no more irrigation water is required. For example, in the month of September green beans and soy beans will be harvested so the total irrigated area becomes 97%. This value keeps on declining as more crops reach the harvesting stage. Cotton is the last crop that will be harvested in the month of December.

CHAPTER VI

CONCLUSION AND RECOMENDATION

6.1 Conclusion

According to the findings of this study, Reference Crop Evapotranspiration, Crop Water Requirement, Effective Rainfall and Irrigation Water Requirement can be calculated by utilizing CROPWAT 8.0 Software and climatic data such as minimum and maximum temperature, relative humidity, sunshine hours, wind speed, and rainfall.

The Study revealed that the total CWR for the entire growing season for fourteen (14) different crops sorghum, maize (grain),Tomato, Soybean, Potato, Sunflower, Cotton, Barley, Pulses, Sweet Peppers, Cabbage, Tobacco, Green beans&Dry beans with the values of 28.55, 31.49, 46.08, 24.02, 39.83, 33.70, 61.27, 31.19, 28.96, 36.16, 54.52, 32.45, 25.08, & 28.96 (mm/day) respectively. Furthermore, the CWR value increased for crops with longer life cycles, such as cotton, which has a CWR value of 61.27 mm/day.

CWR was also found to be higher during dry periods due to higher temperatures and lower relative humidity, resulting in increased evapotranspiration. The amount of irrigation required for each crop was initially reduced and then raised during the development stage in terms of irrigation scheduling. Furthermore, it was essentially steady, with a peak in the middle and a drop at the end to aid harvesting.

6.2 Recommendation

The study recommends using scientific methodologies like as CROPWAT and CLIMWAT to examine crop water requirement(CWR), Irrigation water requirement (IWR), and irrigation scheduling with a high level of precision, which farmers all over the world, including Ethiopia, willingly embrace. The study's findings can be used as a reference for farmers to distribute irrigation water for the various crops researched here, and also by water resource planners for future planning, assisting in water conservation and agricultural water demand fulfilment. These findings can be applied to the study district to improve crop yield and water use efficiency.

References

Abdalla N, Zhang X, Ishag A, Gamareldawla H (2010) Estimating reference evapotranspiration using CROPWAT model at Guixi Jiangxi Province.

Abraham Tadesse (ed.). 2009. Increasing Crop Production through Improved Plan Protection-Volume II

Abtew W, 1996. Evapotranspiration measurement and modeling for three wetland systems in South Florida

Adeniran K A, Amodu M F, Amodu M O, Adeniji F A. 2010. *Water requirements of some selected crops in Kampe dam irrigation project.Agriculture*

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. 1998. Crop Evapotranspiration: Guidelines for computing crop water requirements. *Irrigation and Drainage Paper 56, FAO of the United Nations, Rome. 300 pp.*

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. 1998. Crop Evapotranspiration: Guidelines for computing crop water requirements. *Irrigation and Drainage Paper 56, FAO of the United Nations, Rome.*

Ashinie, S. K., & Tefera, T. T. (2019). Horticultural crops research and development in Ethiopia

ATA (Agricultural Transformation Agency). *2013. Ethiopia seed system development strategy*

ATA (Agricultural Transformation Agency). *2013. Ethiopia seed system development strategy.*

ATA (Agricultural Transformation Agency). *2014. Ethiopia national mechanization strategy.*

Awulachew SB, Erkossa T, Namara RE (2010) Irrigation potential in Ethiopia. In: Constraints and Opportunities for Enhancing the System; *International Water Management Institute. Addis Ababa, Ethiopia*

Awulachew SB, Merrey D, Kamara A, Van Koppen B, De Vries P, F. &Boelee E (2005) Experiences and opportunities for promoting small-scale/micro irrigation and rainwater harvesting for food security in Ethiopia. IWM

Awulachew SB, Yilma AD, Loulseged M, Loiskandl W, Ayana M, Alamirew T (2007) Water resources and irrigation development in Ethiopia. International Water Management Institute (IWMI)

Awulachew, S. B., Yilma, A. D., Loulseged, M., Loiskandl, W., Ayana, M., &Alamirew, T. 2007. Water resources and irrigation development in Ethiopia.

B. Nurpilihan, S. Dwiratna, and D. R. Kendarto, 2016 "Differences Growing Media InAutopot Fertigation System And Its Response To Cherry Tomatoes Yield,"

Benin, S., 2006. Policies and programs affecting land management practices, input use, and productivity in the highlands of Amhara region, Ethiopia

Berhanu, B., Seleshi, Y., Assefa, M., & Melesse. (2014). Surface water and groundwater resources of Ethiopia

Crops

D. M. Sumner and J. M. Jacobs, 2005. "Utility of Penman-Monteith, Priestley-Taylor, reference evapotranspiration, and pan evaporation methods to estimate pasture evapotranspiration,"

Dalton, 1802. Experimental essays on the constitution of mixed gases: On the force of steam or vapor from water or other liquids in different temperatures, both in a Torricelli vacuum and in air; on evaporation; and on expansion of gases by heat.

Dariush et al., Estimation of Evaporation and Transpiration of Wheat Plant in Zaraghan Station Using CROPWAT Model, 2014

Diriba, G. 2020. Agricultural and rural transformation in Ethiopia: Obstacles, triggers and reform considera-tions policy working paper.

Doorenbos J, Pruitt W O, 1977. Crop Water Requirements. FAO Irrigation and Drainage Paper 24, Land and Water Development Division, FAO. Rome.

Elkiran, G. 2006. Integrated water resources planning andmanagement of TRNC.

Evans RG and EJ Sadler. 2008. Methods and technologies to improve efficiency of water use.

Ewaid, S. H., Abed, S. A. & Al-Ansari, N. 2019 Crop water requirements and irrigation schedules for some major crops in Southern Iraq

F. Zhiming, L. I. U. Dengwei, and Z. Yuehong, 2007. "Water Requirements and Irrigation Scheduling of Spring Maize Using GIS and CropWat Model in Beijing-Tianjin-Hebei Region,"

FAO, (Food and Agriculture Organization). 2009. CROPWAT Software, Food and Agriculture Organization, Land and Water Division; Available at: http://www.fao.org/nr/water/infores_ data bases_cropwat.html.

Feng, Z., Liu, D. & Zhang, Y. 2007 Water requirements and irrigation scheduling of spring maize using GIS and CROP model in Beijing-Tianjin-Hebei region.

Hashem et al., (2016), Performance Evaluation and Development of Daily Reference Evapotranspiration Model, Irrigat Drainage Sys Eng 2016Irrig sched

Jensen M.E., Haise H.R, 1963. Estimation of evapotranspiration from solar radiation

Kashyap, P. S. and Panda, R. K. 2001. Evaluation of evapotranspiration estimation methods and development of crop-coefficients for potato crop in sub humid region.

Khan, M. J., Malik, A., Rahman, M., Afzaal, M. & Mulk, S. 2019 Assessment of crop water requirement for various crops in Peshawar, Pakistan using CROPWAT model

L. Zhao, J. Xia, C. yu Xu, Z. Wang, L. Sobkowiak, and C. Long, 2013. "Evapotranspiration estimation methods in hydrological models,"

M. Kercheva and Z. Popova, 2010 ."*Use of Irrigation Requirements and Scheduling as Drought Indicator Maize growth stages phases Sowing Late germination*,"

Makkink G F, 1957. Testing the Penman Formula by means of lysimeters.

Mason, B., Rufi-Salis, M., Parada, F., Gabarrell, X. & Gruden, C. 2019 Intelligent urban irrigation systems. saving water and maintaining crop yields.

Merga, B., & Ahmed, A. (2019). A review on agricultural problems and their management in Ethiopia.

MoFED (2010) Plan for Accelerated and Sustained Development to End Poverty (PASDEP). Addis Ababa

Moges, M.F.2019. Evaluation of Golda Small Scale Irrigation Scheme Using External Indicators in Assosa District, Benishangul Gumuz Regional State, Ethiopia.

Moseki, O., Murray-Hudson, M. & Kashe, K. 2019 Crop water and irrigation requirements of Jatropha curcas L. in semi-arid conditions of Botswana: applying the CROPWAT model

MoWE and FAO (2011) Agricultural Water Management Information system of Ethiopia Database (AWMISET). Addis Ababa

MoWE and FAO (2012). Coping with water scarcity—the role of agriculture: developing a water audit for Awash Basin

MoWR (2010) Update of Water Sector Development Program (WSDP): Main report volume II. Addis Ababa

MoWR (2010) Update of Water Sector Development Program (WSDP): Main report volume II. Addis Ababa

MoWR (Ministry of Water Resources) (1996) Integrated development of Omo-Ghibe river Basin master plan study, vol. XI (F1, F2, F3, Addis Ababa, Ethiopia)

Mozumdar L (2012) Agricultural productivity and food security in the developing world. Bangladesh Journal of Agricultural Economics 35:53–69

O. Toda, K. Yoshida, S. Hiroaki, H. Katsuhiro, and H. Tanji,2005. "Estimation of Irrigation Water Using Cropwat Model at Km35 Project Site, in Savannakhet, Lao PDR,".

P. Banik and S. Ranjan,2014. "CROPWAT Crop Water Assessment of Plain and Hilly Region Using CROPWAT Model,".

R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, 1998 "Crop evapotranspiration: Guidelines for computing crop requirements," *Irrig. Drain. Pap. No. 56, FAO, no. 56, p. 300,.*

Rowshon M. K., Amin M. S. M., Mojid, M. and Yaji, M. 2013. Estimate evapotranspiration of rice based on pan evaporation as a surrogate to lysimeter measurement. *Paddy Water Environment., 13(4): 356-364*

S. Dwiratna, N. Bafdal, C. Asdak, and N. Carsono, 2018. *"Study of Runoff Farming System to Improve Dryland Cropping Index in Indonesia,"*

Selamawit Ketema. 2013.The State of Science and Art of Vegetable Crops in Ethiopia. Proceeding of the state of agricultural science and technology in Ethiopia. 20-30 November 2011. *Addis Ababa, Ethiopia.*

Solangi, G. S., Shah, S. A., Alharbi, R. S., Panhwar, S., Keerio, H. A., Kim, T.-W., Memon, J. A. &Bughio, A. D. 2022 Investigation of irrigation water requirement for major crops in Pakistan using CROPWAT model based on climate data.

T. Erkossa, A. Haileslassie, and C. MacAlister,2014. "Enhancing farming system water productivity through alternative land use and water management in vertisol areas of Ethiopian Blue Nile Basin (Abay),"

Tarate et al., (2017). Estimation of reference evapotranspiration for Parbhani district

Turc L, 1961. Estimation of irrigation water requirements, potential evapotranspiration: a simple climatic formula evolved up to date

U. Surendran, C. M. Sushanth, G. Mammen, and E. J. Joseph, 2015. "Modelling the Crop Water Requirement Using FAO-CROPWAT and Assessment of Water

Resources for Sustainable Water Resource Management: A Case Study in Palakkad District of Humid Tropical Kerala, India,” Water

Xu C Y, Singh V P, 2000. Evaluation and generalization of radiation-based methods for calculating evaporation. Hydrological Processes

Xu et al., (2000), Evaluation and generalization of radiation-based methods for calculating evaporation

Xu et al., (2001), Evaluation and generalization of temperature-based methods for calculating evaporation

Zeleke et al., (2012). Evapotranspiration Estimation using Soil Water Balance, Weather and Crop Data.

Zeleke T, Giorgi F, Mengistu GT, Diro GT (2013) Spatial and temporal variability of summer rainfall over Ethiopia from observations and a regional climate model experiment

Zhao et al., (2013). ―Evapotranspiration estimation methods in hydrological models

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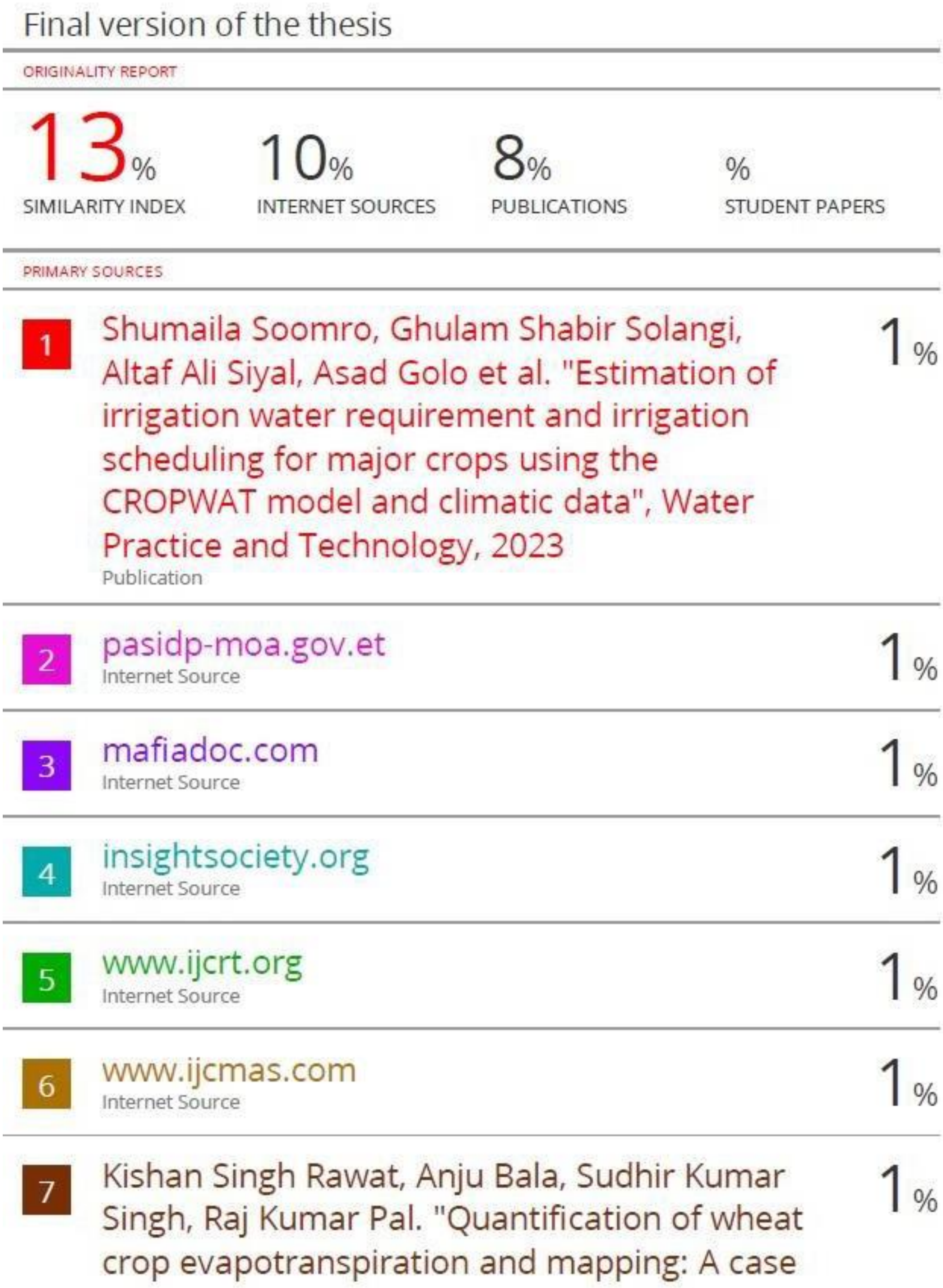

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