EVALUATION OF IRRIGATION SCHEDULING PRACTICES IN THE KESEM SUGAR DEVELOPMENT PROJECT IN AFAR REGIONAL STATE

Endris Teferi Dagne

A Thesis Submitted to

The Department of Water Resources Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirement for the Degree of

Master's in Water Resources Engineer (Specialization in Irrigation Engineering)

Office of Graduate Studies

Adama Science and Technology University

June, 2021

Adama, Ethiopia

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Advisor

Dr. Abdulkerim Bedewi

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DECLARATION

I hereby declare that this Master Thesis entitled ***"Evaluation of Irrigation Scheduling Practices in Kesem Sugar Development Project in Afar Regional State"*** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Endris Teferi Dagne	__________________	__________________
Name of the Student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled ***"Evaluation of Irrigation Scheduling Practices in Kesem Sugar Development Project in Afar Regional State"*** prepared under my guidance by Endris Teferi Dagne submitted in partial fulfilment of the requirements for the degree of Mater's of Science in Water Resources Engineering (Specialization in Irrigation Engineering).

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Abdulkerim Bedewi	____________________	_________________
Major advisor	Signature	Date

APPROVAL PAGE OF M.Sc. THESIS

I, the advisors of the thesis entitled "**Evaluation of Irrigation Scheduling Practices in Kesem Sugar Development Project in Afar Regional State"** and developed by Endris Teferi Dagne, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Abdulkerim Bedewi	____________________	________________
Major advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Endris Teferi Dagne have read and evaluated the thesis entitled "**Evaluation of Irrigation Scheduling Practices in Kesem Sugar Development Project in Afar Regional State"** and examined the candidate during open defence. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Water Resources Engineering (Specialization in Irrigation Engineering).

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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LIST OF ACRONYMS AND ABBREVATIONS

AWC	Soil available Water Capacity
Bd	Bulk Density
ESC	Ethiopian Sugar Corporation
ETc	Crop Evapotranspiration
ETo	Reference Evapotranspiration
FAO	Food and Agriculture Organization
FC	Field Capacity
GIR	Gross Irrigation Requirement
Ha	Hectare
HDPE	High Density Polyethylene
Kc	Crop Coefficient
Km	Kilo Meter
M	Meter
MM	Mil Meter
NIR	Net Irrigation Requirement
NPC	North Primary Canal
PWP	Permanent Wilting Point
SCS	Soil Conservation Service
SMD	Soil Moisture Deficit
SPC	South Primary Canal
TAM	Total Available Moisture
USDA	United State Department of Agriculture
WWDSE	Water Works Design and Supervision Enterprise

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ABSTRACTS

Appropriate field water application practices safeguard that plants could get peak supply of water in their root zone for achieving best yield of crops without facing water stress and damaging the quality of soils. However, there is a big problem on applying water without considering the soil type and crop characteristics on sugar estate farms. Therefore, this study was conducted to assess the existing irrigation application practices and develop irrigation scheduling. Climatic, soil and crop data were used to accomplish the planned objectives. Climatic data's from metrology station and crop data's from research finding and previous studies were collected. The soil data's from selected irrigation fields were collected and analyzed in soil laboratory of Melka-Werer Agricultural Research Centre using gravimetric method. Crop evapotranspiration was analysed using Cropwat software based on Penman-Monteith method. Net depths of application, net irrigation requirements and irrigation interval were analyzed using standard equations. Crop evapotranspiration obtained for the age of 0 to 3, 3 to 6, 6 to 12 and above 12 months were 3.74, 5.26, 5.68 and 3.88 mm/day respectively. Net depths of water application obtained for 0 to 3, 3 to 6, 6 to 12 and above 12 months age were 33.80, 50.70, 67.60 and 101.30 mm respectively. Net irrigation requirements obtained for 0 to 3, 3 to 6, 6 to 12 and above 12 months were 2.32, 3.82, 4.24 and 2.45 mm/day respectively. Irrigation interval obtained for age of 0 to 3, 3 to 6, 6 to 12 and above 12 months were 9, 10, 12, and 27 days respectively. From field evaluation, most of irrigation activities were not carried out as per the design document. The irrigation scheduling practices considering site condition (soil type, growing months and stages) was suggested to implement in the Kesem Sugar Development Project.

Keyword: Sugarcane, Crop evapotranspairation, Depths of application, Irrigation water requirement, Irrigation interval.

1. INTRODUCTION

1.1. Background

The Federal Democratic Republic of Ethiopia has given one of the highest priorities to Agriculture. About 85% of the people of the country are engaged in agriculture. However, the activity still depends on rain –fed, rainfall distribution is seasonal and variable and suffers from the most unstable rainfall regime. As a result the increase in crop production does not match with the population growth of the country. The development of irrigation and improved agricultural water management has many potential benefits to improve productivity. Irrigated agriculture is important to meet an increasing demand to feed an ever growing population (Hailegebriel, 2007).

The development of irrigated agriculture will open–up the opportunity of vastly increasing agricultural production for local consumption and exporting items. The implementation of large scale irrigation project can create different opportunities of development for other economic sectors like agro-industries and by products as raw materials to other industries. Therefore, the expansion of irrigated agriculture for achieving food self-sufficiency is currently the most important promising option. To meets the food demand of steadily growing population and to increase foreign exports, the government of Ethiopia envisaged many development studies. Under these circumstances, Ethiopian government, considered the introduction of irrigated agriculture for crop production in the Awash River Valley (Awulachew, 2010).

Modern irrigation development started in the 1950s in the Awash River Valley with the objective of producing industrial crops such as cotton and horticultural crops and sugar cane (Awulachew et al., 2007). The Dutch company, which had started modern sugarcane industry in 1951 in Ethiopia in a joint venture modality by signing an agreement with the then Ethiopian government, had established Wonji and Shoa sugar factories in 1954 and 1963 respectively. Being well aware of the huge potential Ethiopia has for the sector by then, Dutch company had also established Metahara Sugar Factory in the same modality in 1965.

Currently, sugarcane agriculture is one of Ethiopian agricultural economy. As a result, in 2005 Federal Democratic Republic of Ethiopia has launched sugar development program to undertake the new and Expansion projects across the country with a clear objective of boosting sugar production to satisfy the domestic sugar demand as well as for any possible export. According to the government plan, the development of massive irrigation projects for sugar production in different parts of the country is involved. The one among the new sugar development projects is Kesem Sugar Development Project.

Kessem Sugar Factory which had first been started as an expansion project of Metehara Sugar Factory's sugarcane plantation field was made to operate independently in 2010 due to its long distance from Metehara Sugar Factory following the establishment of Ethiopian Sugar Corporation. The project lies on the left bank of middle Awash River basin which is found at Zone Three in Awash Fentallie and Dulecha districts of Afar Regional State, 250 km from Addis Ababa (sugar.gov. www.et, 2019).

The Project command area is located on both banks of Kesem River. It includes North and South irrigation sites. Kesem River is the source of irrigation water. The irrigation system has an intake, conveyance and distribution system. The dam is constructed across the river to carry 0.5 billion m^3 of water to cultivate around 20,000 ha of land by Sugarcane crop by using a furrow irrigation system with the aid of diversion Weir using surface irrigation method (WWDSE, 2008).

Today, the project irrigates the sugarcane fields using somewhat fixed intervals and fixed depths of irrigation application practices. Currently, the project faces the irrigation water management problems. Due to these problems, some irrigation fields are under watering, over watering in most fields and non-uniformity of water application. These results in loss of cultivated land and reduce the productivity. Therefore, this study was very important to evaluate irrigation scheduling practices and develop irrigation scheduling of the project within the soil type, crop growth stage and climate condition.

1.2. Statement of the Problem

Furrow irrigation system is a widely used irrigation system in Ethiopia and practiced by many farmers and state farms. However, the irrigation practice is characterized as less efficient, high water loss during application and low uniformity during distribution. The losses have been observed largely by improper irrigation management practices (Solomon, 2010). Improved irrigation scheduling and water application methods are among the means of cutting losses and increasing efficiency. Proper choice of application strategy using available water is an obligatory work ((Duke, 1987).

The use of applicable field irrigation practices safeguard that plants could get peak supply of water in their root zone for achieving optimum yield of crops without facing water stress and damaging the quality of soils. This is achieved by knowing the interaction among soil, plant and water because soil and crop characteristics, weather conditions and environmental factors can affect soil-crop-water regime (Allen et al., 1998). However, the major challenges facing most of irrigation areas concerning efficient and effective use of water for agriculture is to apply the required amount of water uniformly with minimum loss (Habib , 2001).

According to Pereira et al.(1996), irrigation scheduling practices affect field application performance. Water deficit in sugarcane limits growing and maturity of tissues, reduces nitrogen uptake and utilization. It is observed that sugarcane under water-logging causes a higher rate of mortality, retarded growth and poor juice quality. Those problems are also highly reflected on Kesem Sugar Development Project.

The project started sugarcane cultivation using furrow irrigation method with flexible hose (flexi-flume). Currently, the project irrigating the fields by using fixed interval and fixed depth irrigation application practices for all soil groups and crop growth stages. This show that the project water application practices not considering the crop characteristics (crop root depth, growth stage and month) and soil types (i.e. both irrigation interval and amount could not correspond to the project climate and soil moisture characteristics).The project also has a problem of poor operations and maintenance of irrigation infrastructures.

Due to those above problems, some fields are under watering, over watering in most fields and non-uniformity of water application. As a result, the sugarcane growth is not uniform, showing yellow color and wilt, retarded growth, reduction of soil productivity and loss of cultivated land due to water-logging and formation of salt in the farms. So far there was no study done in this area concerning the above stated irrigation problems.

Therefore, this study was conducted to evaluate irrigation scheduling practices to achieve high water use efficiency and to improve productivity of land and quantity of sugarcane by preventing over or under irrigation application based on site specific information.

1.3. Objectives of the Study

1.3.1. General objectives

The general objective of the study was to evaluate the irrigation scheduling practices of Kesem Sugar Development Project.

1.3.2. Specific objective

- ✓ To evaluate the existing irrigation application practices.
- ✓ To develop improved irrigation scheduling for the existing irrigation system.

1.4. Research Questions

1. What are the drawbacks of the existing irrigation application practices?
2. How much quantity of water to be applied and when to irrigate in the study area?
3. How long does it take to apply required depth of water for irrigating sugarcane field at each growth stage?

1.5. Significance of the Study

Irrigation scheduling can help to avoid several problems. It enables to schedule water rotation among the various fields to minimize crop water stress and maximize yields, reduces the cost of water and labor through fewer irrigations, thereby making maximum use of soil moisture storage, lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum, increases net returns by increasing crop yields and crop quality, minimizes water-logging problems by reducing the drainage requirements and it results in additional returns by using the saved water to irrigate non-cash crops that otherwise would not be irrigated during water short periods(Jones, 2004).

The importance of proper irrigation scheduling beyond optimal sugarcane productivity, it helps to ensure sustainable agriculture by preventing and mitigating long-term impacts of improper water applications in the scheme. The correct amount of water should be applied as needed by the crop for best growth to get maximum yield (Habib, 2001).This study is important to avoid irrigation scheduling related problems for kesem Sugar Development Project by providing useful information on: appropriate irrigation scheduling practices to determine the correct amount of irrigation water to be applied uniformly with minimum loss, relevant practicing facts for the project farm areas to develop improvement options and time required for irrigating sugarcane field to determine the number of irrigators to be engaged in, the required amount of irrigation water to be released at a specific period, and to monitor irrigation calendar.

Apart from this, this study could use to maximize the efficiency of irrigation application by knowing irrigation time, quantity and duration. This could give result in, the increase of sugarcane yield and minimum water losses in field to improve productivity of land by reducing water-logging and salinity. Furthermore, it is expect that, this study serve as a facilitator to undertake proper irrigation scheduling actions in other areas, which have planned to expand the irrigation command area and as a reference for other researchers. Therefore, the study could give important information for the sugar estate and provide relevant practicing facts for the project farm areas.

1.6. Scope of the Study

The study was conducted on sugar development irrigation project in Afar regional state with the latitude of $9^0$7' to $9^0$26' North , longitude of $39^0$9' to $40^0$07' East and elevation of 820 to 785 meter above sea level to evaluate existing irrigation scheduling practice.

The representative soil data's of the irrigation project analyzed at Melka-Werer Research Center due to the absence of required materials and soil laboratory accesses in the study area. The evaluation were done by evaluate the existing irrigation application practices, by determine the amount of water to be applied and time interval to irrigating at each growth stage based on the Penman-Monteith equation using Computer program (Cropwat model).

1.7. Thesis Organization

The thesis is organized into five sections. Section one includes background, statement of the problem, objectives, research questions, significance and scope of the study. Section two contains literature review part. Section three focused on material and methods which includes description of the study areas, evaluation of current irrigation practices and development of irrigation scheduling. Section four contains the result and discussion part of the research. Finally, Section five includes conclusion and recommendation part of the thesis.

2. LITERATURE REVIEW

In this section there are different theoretical approaches and related studies by different scholars that have relation with evaluation of irrigation scheduling practices under existing condition are dully described.

2.1. Irrigation

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year. Where the traditional rain-fed farming is a high-risk enterprise, the irrigation can help to ensure sustainable agricultural production. Therefore, the accessibility of irrigation water is not alone significant for reliable and sustainable food security development (Dinka et al., 2014).

Irrigated agriculture makes a major contribution to food security, producing nearly 40% of food and agricultural commodities on 17% of world agricultural land. Irrigated areas have almost doubled in recent decades and contributed much to the growth in the agricultural productivity over the last 50 years. Irrigated agriculture uses more than 70% of the water withdrawn from the earth's rivers; in developing countries, the proportion exceeds 80% (FAO, 2002).

2.2. Irrigation Development in Ethiopia

Ethiopia has 12 river basins with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6 to 6.5 billion m^3 of ground water potential, which makes an average of 1575 m^3 of physically available water per person per year, relatively the large volume. However, due to lack of water storage capacity and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year with frequent crop failures due to dry spells and droughts. Moreover, there is significant erosion, reducing the productivity of farmland (Awulachew et al., 2007).

In Ethiopia, about 90% of the irrigation potential in terms of land and water resources has not been developed so far. However, there have been many ongoing medium and large-scale irrigation developments in recent years. While about 47% of the developed area is under large scale irrigation schemes, mainly industrial crops such as cotton, sugarcane and various fruits are grown. About 65% of the irrigated area is under small scale irrigation schemes; either modern or traditional (FAO, 2005).

Awash River is the only river in Ethiopia extensively used for commercial plantations of industrial and horticultural crops. The estimated irrigation potential is 134,121 ha. Out of these 30,556 ha are for small scale, 24,500 ha for medium scale and 79,065 ha for large scale development (Awulachew et al., 2007).

2.3. Irrigation Methods

Irrigation application methods are categorized under two broad system types: gravity or surface, and pressurized systems. In Pressure irrigation method the water is given to soil by using closed pipe systems with an additional energy or a drawing effect. Pressure methods can be categorized as overhead (spray) irrigation with water delivered through nozzles, or drip irrigation with water delivered through tubes and emitters. The second method, surface irrigation method, is the process of introducing a stream of water at the head of the field and allowing gravity and hydrostatic pressure to spread the flow over the surface throughout the field (USDA, 1999).

2.3.1. Surface irrigation methods

Surface irrigation is used on about 85% of the 299 Million ha of irrigated crop land in the world. Approximately 95% of irrigated land is surface irrigated in India and China, each irrigate more than 60 Million ha of crop land, accounting for almost half of the irrigated land in the world (FAO, 2010).

The process of surface irrigation method is characterized by four phases: advance, storage, depletion and recession. As water is applied to top end of the field, it will flow or advance over the field length. The advance phase refers to that length of time as water is applied to the upstream end of the field and flows or advances over the field length. After the water reaches end of the field, it will either runoff or start to pond. The period of time between the end of the advance phase and the shut-off of the inflow is termed the wetting or storage phase. As the inflow ceases, the water will continue to infiltrate and runoff until the entire field is drained. The depletion phase is short period of time after cut-off when the length of the field is still submerged. The recession phase describes the time period while the water front is retreating towards the downstream end of the field. The depth of water applied to any point in field is a function of the opportunity time, the length of time for which water is present on the soil surface (Jurriens et al., 2001).

Surface irrigation methods are typically less efficient in applying irrigation water than either sprinkle or trickle irrigation method, and it tends to cause water-logging and salinity problems. The need to use irrigation field surface as a conveyance and distribution facility requires that fields be well graded. Land leveling costs are high, so the surface irrigation practice tends to be limited to land already having small, even slopes (Walker, 2003).

Well designed and managed surface irrigation systems may have application efficiencies of up to 90%. Many commercial systems in the world have been found to be operating with highly variable efficiencies at significantly lower levels. For example, commercial furrow application efficiencies in the Australian sugar industry have been found to range from 14 to 90% for single irrigations and from 31 to 62% for seasonal application (Raine and Bakker, 1996). Similarly, the application efficiencies of 54.7 to 92% have been found in Kenyan sugarcane industry (Muturi et al., 2006).The mean application efficiency at Metehara Sugar Estate of Ethiopia has been found to range from 74% to 76% for furrow irrigation system (Habib, 2004)

2.3.1.1. Furrow irrigation

Furrow irrigation is the most common method of applying water to row crops. Water is applied in the furrows between the rows of plants. As water runs down the row, part of it is being absorbed all along the furrow and is moving through the soil to refill the moisture-storage reservoir of the soil under the growing plants. It is adapted to all row crops, truck crops, orchards, vineyards, and berry patches on gentle slopes on all but the coarser soils. The lay out and management of the irrigation system needs careful planning as to soils and topography, intake rates and water holding capacities of the soils, the amount of water that can be run in each furrow or border strip without causing soil erosion, and the relationship between the length of run and the size of irrigation stream to get the proper amount and distribution of moisture in the root zone (Namara et al., 2005).

Furrows must be on consonance with the slope, the soil type, the stream size, the irrigation depth, the cultivation practice and the field length. Although furrows can be longer when the land slope is steeper, the maximum recommended furrow slope is 0.5% to avoid soil erosion. The furrows can also be level and are thus very similar to the long narrow basins. However a minimum grade of 0.05% is recommended so that effective drainage can occur following irrigation or excessive rainfall. If land slope is steeper than 0.5%, then furrows can be set at an angle to main slope or even along the contour to keep furrow slopes within the recommended limits. The furrows can be set in this way when the main irrigation land slope does not exceed 3% (Holden, 1998)

Furrow irrigation of sugarcane is popular due to the following reasons: water is applied by gravity, it is a simple and cheap system to install and operate, it can be adapted to a wide range of soil types, it can use a different water delivery methods at the head of the furrow, and wind has no effect on application efficiency (Glyn, 2004). According to Holzapfel et al. (2009), the water application efficiency increases its value while the furrow length is increased, whereas its value decreases when either the inflow or cut-off time increases. Thus, it can be deduced that a furrow irrigation using a large inflow, a small furrow length, and a long cut-off time losses more water than using a large furrow length, a small inflow, and a small cut-off time.

Habib (2004) conducted the performance evaluation and sensitivity analysis for the furrow irrigation at Metehara Sugar Estate. A sensitivity experiment was attempts to quantify the performance parameters of different irrigation furrow length and inflow rate combinations. He examined the two furrow lengths (50 and 100 m) and the four inflow rates (2, 3, 4 and 5 lit/sec). He concluded that application efficiency and uniformity coefficient were more sensitive to furrow length than inflow rate. On the other hand, distribution uniformity and storage efficiency were more sensitive to the inflow rate than the furrow length. The mean project irrigation application efficiency, distribution uniformity, uniformity coefficient and storage efficiencies were 74.1, 73.4, 77 and 96.7% 50 m furrow length while 76.2, 74.3, 81.2 and 98.4% for 100 m furrow length respectively. Almost all performance parameter increased by doubling the furrow length from 50 to 100 m.

2.3.1.2. Flexible gated pipe

Gated pipe has made furrow irrigation more efficient and easy to operate and maintain. It is one of the ways to improve the efficiency of surface irrigation. Gated pipe used for distributing water into irrigation furrows can either be rigid or flexible (polyethylene) with outlets aligned to each furrow shots normally spaced according to the crop row spacing. It provides a more equal distribution of water into each furrow and eliminates seepage and evaporative losses which occur in unlined irrigation ditches. Rigid gated pipes are rarely used in the irrigation sector and large projects mainly because of difficulty experienced in transportation. Flexible gated pipe is relatively low cost, easily transportable and requires little storage space (Smith and Gillies , 2015).

Flexible gated pipes are widely used in the sugar industry. Gated pipe has made furrow irrigation more efficient and easy to operate and maintain. It is one of the ways to improve the efficiency of surface irrigation method and can result in a 35 to 60% reduction in water and labor costs. This system has attained an application efficiency of 90% for a recycling system (Till and Chapman, 1999). The application efficiency and irrigation distribution efficiency increased to 72.5% and 92% respectively by using gated pipe system through furrow irrigation method (Omara, 1997).

2.4. Irrigation Scheduling

The most common definition of irrigation scheduling is simply the determination of when and how much water to apply .The main purpose of preparing irrigation scheduling of a given project is to maximize project efficiency and to save water and energy loss. In most developing countries these days irrigation scheduling is just at inception level, although irrigation scheduling is one of the main managerial issues that aim for further efficient water utilization. The raises of competitions among agriculture as well as non-agriculture sectors have increased. Therefore, the water is becoming a limiting factor nearly in the all irrigation projects, so these will be guidelines for the effective and efficient utilization of water through many water saving techniques (Hengeller et al., 2011).

According to Smajstrla et al.(2006), irrigation scheduling can be a source of preserving water that supports to make decisions for allocation of quantity and timing of supply of water according to water requirement of different crops. It is the key and major concern which has the potential to assure the performance to gain sustainability in the agriculture farming systems, particularly the stability, productivity and equity. George (2000) pointed down the two questions has to be answered through irrigation scheduling firstly when to irrigate the crops and secondly how much water should be applied. Irrigation scheduling quantitatively is based on three ideas, namely crop monitoring, soil monitoring and water balance technique.

2.4.1. Irrigation scheduling methods

There are three main approaches regarding irrigation scheduling methods based on soil water measurements, meteorological data and monitoring plant water stress. The choice of irrigation scheduling method depends on the irrigation strategies and the irrigation system capabilities. More sophisticated scheduling method techniques may be more accurate, but they require higher investments in more precision agricultural tools, nevertheless, simpler irrigation systems as flood irrigation can achieve improvements when accurate irrigation scheduling is applied (Jones , 2004).

2.4.1.1. Water balance method

The basic method for irrigation scheduling is referred to as water balance estimate method, which involves estimation or determination of the soil water by measuring the amount of rainfall and/or irrigation and then estimating water deficit using crop water requirement and evaporation (FAO, 1998).Since irrigation scheduling by the water balance approach is based on keeping a balance of soil water content, the irrigation criterion is the percent of water depleted from the soil water available to plants. The objective is to obtain a balance of incoming and outgoing soil water so that adequate available water is maintained for the plant. Inputs include incoming water in any form whether rainfall or irrigation. Outputs include any type of water removal (Harrison , 2012).Water balance is not merely limited to irrigation, rainfall, or groundwater. It has to enclose all water which enter and leave the spatial boundaries (Burt, 1999).

Irrigation scheduling based on soil water balance is the simplest and the most practical. Cranfield University (2007) proved that irrigation scheduling with water balance approach is grounded on calculating the soil water content. Change in water content of soil is equal to inputs minus outputs. It is common in irrigation to describe soil water status in terms of the soil water deficit. The initial in-field soil water deficit can be estimated using tension meters or the feel and appearance technique. Daily crop water use or water requirement estimates can be found in agronomy or extension reports; furthermore the closest weather station will provide relevant useful information in terms of meteorological data. Therefore, irrigation scheduling based on water balance measurements is a good or best management tool when used correctly (Wright and Bergsrud, 1991).

The water content in the crop effective root zone can estimate by using the water balance equation (Broner, 2005).

$$WCt = WCt1 + Ir + R - ETa - DP \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.1)}$$

Where, WCt=the soil water content today (mm), $WCt1$= the soil water content yesterday (mm), Ir= the irrigation depth since yesterday (mm), R= the rain since yesterday (mm), ETa= the actual ET (mm) and DP=deep percolation (mm).

2.4.1.2. Sensor-based method

Several innovations to increase farming efficiency and improve water management have been developed using different approaches such as sensors capable of monitoring the soil moisture content or the plant water stress based on key soil or plant parameters (Hanson, 2000). For instance, crop water status can be measured using soil moisture sensors, which provide the water content in the soil profile, and soil matrices potential sensors, which indicate the tension plant roots must exert to uptake soil water. Another method used for irrigation scheduling is the use of remote sensors, either spectral or canopy temperature sensors, to assess plant water stress or plant water use (Sui et al., 2012).

The new technologies and practices of irrigation management can vary in many aspects that include operating and device cost, accuracy, reliability, and risk in terms of functional management. There are vast options of tool to conduct irrigation management. Those are: Neutron scattering, Gravimetric measurements, Capacitance sensors, Electrical resistivity measurements, Heat pulse sensors and Fiber optic sensors. Based on these technologies, producers have many options to upgrade their irrigation schedule strategy; thus they are able to choose something that fit in their budget and conditions (Leib et al., 2003).

2.4.2. Irrigation scheduling parameters

According to Doorenbos and Pruitt (1996), the parameters for irrigation Scheduling are water holding capacity, effective root zone depth and daily crop water requirements. The parameters that are used for determining soil water holding capacity are field capacity, permanent wilting point. The maximum root depth depends on crop type and variety, soil structure and depth, depth to water table, soil temperature and water.

2.4.2.1. Crop evapo-transpiration

According to Allen et al. (1998), evaporation (ET) is the process whereby liquid water is converting to water vapor from the evaporating surface. Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation. Transpiration, in turn, is the transfer of the water from plants through their aerial parts. Water transfer from plant to atmosphere occurs mainly through the stomata through which they pass more than 90% water transpired. The crop evapotranspiration (ETc) refers to the combined amount of water that is lost from the growing system through evaporation and transpiration (Zhang et al., 2015).

According to Smajstrla et al. (2006), the crop water requirement defined as the total water allocated to fulfill crops evapotranspiration demand from irrigation or precipitation hence; it does not decrease the crop production. Crop evapotranspiration relates to the quantity of water that is lost by evapotranspiration. It is important to verify the crop water requirement in order to understanding the irrigation demand in better way. Irrigation water requirement is basically understood the variation in the crop water requirements and the effective amount of available precipitation. With irrigation water requirement we have to consider including the amount of water for leaching of soil and its adjustment for non-uniformity of water application (FAO, 1998).

The most popular method for crop evapotranspiration estimation is the crop coefficient method (Pereira et al., 2015). Allen et al. (2011) suggested the equations used to estimate crop evapotranspiration in normal considerations. Having in mind, there are no restraints placed on crop growth like crop density, diseases, water shortage and salinity pressures.

Reference evapotranspiration is defined as the evapotranspiration from disease free, well-fertilized crop, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic condition. Crop coefficient (Kc) which is a crucial factor in sense of calculating the crop water requirement (ETc), shows the difference in evapotranspiration among cropped and a reference grass surface. The crop Kc values are quite dissimilar due to the crops and stage of development growth. The crop development growth has four stages: the initial stage, crop development stage, mid stage and late stage (Smith , 1992).

2.4.2.2. Depth of irrigation application

Depth of irrigation application is the depth of water that can be stored within the root zone between field capacity and the allowable level the soil water can be depleted for a given crop, soil and climate. It is equal to the readily available soil water over the root zone (James, 1988). The moisture deficit in the effective root zone is finding out by determining the field capacity moisture contents and bulk densities of each layer of the soil (Mishra and Ahmed , 1990).

According to FAO (1998), the total available water for plant use in the crop root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar called field capacity and 15 bars called the permanent wilting point. The TAW will vary from 25 cm/m for silt loams to low as 6 cm/m for sandy soils. Previous studies of Habib (2004) considered the maximum rooting depth of 1.0 m for Metahara sugar estate to calculate water application depths in each soil types of the estate. Similarly, in his study the optimum factor of depletions for sugarcane was in between 0.50 to 0.65 used for sugar estate soils, and in agreement with recommended 0.65 (FAO, 1979).

2.4.2.3. Irrigation water requirement

Adequate soil moisture throughout the crop growing season is important for obtaining maximum yields. To avoid the crop water stress, rainfall and irrigation must be sufficient to meet the crop water requirement. This means that for any period of time during the crop growing season, the net irrigation requirement (NIR) is the amount of water which is not effectively provided by rainfall. It does not include the losses that are occurring in the process of applying water and it can be obtain by subtracting from crop water requirement the expected incoming of moisture in the soil water balance using the following formula. (Netafim , 2009).

$$\mathrm{NIR} = \mathrm{ETc} - (\mathrm{Pe} + \mathrm{Ge} + \mathrm{Wb}) + \mathrm{LR} \qquad (2.2)$$

Where, NIR=net irrigation water requirement, ETc=crop water requirement, Pe= effective rainfall, Ge= the ground water contribution from water table, Wb= the water stored in the beginning of each period and LR=leaching requirement.

The irrigation water requirement therefore includes additional water for leaching of salts and to compensate for non-uniformity of plant water demand (FAO, 2010). Net irrigation requirement is irrigation water which is delivered to the field and available for the crop to use. This is primarily water which is stored in the soil in the crop root zone, although some of the water which is evaporated from the water, soil and plant surfaces during application also effectively reduces climate demand. Some water is lost while transporting it from the source to crop root zone. The losses occur due to such causes as leakage from pipelines, the seepage and evaporation from the open channels and droplets sprayed through the air. Because of these, more water must be pumped than that required to be stored in crop root zone. The gross irrigation requirement is the amount that must be pumped. It is greater than NIR by a factor which depends on the irrigation efficiency (Michael , 2008).

In general, irrigation water requirement depends on the crop grown area of each and stage of growth, moisture condition in each field and weather condition expected. During early stages of growth, the water needs are generally low, but they increase rapidly during the maximum growing period to the fruiting stage. During the later stages of maturity, water use decreases as the crops ripen (Schwab et al., 1995). According to Abdel Wahab (2005), water required by sugarcane increased gradually with plant growth stage and the quantities of water required in the crop root zone amounted to 17220 and 20570 m^3/ha/season for ratoon and plant sugarcane respectively.

2.4.2.4. Irrigation interval

Irrigation interval is the number of days between two consecutives irrigations. Irrigation is a major factor in the sugarcane production. Sugarcane is one of the most water demanding after rice. It is criticized for its high water consumption and usage. Irrigation frequency is the frequency of applying water to a particular crop at a certain stage of growth and can be expressed in days. Using the net depth of irrigation application and crop water requirement we can determine irrigation interval. Frequency and depth of irrigation should vary with growth periods of the sugarcane (Michel and Pierre, 2009).According to Mishra and Ahmed (1990), irrigation interval can be calculate using the following formula:

$$\mathrm{I} = \frac{\mathrm{AMD}}{\mathrm{ETc}} \quad \text{(2.3)}$$

Where, I= irrigation interval (day), AMD=allowable soil moisture depletion (mm) and ETc=daily crop water use (mm/day).

The early vegetative period or stage is in-direct proportion or inversely to the frequency of irrigation. During stem elongation and early yield formation irrigation interval can be extended but depth of water should be increased. The response of sugarcane to irrigation is greater during the vegetative and the early yield formation periods than during the latter part of the yield formation period when the active leaf area is declining and the crop is less able to respond to sunshine. In the ripening period, irrigation intervals are extended when it is necessary to bring crop to maturity by reducing rate of vegetative growth, dehydrating the sugarcane, and forcing the conversion of total sugar to recoverable sucrose (Michael , 2008).

According to Solomon (2010), on the study of The Evaluation of Irrigation Scheduling at Metahara Sugar Estate, the irrigation interval of four different soil types of the sugar state almost relatively similar (9 to 11) days for 0 to 3 months stages and maximum of once per month for last growth stages.

2.5. Irrigation System Performance

Irrigation performance can be defined as the level at which resources such as water; land and labor are being effectively utilized for the production of food. Performance is assessed for a variety of reasons. to improve system operations: to assess progress against strategic goals; as an integral part of performance-oriented management, to assess general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time (Boss et al., 2005). Type of performance measures chosen depends on the purpose of performance assessment activity (Molden et al., 1998)

According to Douglas and Juan (1999), there are four potential kinds of performance gaps that can occur with irrigation systems. The first (1^{st}) is technological performance gap. This is when the infrastructure of an irrigation system lacks the capacity to deliver a given hydraulic performance standard. The second (2^{nd}) is when the difference arises between how management procedures are supposed to be implemented and how they are actually implemented. The third (3^{rd}) is the difference between management targets and the actual achievements .The fourth type of performance problem concerns impacts of management.

This is a difference between what people think should be the ultimate effects of irrigation and what actually results.

2.5.1. Irrigation time

Irrigation time is the time taken to irrigate a given area of an irrigation field. Knowing the time required to irrigate a specific field or irrigation speed of a scheme, helps to determine the number of irrigators to be engaged in, the amount of water to be released at a specific period, to monitor irrigation calendar and in general to assess or monitor the performance of the irrigation system as a whole(Muhammad , 2012).

According to Solomon (2010), on the study Evaluation of Irrigation Scheduling and Field Application Performance of The Hydro flumes Furrow Irrigation at Metahara Sugar Estate to determine irrigation scheduling for sugarcane under the current soil using furrow length of 100 m and 200 m obtained the following results: for all soil types at 5 lit/sec inflow rate cut-off time was in between 44 to 54 minutes for 100 m length and 92 to 118 minutes for 200 m furrow length.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Kessem Sugar Development Project is found in Afar region on the left bank of the middle valley of the Awash River, which is located 250 km North East of Addis Ababa. It lies between latitudes $9^0 7'$ to $9^0 26'$ North and longitude $39^0 9'$ to $40^0 07'$ East. The elevation of the area ranges from 820 meter above sea level at the diversion site to 785 meter above sea level at the flood plain in North Kebena. The two sections or block of the project area are named North Kesem or Gurmile Block and South Block.

Irrigation network has been planned for covering the 20,000 ha command area available at different locations. It consists of primary canals and distribution system. The two primary canals off taking from the right and left bank of the diversion weir, which is located 8 km downstream of the Kesem Dam, proposed to serve the command areas which located at the right bank of Kesem river and on the left side of the river crossings Kebena river .The general location map of Kesem irrigation project is shown in figure 3.1:

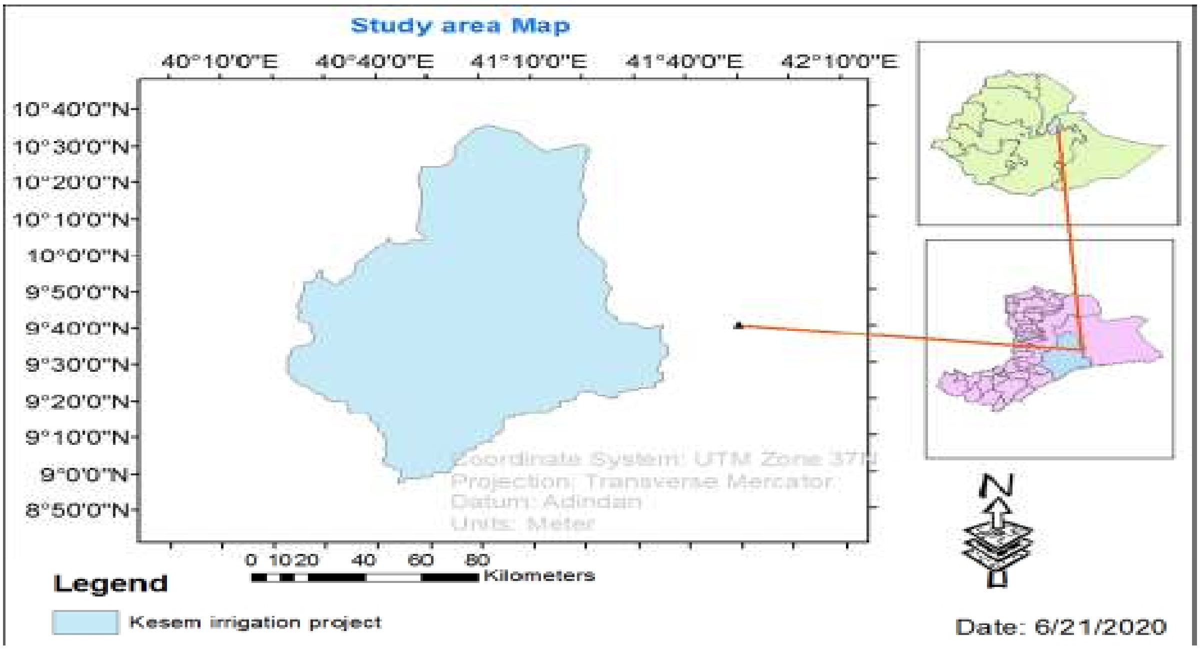

Figure 3.1: Location map of study area

Kesem left bank (Northern Block) or "Boloyta" irrigation site has a gross area of 10,000 ha. This area is supplied by secondary canals off taking from Northern Primary canal. The

Right bank (Southern Block) or “Ali-Bette “and “Deho” irrigation site has a gross area of 10,000 ha. This area is supplied by Southern primary canal off taking from the diversion weir. The distribution system comprising a network that the secondary canals off taking from the primary, the tertiary canals off taking from the secondary canals, the quaternary canals off taking from the tertiary canals and the field canals from the quaternary canals (WWDSE, 2008).

3.1.2. Climate Characteristics of Study Area

The study area is located close to Melka-Werer Metrology Center, the climate is semi-arid with the mean relative humidity lowest in June (42%) and highest in August (60%) and the minimum temperature varies from 14.5^0C to 23^0C in December and June respectively. The actual mean daily sunshine hour in annual basis is 7.32 hour and the wind speeds are largest in June and July when exceed 8.3 km per hour. Monthly maximum temperature of the study area varies from 31.4 ^{0}C in December to 38.3 ^{0}C in June (Figure 3.2).

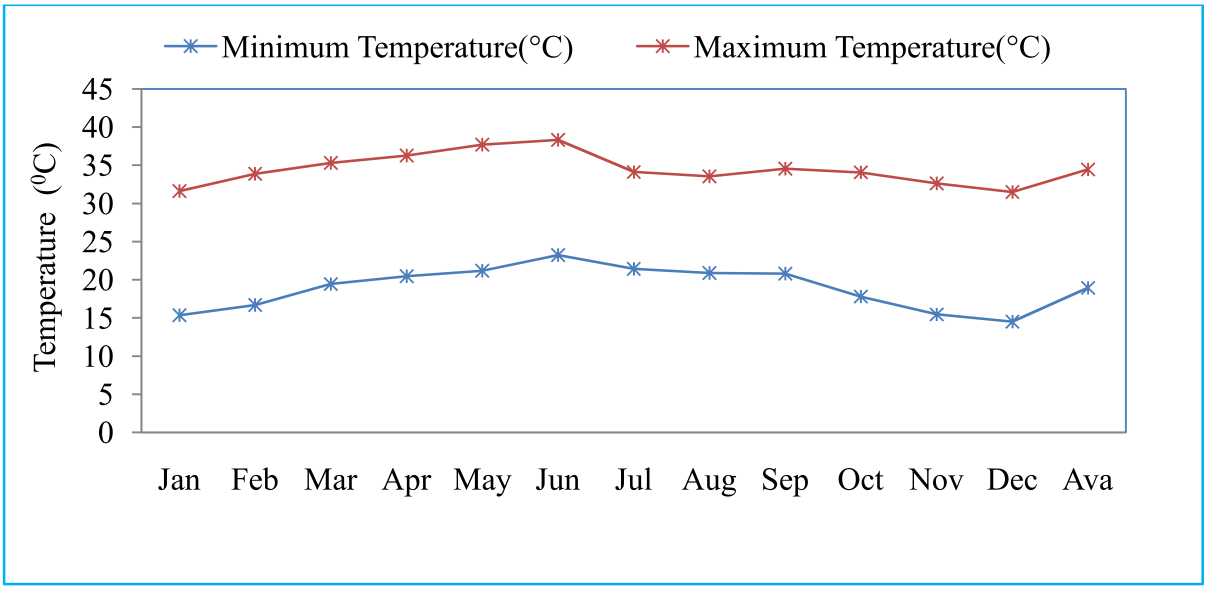

Figure 3.2: Mean maximum and minimum temperature characteristics of study area

The mean annual rainfall around the irrigation scheme is represented by Melka-Werer Meteorology Station with mean annual rainfall value of 626.45 mm (Appendix1and 2) and variation from 269.13 mm in year 2002 to 1258.8 mm in year 2018.

Monthly rainfall of the project varies from 4.20 mm in December to 160.9 mm in August (Figure 3.3) with mean value of 52.39 mm.

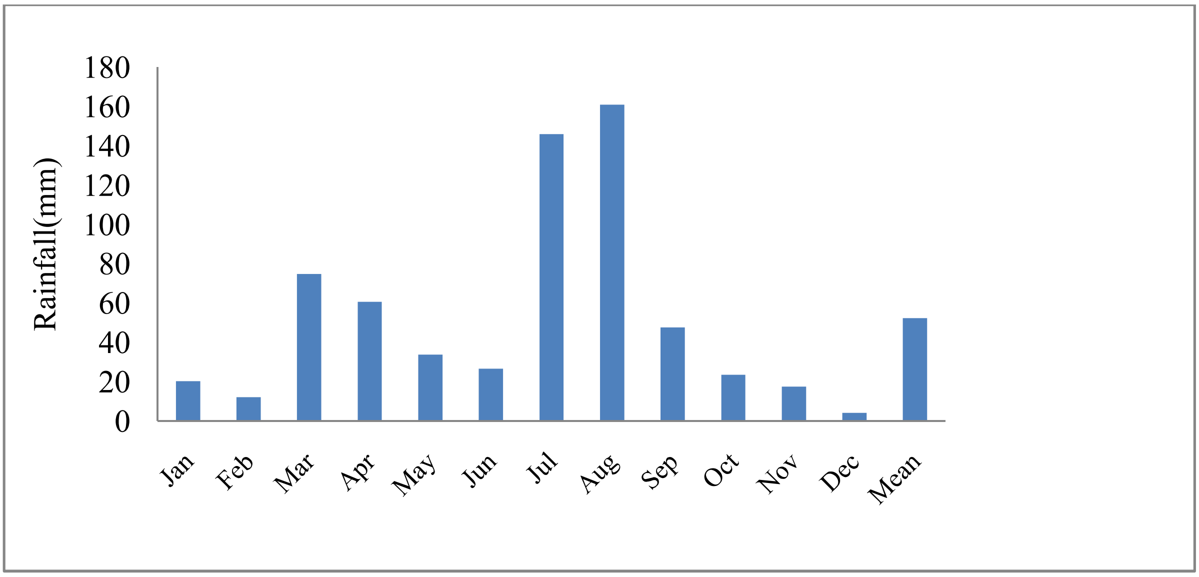

Figure 3.3: Long–term monthly rainfall (mm) characteristics of study area

3.1.3. Land use and soil type

Kessem sugar project is one of sugar estates in the country. The land use type of the area is agricultural land for cultivating sugarcane. Its total sugar production land is around 20,000 ha for sugarcane plantation. Leptosolos, Fluvisols, Vertisols and Soonchaks are the major soil groups identified for the project command area. Most of the soils are medium textured typically, silt loams, silt clay loams, clay loams and sandy loams. Texturally, most of the soils in the command area can be considered as highly suitable and at least moderately to marginally suitable from the context of sugarcane production. The mean soils bulk density of the project were 1.18 g/cm^3 for top soils (0 to 20 cm) and 1.17 g/cm^3 for sub soils (>20 cm) (WWDSE, 2008).

3.2. Materials and Software Program Used

The materials which were used in this thesis work were: Notebook, Stopwatch, Measuring tapes, Auger hole, Core samplers, Oven dry, Container (5 lit), Shovels, Hydro flumes, Tag paper, Markers and Computer program (Cropwat model).

3.3. Climate Data Used

For this study the climatic data were collected from Melka-Werer Agricultural Research Institute. Twenty-five years from 1994 to 2018 rainfall, maximum temperature, minimum temperature, sunshine hour, relative humidity and wind speed data were used to develop irrigation scheduling of sugarcane.

3.4. Evaluation of the Existing Irrigation Application Practices

Evaluation of current irrigation application practices were done by referring the feasibility and design study document, field observation, field report and by physical contact with Technical responsible Staffs such as Irrigation and Plantation. The assessment contains irrigation hour per day and the number of outlet opening at a time and application of water with respect to soil and growth stage.

The methodology used for evaluation of the irrigation application practices follows the measurements of outlet inflow rate or discharge and the number of out late opening. The evaluation procedure begins by defining the inflow rate at the irrigation field by checking all dimensions. The individual performance of over eleven fields of the sugar estate was monitored during this study. Fields were selected based on soils types, growth age and management practices. The furrow lengths were 100m; points on each length are marked with the stakes at a regular interval in order to determine the soils characteristics, irrigation application depths and to record the number of outlet opening and irrigation hour data.

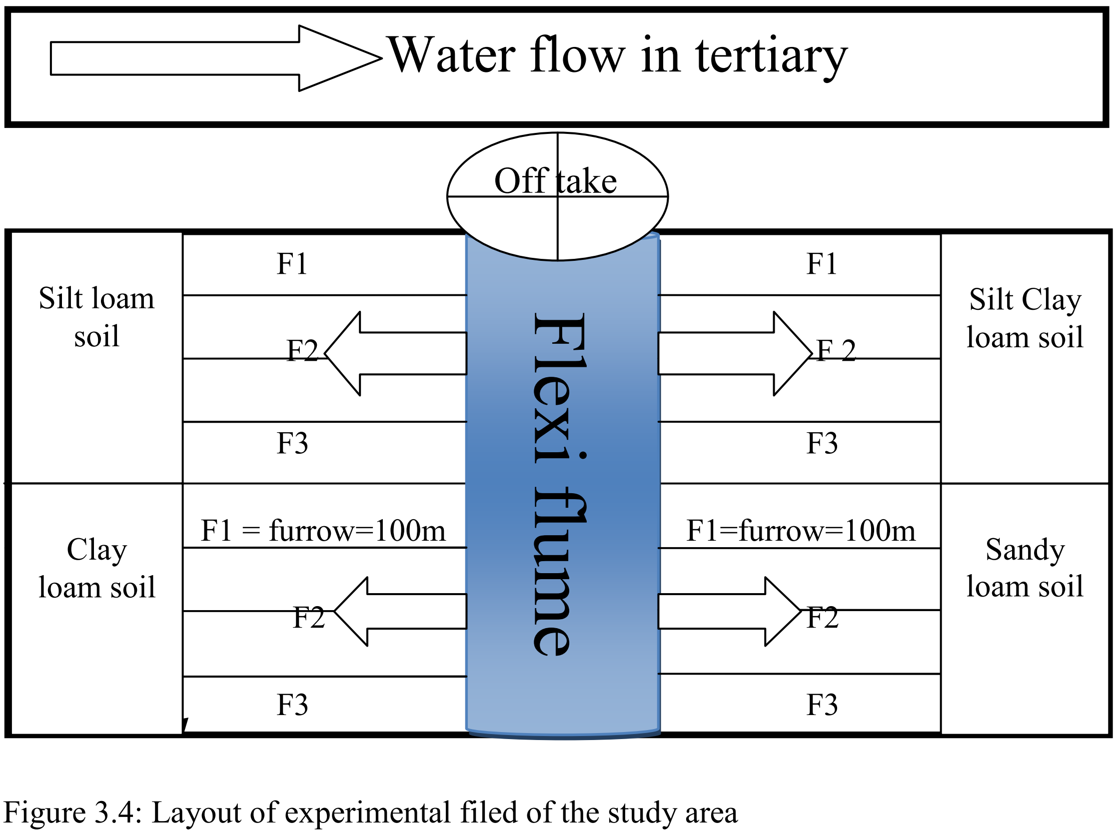

Figure 3.4: Layout of experimental filed of the study area

3.5. Development of Irrigation Scheduling

The successful irrigation scheduling requires good understanding of the knowledge of soil water holding capacity, crop water use and crop sensitivity to moisture stress at different growth stages. The following information about field conditions were determined before scheduling can begin: the active crop root zone, the amount of soil water holding capacity in the crop root zone, the amount of allowable soil water depletion before irrigation and irrigation application amount. The information about active crop root zone and soil water depletion was collected from research finding and previous studies. The soil water holding capacity data was collected from filed measurement and analyzed in the soil laboratory. Then, the required amount of irrigation water was determined using Cropwat computer model and mathematical formulas.

Therefore, proper and relevant information from available data of secondary sources, were collected and carefully analyzed. Melka-Werer Agricultural Research Institute was used for climatic data (rainfall, maximum temperature, minimum temperature, sunshine hour, relative humidity and wind speed) and soil data. International study reports were being utilized for appropriate soil and sugarcane crop characteristics.

3.5.1. Data analysis for irrigation scheduling

In soil laboratory water available to the crop can be measured from soil moisture contents. For this study the soil data's were analyzed at Melka-Werer Research Centre .The method of the soil water content measurement were involves taking a physical sample of the soil, weighing it before any water is lost, and drying it in an oven dry before weighing it again. Then, the soil moisture content was determined using gravimetric method as expressed by equation (3.1.). It is the ratio of mass of water to the mass of soil.

$$W = \frac{(Ww - Wd)}{Wd} \times 100 \qquad (3.1)$$

Where, Ww= weight of wet soil sample (g), Wd= weight of oven dry soil sample (g), and W= water content expressed on weight basis in (%).

A total of 33 representative soil samples at a depth of 0 to 30 cm and 30 to 60 cm were taken from three irrigation sites based on soil type consideration using auger hole and core samplers which were covered with sugarcane and the sample depths considered average crop root depth concentration of 60 cm. The undisturbed soil samples were analyzed for the particle size distribution (i.e. soil texture), field capacity, bulk density and permanent wilting point at Melka-Werer Research Centre. Particle size distribution was determined using mechanical analysis. The percentage of sand, silt and clay were determined by using the sieve analysis and hydrometer method. The soil textural class was assigned by USDA textural triangle. Using the core samplers of known volume the samples were weighed and placed in the oven dry at 105 ^{0}C for 24 hours, and then from the oven dried soil the Bd (g/cm^3) was calculated as described in Walker (2003) using the following formula:

$$\mathrm{Bd} = \frac{\mathrm{Md}}{\mathrm{Vs}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

Where, Bd= soil bulk density (g/cm^3), Md=oven dry weight of soil (g) and Vs=volume of soil (cm^3).

The total available water (TAM) for plant use in the root zone was a difference in moisture content between field capacity and permanent wilting point. The following methods and procedure were used to determine the soil water content at FC and PWP of the selected fields. First, place the soil sample retainer rings on porous plate. Then, add distilled water to the porous plate and cover the plate. When the samples are saturate, transfer the plate on the pressure chamber and connect the outlet tube. After that, apply 1/3 bar pressure for FC and 15 bar pressure for PWP. Lastly, transfer the soil from each ring to a weighing tin and determine the total available content using the formula given by James (1988):

$$\mathrm{TAM} = \mathrm{FC} - \mathrm{PWP} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where, TAM= total available water (%), FC= moisture content of the soil at field capacity (%) and PWP = moisture content of the soil at permanent wilting point (%).

3.5.2. Estimating irrigation scheduling parameters

Irrigation scheduling based on soil water balance is the simplest, most practical way and a good management tool when used correctly. The soil water holding capacity, which is the amount of water measured in (mm/m) held in the soil by capillary forces, and the effective root zone , which is the soil depth of the roots were the two parameters used to determine total soil water available to plants. For scheduling long year’s climate data (1994 to 2018) were collected from Melka-Werer Agricultural Research Institute. From research findings and previous studies of Habib (2004) and Solomon (2010) the sugarcane root depth and crop coefficient values for each growth stage were collected. The depth of water required to refill the soil to its field capacity was maintained by taking the soil bulk density to root depth of sugarcane crop. Finally, using Microsoft excels and Cowpat computer model the irrigation scheduling parameters were computed.

The parameters such as reference evapotranspiration (ETo), crop water requirement (ETc), irrigation water requirement (NIR), application depths (Dn) and irrigation interval (I) were estimated to develop irrigation scheduling of the Project.The Computer program (Copwat model) was used for preparation of irrigation scheduling as per the local area and climatic information. The meteorological data such as; mean minimum and maximum temperature, relative humidity, wind speed at 2 m height and daily sunshine hours were used for driving the reference evapotranspiration using Penman-Monteith method. The soil characteristics such as; soil texture and total available water and the crop data such as; length of growth period, crop coefficient and root depth at different growth stages also used as input. Then, the crop evapotranspiration and irrigation application depths with respective project soil types were computed by using different empirical formulas.

3.5.2.1. Reference evapotranspiration

To estimate the rate of reference crop evapotranspiration based on climatic factors many methods were developing. From several methods the Penman-Monteith method is the most accurate, complex and more reliable for any length period than the methods that use less climatic data as presented by Allen et al. (1998), using Cropwat computer software model. Therefore, for this research work the Penman-Monteith method was selected to determine reference evapotranspairation of sugarcane using the following formula:

$$\mathrm{ETo} = \frac{0.408\triangle(\mathrm{Rn}-\mathrm{G})+\gamma\frac{900}{(\mathrm{T}+273)}\mathrm{U2}(\mathrm{es}-\mathrm{ea})}{\triangle+\gamma(1+0.34\mathrm{u2})} \quad \text{(3.4)}$$

Where, ETo is reference evapotranspiration (mm/day), Rn is net radiation ($MJ/m^2/day$), G is the soil heat flux density ($MJ/m^2/day$),T is the mean daily air temperature at 2 m height (°C), U2 is the wind speed at 2 m height (m/s), es is the saturation vapour pressure (kPa), ea is actual vapor pressure (kPa), es - ea is the saturation vapor pressure deficit (kPa), Δ is the slope of vapor pressure curve (kPa/°C) and γ is a psychometric constant (kPa/°C).The equation uses the standard climatologically records of the solar radiation (sunshine), air temperature, humidity and wind speed.

To find out the reference evapotranspiration (ETo) in respective months of the study area through Cropwat model the following steps and information were used. First insert the location of the station (i.e. altitude, latitude and longitude) and then, insert the long years (1964 to 2018) monthly climatic data (i.e. minimum and maximum temperature, relative humidity, sunshine duration and wind speed at 2 m height) in to software model. Finally, obtain calculated the reference evapotranspiration of the study area in mm/day.

3.5.2.2. Effective rainfall

According to Dastane (1974), effective rainfall is defined as the portion of rainfall which is useful directly and /or indirectly for crop production at the site where it falls. It helps in predicting more precisely the irrigation water requirement of crops. Effective rainfall of the study area was estimated using the Cropwat Software model. This software has four different methods. Out of these methods, the Soil Conservation Service Method (USDA) was selected for estimation of effective rainfall by processing 25 years rainfall data.

In this method, it is supposed that crops can use 60 to 80% of rainfall higher than 250 mm. Rainfall, which is higher than 250 mm in month, reaches use of crops from total rainfall to 10%.To determine effective rainfall in respective months using the USDA method through Cropwat model the following relation were used:

Relation 1: When Ptot<250mm, $\mathrm{Pef} = \mathrm{Ptot}(125 - 0.2\mathrm{Ptot})/125$

Relation 2: When Ptot>250mm, $\mathrm{Pef} = (125 - 0.1\mathrm{Ptot})$

Where, Pef is representation of effective rainfall in (mm/ month) and Ptot is total rainfall in (mm/ month).

3.5.2.3. Crop coefficient

Crop coefficient (Kc) is the factor that relates actual crop water requirement to reference crop evapotranspiration. The knowledge of crop type, date of plantation, length of growing season (i.e. duration of initial, development, mid and late stage) and climatic data (relative humidity and wind speed) are required for the determination of Kc. However, Kc values of sugarcane are available in the literature for respective growth stages.

According to Doorenbos and Puritt (1996), growth stage of sugarcane can be classified to four stages. Thus, the values from Table 3.1 were used as sugarcane crop coefficients (Kc) of the study area.

Table 3.1: Growth stages of sugarcane at kesem sugar estate (Doorenbos and Puritt ,1996)

Cane age group (month)	Canopy cover estimated (%)	Crop coefficients (Kc)	Eff.Root zone (m)
0 to 3	0 to50	0.675	0.30
3 to 6	50 to100	0.950	0.50
6 to 12	100	1.025	0.60
Above 12	Senescence	0.7	0.90

3.5.2.4. Estimation of crop water requirement

Crop water requirement or crop evapotranspiration is the amount of water that required to compensate the evapotranspiration loss from cropped field and was determined by using empirical method. In the empirical method reference evapotranspiration (ETo), and factors known as crop coefficients (Kc) were used which vary from crop to crop and depending on the stage of the crop. It was calculated by multiplying ETo by corresponding Kc value of different growth stages. Therefore, sugarcane evapotranspiration (ETc) of the study area at each growth stages was calculated as:

$$\mathrm{ETC} = \mathrm{ETo} \times \mathrm{Kc} \quad \ldots\ldots (3.5)$$

Where, ETc is crop evapotranspiration (mm/day),ETo is reference evapotranspiration (mm/day) and Kc is the crop factor/crop coefficient (fraction).

3.5.2.5. Determination of net and gross irrigation requirement

Net irrigation requirement is derive from the water field balance equation. It is obtained by subtracting from crop water requirement (ETc) the expected incoming of moisture in the soil water balance. The gains include effective rainfall, capillary rise from ground water and stored soil moisture. Here, however, the actual net irrigation water requirement of the study area was estimated using the method outlined by (Duggal and Sony, 1996 as cited in Habib,2001). In this method, the actual net irrigation water requirement of sugarcane was determined by subtracting effective rainfall and ground water contribution from crop water requirement at each growth stages as the following formula:

$$\text{NIR} = \text{ETc} - \text{Pef} - \text{Gw} \quad \text{(3.6)}$$

Where, NIR is net irrigation requirement (mm/day), Pef is effective rainfall (mm/day), and Gw is ground water contribution. In our case, the value of Gw is zero, because there is not a detail survey study take place in this study area.

According to Merriiam and Keller (1978), the gross irrigation requirement of sugarcane at each growth stages was computed by dividing the net irrigation requirement to application efficiency, to achieve at least the design application efficiency (65%) in respective soils, as the following formula:

$$\text{GIR} = \frac{\text{NIR}}{\text{Ea}} \quad \text{(3.7)}$$

Where, GIR is gross irrigation requirement (mm/day) and Ea is application efficiency (%).

3.5.2.6. Estimation of application depths

Application depth refers to the depth of irrigation water to be applied in to the soil at a particular irrigation event. The amount of irrigation water to apply depends on irrigator's strategy, i.e. whether to fill the soil back to filed capacity or not and the level of allowable soil moisture depletion. Proper irrigation application depth can be determined from known crop and soil characteristics.

The maximum required depth can be determined from the total available moisture between field capacity and wilting point, and allowable depletion fraction. Together with effective rooting depth, this gives the maximum depth to which the soil can dry out and the depth that irrigation water supply must reach by the end of an irrigation interval. Then, the net depth of irrigation water applied (Dn) was determined using the following formula:

$$\text{Dn} = \text{TAM} * \text{Dr} * \text{Sg} * \text{p} \quad \text{(3.8)}$$

Where, Dn= the net depth of water application (mm), Dr = maximum effective root depth (mm) Sg = the specific gravity, p= the soil moisture depletion factor (%).

Previous studies of Habib (2004) and Solomon (2010) optimum factor of depletions used in their studies for sugarcane at Metahara Sugar was 50% to 65% and in agreement with recommended 65% by (FAO, 1979). Considering 90% concentration of the effective crop rooting depth at the top of 60 cm was appropriate to estimate the soil moisture deficit for irrigation timing of the crop (Booker , 2009). This was to protect from moistures stress in its effective root area. Thus, 60% soil moisture depletion factor was used for this study.

Gross water application depth of sugarcane at different growth stages was estimated using the net depth of water application and project irrigation application efficiency using the following formula:

$$\mathrm{Dg} = \mathrm{Dn}/\mathrm{Ea} \quad \ldots\ldots\ldots\ldots \quad (3.9)$$

Where, Dg = the gross depth of water application (mm) and Ea= the irrigation application efficiency (%).

3.5.2.7. Determination of irrigation interval

The number of days between the two consecutive irrigations is called irrigation interval (Borner, 2005). It varies with depth of crop development because crop water requirement is different for each growth stage. The proper irrigation interval (I) in days can be estimate relating the net application depth to crop water requirement (Mishra and Ahmed , 1990). Therefore, the irrigation intervals of the study area for respective growing months, soil and growth stages were estimated using the following formula:

$$\mathrm{I} = \frac{\mathrm{D_n}}{\mathrm{ETc}} \quad \ldots\ldots\ldots\ldots \quad (3.10)$$

Where, I is irrigation interval (days), Dn is Net depth of application (mm) and ETc is peak crop water requirement (mm/day).

3.6. Research Methodology Framework

The concept of this research methodology shows the evaluation of irrigation scheduling practices at Kesem Sugar Development Project. For this reason the solution ways for the problems that have been addressed by assessing the current irrigation practices from filed observation, measurement and develop irrigation scheduling by using Cropwat model. The general suggested methodological framework for this study is shown below in figure 3.5:

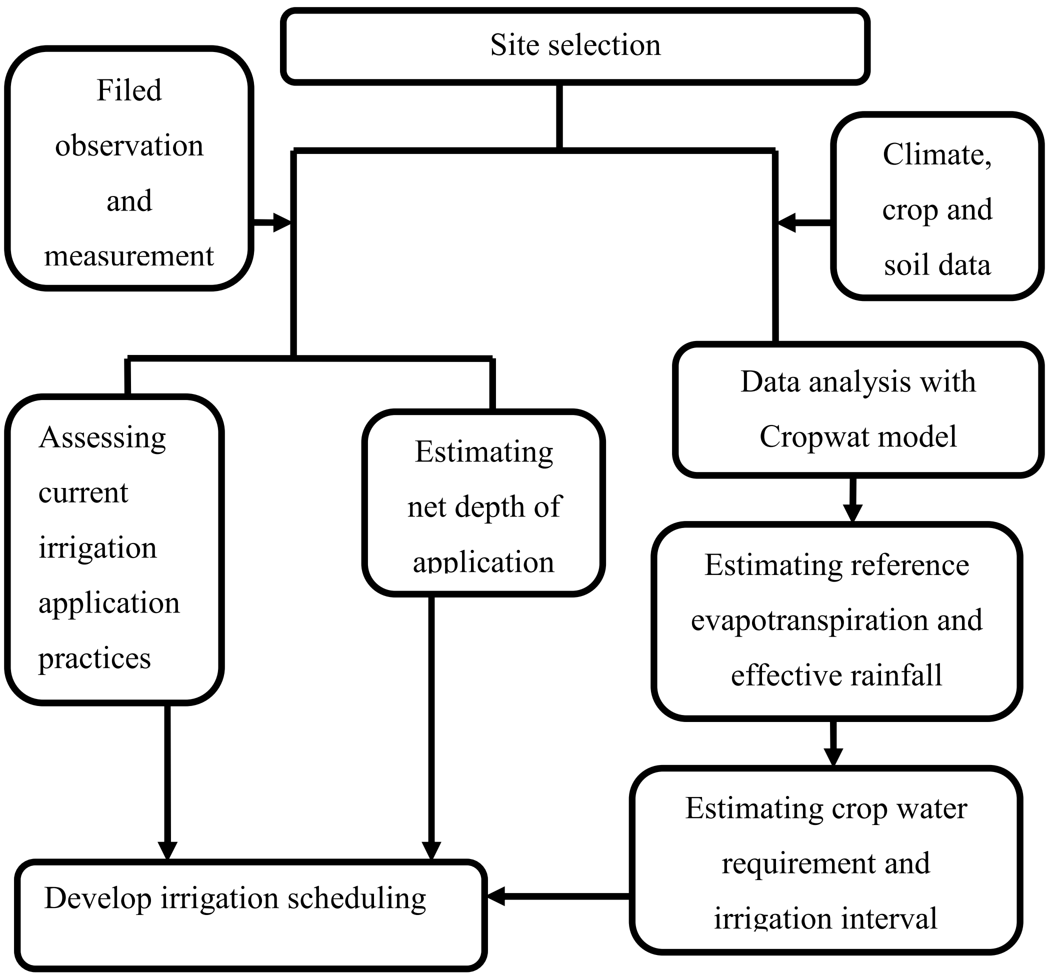

Figure 3.5: Conceptual framework of research methodology

4. RESULTS AND DISCUSSION

4.1. Evaluation of Current Irrigation Application Practice

According to WWDSE (2008), the primary canals of irrigation system are proposed to be lined with High Density Polyethylene (HDPE) film and gabion with adequate thickness of rock covers. But now, the lined canals were losing HDPE lining. The operation service, care, and maintenance of the irrigation systems were clearly put in the Feasibility and Design Study document (2008). But, in practicing now, regular maintenance and repair of canal not done and the system is not working as per design capacity. Due to this, most of conveyance canals are covered with weeds, distribution boxes are filled by silt and the hydro flume carries water less than design capacity. The effect of these entire problems creates the system to poor, and malfunction, increasing cost of maintenance.

Similarly, the drainage structures were not constructed and there is no drainage water flow out of the field. This causing the accumulation of salt water on the soil surface resulting in wide salinity problem and caused poor sugarcane growth which reduced expected yield per ha for the sugar factory. It is better to apply the preventive maintenance program and guided by the design, operation, and management manual to ensure the system efficiency as recommended by the feasibility and design study document (2008).

4.1.1. Evaluation of inflow rate and irrigation time

The project is designed to practices twelve hours per day and the flexi flume is designed to open forty (40) outlets at a time with discharge of 5 lit/sec for each to supply 200 lit/sec. But, the result of study this shows that, the average number of outlets opening at project irrigation site was varied from 24 to 26 with 7.73 average daily irrigation hours. This indicate that the existing water application is irrespective of soil type, growth stage and growing month and the water application at each irrigation site was not uniform and lower compared to expected design to be open 40 outlets and 12 irrigation hours. Similar results have been reported by Tadesse (2015), the number of outlets opening at Tendaho Sugar Project was not more than 20 at a time and lower than the expected design discharge (200 lit/sec).

Table 4. 1: Number of outlets opening and irrigation hours at each irrigation site

Irrigation event	Number of opening	Irrigation Time (hours)
"Ali-Bette"	24.00	8.20
"Boloyta"	26.00	7.20
"Deho"	25.00	7.80
Average	24.00	7.73

Where, IRR1=First irrigation, IRR 2=Second irrigation and IRR 3=Third irrigation

In this sugar estate there was no fixed inflow rate implementation practices. The collected data of the existing inflow rate practices at each irrigation site were presented in Table 4.2.

Table 4. 2: Inflow rate of study area

S/N	Irrigation site	Irrigation event	Inflow rate (lit/sec)	Mean Inflow rate (lit/sec)
1	"Ali-Bette"	IRR1	3.23	3.25
		IRR2	3.25	
		IRR3	3.27	
2	"Boloyta"	IRR1	2.75	2.75
		IRR2	2.70	
		IRR3	2.80	
3	"Deho"	IRR1	3.75	3.72
		IRR2	3.69	
		IRR3	3.72	

According to Table 4.2, the mean values of inflow rate vary in between 2.75 and 3.72 lit/sec. These values were lower compared to expected designed discharge of 5 lit/sec. This was due to lowered hydro flumes bed and the water leaks over all parts of the gated pipes body and outlets. Similarly, the inflow rate at each replication differs from each other. This was happened due to field application condition of the irrigators (poor skills of field irrigators) and water supply conditions. Since the irrigators (daily laborers) main aim was observing whether the water has advanced at downstream reach, they don't have any know how on deciding the amount of inflow rates.

4.2. Irrigation Scheduling Performance Parameters

The following performance parameters were estimated to develop irrigation scheduling of Kesem Sugar Development Project with respect to growing month, growth stage and soil type.

4.2.1. Reference crop evapotranspiration (ETo)

ETo is the crop reference evapotranspiration, which was estimated using average 25 year maximum and minimum temperature, sunshine hour, relative humidity, wind speed based on Penman- Monteith equation by using Cropwat software model. The estimated reference evapotranspiration values of the study area for months of the year are given in Table 4.3.

According to Table 4.3, the monthly average minimum temperatures of 14.5°C occurred in December and maximum temperature varied from 31.5°C in December to 38.3°C in June. The relative humidity was highest in August when it reached 60%, and a minimum of 43% occurred in June. Wind speed varied from 129 to 293 km/day. Sunshine hours varied from 5.7 hours in August to 8.4 hours in February. The ETo value of the study area was varied from 4.32 mm/day in December to7.16 mm/day in June with the mean of 5.54 mm/day. Tadesse (2015) reported that the ETo values at Tendaho Sugar Project were varied from 6.84 mm/day in December to 11.28 mm/day in June with 8.91 mm/day mean value. This shows that crop evapotranspiration varied due to climate variability for the same crop and months.

Table 4. 3: Reference evapotranspiration for each months of the study area

Months	T.Min (°C)	T.Max (°C)	R.H (%)	W.S (km/day)	S.S.H (hr/day)	Rad (MJ/m^2/day)	ETo (mm/day)
January	15.40	31.60	56.00	153.00	7.80	18.90	4.54
February	16.70	33.90	50.00	166.00	8.40	21.00	5.38
March	19.50	35.30	51.00	179.00	7.80	21.30	5.84
April	20.50	36.30	51.00	183.00	7.60	21.20	6.05
May	21.20	37.70	46.00	192.00	7.60	20.80	6.40
June	23.30	38.30	43.00	235.00	7.90	20.80	7.16
July	21.40	35.00	57.00	293.00	6.80	19.30	6.40
August	20.90	33.50	60.00	220.00	5.70	18.10	5.33
September	20.80	34.50	56.00	184.00	5.80	18.20	5.35
October	17.80	34.10	51.00	138.00	6.90	19.00	5.05
November	15.50	32.60	52.00	129.00	7.90	19.30	4.66
December	14.50	31.50	53.00	133.00	7.60	18.10	4.32
Average	18.90	34.50	52.00	184.00	7.30	19.70	5.54

4.2.3. Crop water requirement

The sugarcane crop water requirement (ETc) of the study area was determined by using equation 3.5, multiplying reference evapotranspiration of the crop with corresponding crop coefficient (Kc) for each month and stage of growth. Estimated crop water requirement values of the study area for each growth stages are given in Table 4.4.

Table 4. 4: Crop water requirement of the study area for each growth stages

Month	ETo	ETc (mm/day)			
	(mm/day)	0 to 3	3to 6	6 to 12	Above 12
January	4.54	3.06	4.31	4.65	3.18
February	5.38	3.63	5.11	5.51	3.77
March	5.84	3.94	5.55	5.99	4.09
April	6.05	4.08	5.75	6.20	4.24
May	6.40	4.32	6.08	6.56	4.48
June	7.16	4.83	6.80	7.34	5.01
July	6.40	4.32	6.08	6.56	4.48
August	5.33	3.60	5.06	5.46	3.73
September	5.35	3.61	5.08	5.48	3.75
October	5.05	3.41	4.80	5.18	3.54
November	4.66	3.15	4.43	4.78	3.26
December	4.32	2.92	4.10	4.43	3.02
Average	5.54	3.74	5.26	5.68	3.88

According to Table 4.4, the minimum sugarcane crop water requirement was 2.92 mm/day in December at initial stages. This is due to minimum evapotranspiration in these months and lowest crop coefficient in the stages of 0 to 3 months. The maximum sugarcane water requirement was 7.34 mm/day in June at the third growth stage. This is due to, the highest evapotranspiration in these months and the highest crop coefficient. Initially, it was lower and gradually increases and higher in third growth stage which would decrease after fourth growth stages. With respective initial, development, mid and late growth stages the values were 3.74, 5.26, 5.68 and 3.88 mm/day respectively. But, the ETc values of Blese Sugar Development Project increase from 1.88 mm/day (1^{st} stage) to 5.73 mm/day (3^{rd} stage) and gradually decrease to 2.42 mm/day (4^{th} stage) (Abshiro and Singh , 2018).This shows that water requirement of sugarcane varies from place to place and growth stage (Smajstrla et al., 2006).

4.2.4. Effective rainfall

A part of rainfall which is effectively used by the crop after the rainfall losses is effective rainfall. By feeding the 25 years monthly rainfall data in to Cropwat software model, using USDA Soil Conservation Service method the estimated effective rainfall of the study area was presented in Table 4.5.

Table 4. 5: Monthly and daily effective rainfall of the study area

Month	Rain fall (mm)	Eff. Rain (mm/month)	Eff. Rain (mm /day)
January	20.30	19.60	0.63
February	12.20	12.00	0.43
March	74.90	65.90	2.13
April	60.80	54.90	1.83
May	33.90	32.00	1.03
June	26.70	25.60	0.85
July	146.00	111.9	3.61
August	160.90	119.50	3.85
September	47.70	44.00	1.47
October	23.60	22.70	0.73
November	17.50	17.10	0.57
December	4.20	4.20	0.14
Total	628.70	529.40	17.27

According to Table 4.5, the average monthly effective rainfall of the study area was lower in December (0.14 mm/day) and higher in August (3.85 mm/day). In August, daily effective rainfall value higher than the crop water requirement at initial and late growth stage. These indicate that, in this month no need of irrigation water for sugarcane at the two growth stages. Thus, surface drainage is needed to remove excess water from the field, especially in water logged fields. Other than, this month irrigation water is needed to meet the crop requirement. This show that, effective rainfall varied from month to month. Similarly, the average monthly effective rainfall of Wonji/Shoa Sugar State varied from 0.11 mm/day in February to 5.7 mm/day in July (Tsegaye, 2019).

4.2.5. Estimation of net and gross irrigation water requirement

Considering monthly effective rainfall the net irrigation water requirements of the study area for each growing months and growth stages were estimated using equation 3.6 and given in Table 4.6. It was obtained by subtracting effective rainfall from the crop water requirement (ETc) at each growth stages.

Table 4. 6: Net irrigation water requirement for each month and growth stages

Month	Net irrigation requirement (mm /day)			
	0 to 3	3to 6	6 to 12	Above 12
January	2.43	3.68	4.02	2.55
February	3.20	4.68	5.08	3.34
March	1.81	3.42	3.86	1.96
April	2.25	3.92	4.37	2.41
May	3.29	5.05	5.53	3.45
June	3.98	5.95	6.49	4.16
July	0.71	2.47	2.95	0.87
August	*	1.21	1.61	*
September	2.14	3.61	4.01	2.28
October	2.68	4.07	4.45	2.81
November	2.58	3.86	4.21	2.69
December	2.78	3.96	4.29	2.88

The star sign (*) shows that irrigation is not required, since rainfall will be sufficient. In August, at initial and late growth stage, the average monthly effective rainfall is more than enough to fulfill the need of crop water requirement. In contrary, the full irrigation water is needed from January to June and September to December for all growth stages. Relatively, for the wet season very small amount of irrigation water is needed in August (at mid and development) and in July (at initial and late) stages. Tsegaye (2019) reported that the NIR values of Wonji/Shoa Sugar State increase from 1.58 mm/day in 3 to 6 months to 6.19 mm/day in 6 to 15 months growth age and for wet season irrigation is not required at each growth stages. This shows that, the NIR was varied from place to place and age to age for the same crop due to climate variability.

For currently practicing irrigation application efficiency of 65%, the gross irrigation water requirements (GIR) of the sugarcane at each stage were calculated as shown in Table 4.7. According to Table 4.7, the gross irrigation requirement of sugarcane was initially lower and gradually increases and higher in third stage which would decrease after fourth stages. Its value was lower in July at the first growth stages and higher in June at the third growth stage. Thus, the maximum and minimum GIR were 9.98 and 1.09 mm/day respectively and irrigation water not required in August at first and fourth stages.This show that gross irrigation water requirement of sugarcane varies at each growth stage (Michael , 2008).

Table 4. 7: Gross irrigation water requirement for each month and growth stages

Month	Gross irrigation requirement (mm /day)			
	0 to 3	3to 6	6 to 12	Above 12
January	3.74	5.66	6.18	3.92
February	4.92	7.20	7.82	5.14
March	2.78	5.26	5.94	3.02
April	3.46	6.03	6.72	3.71
May	5.06	7.77	8.51	5.31
June	6.12	9.15	9.98	6.40
July	1.09	3.80	4.54	1.34
August	*	1.86	2.48	*
September	3.29	5.55	6.17	3.51
October	4.12	6.26	6.85	4.32
November	3.97	5.94	6.48	4.14
December	4.28	6.09	6.60	4.43

4.2.6. Estimation of net depth of water application

Based on the consideration of soil water holding capacity, maximum crop rooting depth and optimum factor of depletion the readily available water in root zone and the net depth of water application for the current four different soil types were determined. The soil physical parameters of the study area that were tested in soil laboratory are given in Table 4.8. The soil textural type, percent of clay, silt, and sand were given in appendix table 3.

Based on Table 4.8, the soil textural types selected for evaluation were categorized under medium textured. They cover more than 78% of Project command area (WWDSE, 2008). The bulk density values ranges from 1.10 to1.36 g/cm^3. It was also in agreement with bulk density of the soils for sugarcane should be with a range of 1.1 to 1.4 g/cm^3 (Sundrara , 2000).The total soil available water content ranges from 10.4% to 18.9%. According to Cropwat software the default data, the sugarcane root depth may go up to 1.5 m, but in Ethiopian sugar estates the maximum is considered to be 90 cm and effective root depth of 60 cm. Thus, 60% soil moisture depletion factor was used for this study.

Table 4. 8: The soil textural type and physical parameters of the study area

Field Name	FC (%) Soil depth(cm)			PWP (%) Soil depth(cm)			BD (g/cm^3)	Soil texture type	TAW (%)
	0-30	30-60	Mean	0-30	30-60	Mean			
KA4	37.80	35.80	36.80	22.10	19.50	20.80	1.17	SiCL	16.00
KA8	37.80	34.50	36.20	22.70	17.40	20.10	1.20	SiCL	16.10
KD4	37.00	38.90	38.00	17.80	22.00	19.90	1.30	SiCL	18.10
KB 1	32.50	32.50	32.50	17.50	17.50	17.50	1.14	CL	15.00
KB3	36.20	31.80	34.00	20.60	17.50	19.10	1.10	CL	14.90
KA6	32.50	38.20	35.30	17.50	23.80	20.65	1.23	CL	14.70
KD2	24.40	14.20	19.30	9.30	8.60	8.95	1.19	SL	10.40
KA10	24.60	24.50	24.60	12.60	13.20	12.90	1.22	SL	11.70
KA2	33.50	32.70	33.10	14.70	14.70	14.70	1.31	SiL	18.40
KD 8	340	36.40	35.20	16.90	15.70	16.30	1.36	SiL	18.90
KD 9	32.30	33.40	32.90	14.70	13.60	14.20	1.20	SiL	18.70

Where, SiCL =Silt clay loam, CL = Clay loam, SL =Sandy loam and SiL = Silt loam

The net depth of irrigation water application (Dn) applied for silt clay loam, clay loam; sandy loam and silt loam soil of the study area were estimated using equation 3.8 for each growth stages are given in from Tables 4.9 to 4.12, by corresponding root depth, allowable factor of depletion and water holding capacity of soils.

Table 4. 9: Net depth of water application of silt clay loam soil for each growth stage

Parameters	Growth stages (month) 0 to 3	3to 6	6 to 12	Above 12
Root depth (m)	0.30	0.45	0.60	0.90
Depletion factor (%)	60.00	60.00	60.00	60.00
Total available water (%)	16.70	16.70	16.70	16.70
Bulk density ($g/cm^{3)}$	1.22	1.22	1.22	1.22
Net depth of application (mm)	36.70	55.0	73.30	110.00

Table 4.10: Net depth of water application of clay loam soil for each growth stage

Parameters	Growth stages (month) 0 to 3	3to 6	6 to 12	Above 12
Root depth (m)	0.30	0.45	0.60	0.90
Depletion factor (%)	60.00	60.00	60.00	60.00
Total available water (%)	14.90	14.90	14.90	14.90
Bulk density ($g/cm^{3)}$	1.16	1.16	1.16	1.16
Net depth of application (mm)	31.10	46.70	62.20	93.30

Table 4. 11: Net depth of water application of sandy loam soil for each growth stage

	Growth stages (month)			
Parameters	0 to 3	3to 6	6 to 12	Above 12
Root depth (m)	0.30	0.45	0.60	0.90
Depletion factor (%)	60.00	60.00	60.00	60.00
Total available water (%)	11.10	11.10	11.10	11.10
Bulk density (g/cm$^{3)}$	1.20	1.20	1.20	1.20
Net depth of application (mm)	24.00	36.00	48.00	71.90

Table 4.12: Net depth of water application of silt loam soil for each growth stage

	Growth stages (month)			
Parameters	0 to 3	3to 6	6 to 12	Above 12
Root depth (m)	0.30	0.45	0.60	0.90
Depletion factor (%)	60.00	60.00	60.00	60.00
Total available water (%)	18.70	18.70	18.70	18.70
Bulk density (g/cm$^{3)}$	1.29	1.29	1.29	1.29
Net depth of application (mm)	43.40	65.10	86.80	130.30

According to the above four tables, the net irrigation application depth is increasing with respective increasing of age and effective crop root depth. The silt loam has relatively higher available water holding capacities than the sandy loam and clay loam soils. This is because of the high water holding capacity of the soil type. The values were ranging from 36.7 mm to 110 mm for silty clay loam, 31.1 mm to 93.3 mm for clay loam, 24.0 mm to 71.9 mm for sandy loam and 43.4 mm to 130.3 mm for silt loam soils, varying with cane growth stages. Thus, the irrigation depth varied with the crop growth stages and soil type.

Similar results have been reported by Tadesse (2015), net depth of application at Tendaho Sugar Project varied from 86.53 mm to 104.40 mm. During the beginning of the growing season, the amount of water given per irrigation application is small. This is due to the low water requirement of young plants and their shallow root depth. In the mid-season, the irrigation depth is larger due to the higher root depth and soil moisture extracting capacity. During the late season, the sugarcane root depth become maximum and the corresponding water requirement is maximum.

4.2.7. Irrigation interval

Estimated irrigation intervals for the respective stages and soil type of the study area using equation 3.10 were presented in the next four tables. Currently 10 days irrigation interval is used without consideration of the sugarcane growth stage, growing month and soil type.

But, according to this study the irrigation interval varied with respect of growing month, stage of growth and soil type as shown in the Tables from 4.13 to 4.16.

Table 4. 13: Irrigation interval at each growth stages and months for silt clay loam soil

Growth stages (month)	Irrigation interval (days)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 to 3	12	10	9	9	8	7	8	10	10	11	11	12
3 to 6	13	11	10	9	9	8	9	11	11	11	12	13
6 to 12	16	13	12	12	11	10	11	13	13	14	15	16
≥12	34	29	27	26	24	22	24	29	29	31	30	31

Table 4.14: Irrigation interval at each growth stages and months for clay loam soil

Growth stages (month)	Irrigation interval (days)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 to 3	10	8	8	7	7	6	7	9	9	9	10	11
3 to 6	11	9	8	8	8	7	8	9	9	10	10	11
6 to 12	13	11	10	10	9	8	9	11	11	12	13	14
≥12	29	25	23	22	21	19	21	25	25	26	29	31

Table 4.15: Irrigation interval at each growth stages and months for sandy loam soil

Growth stages (month)	Irrigation interval (days)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 to 3	8	7	6	6	5	5	5	7	7	7	8	8
3 to 6	8	7	6	6	6	5	6	7	7	7	8	9
6 to 12	10	9	8	8	7	6	7	9	9	9	10	11
≥12	23	19	17	17	16	14	16	19	19	20	22	24

Table 4.16: Irrigation interval at each growth stages and months for silt loam soil

Growth stages (month)	Irrigation interval (days)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 to 3	14	12	11	11	10	9	10	12	12	13	14	15
3 to 6	15	13	12	11	11	9	11	13	13	13	14	16
6 to 12	19	16	14	14	13	12	13	16	16	17	18	19
≥12	41	34	32	31	29	26	29	31	30	31	30	31

According to Tables 4.13, 4.14, 4.15 and 4.16, the irrigation intervals varied from month to month for the same growing age due to the monthly climatic variations, and also from age to age for the same growing month due to variation of crop coefficient and effective root depth across different age. It ranged from 5 to 31 days based on soil type, irrigation months and growth stages. Silt loam Soils have the longest irrigation interval while sandy loam soils have the shortest irrigation interval with corresponding to the growth stages. The average monthly irrigation interval for the growth stage 0 to 3, 3 to 6, 6 to12, and above 12 months were 9, 10, 12 and 27 days respectively. But the average monthly irrigation interval of Tendaho Sugar Project for growth stage of 0 to 3, 3 to 6, 6 to12 and above 12 months were 7, 8, 11 and 18 respectively (Tadesse, 2015).This indicate that sugarcane irrigation interval differ from place to place for the same growth stage and months.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

The study was conducted to evaluate irrigation scheduling practices of Kessem Sugar Development Project which is located in Afar Regional state. The irrigation scheduling parameters and existing irrigation water management practices were evaluated. The common irrigation scheduling parameters namely; available water holding capacity, crop water requirement, application depths and irrigation water requirements were estimated. The existing irrigation application practices were evaluated by using filed measurements and physical observations. Accordingly, the following conclusions are drawn.

- ❖ The project practices 8 hour irrigation time and 10 days irrigation interval. The current irrigation scheduling of the sugar project undertaking was not as per the design. Also it is not considered the soil type, growing month and stage of growth. As a result, under watering was obtained in some irrigation fields and over watering in most fields, so that the sugarcane crop performance was low as per this application. Thus, improved irrigation scheduling practices with respect to the soil type, growing month and stage of growth is very important.
- ❖ The recommended average net depth of water applications are 68.75 mm, 58.3 mm, 45.0 mm and 81.4 mm for silt clay loam, clay loam, sandy loam and silt loam soils respectively. The recommended average irrigation intervals for silt clay loam soil are 10, 11, and 13 and 29 days for initial, development, mid and late season growth stages respectively. For clay loam soils an average irrigation interval of 8, 9, and 11 and 25 days for respective initial, development, mid and late season growth stages. For sandy loam soils an average irrigation interval of 7, 7, 9 and 19 days for initial, development, mid and late season growth stages respectively. For silt loam soil an average irrigation interval of 12, 13, and 16 and 34 days for respective initial, development, mid and late growth stages. However, irrigation interval is also varying with individual soil types and irrigation months.

5.2. Recommendations

Based on the result found and the challenges faced during the study period, the following recommendation or further research directions are forwarded:

- The calculated irrigation intervals can be used as reference; but during implementation of it, the following points have to be considered. During established period, including emergence of young seedlings, light, frequent irrigations are preferred due to the low depletion level and a poorly formed rooting system. In contrast to this a low soil water level is required during late season (senescence) period and in this stage the irrigation interval is extended or stopped when it is necessary.

- To determine the exact date of irrigation, monitoring of the soil moisture status is very important. In determining irrigation intervals, it needs to check soil moisture status with nearby apparatus such as: augur test and others soil moisture sensors to decide the next date of irrigation. Therefore, it is advisable to start the soil moisture monitoring before three days of theoretical irrigation interval.
- Irrigation schedule where the application depth and interval varies constantly over the season may create the problems in practice. Therefore, the varied interval and average fixed amount practice is selected for this project in which application depth is fixed and interval length is adjusted to the (net) irrigation requirements.

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APPENDIXES

A. Appendix Tables

Appendix table 1: The average yearly climatic parameters of the years (1994 to 2018) Station: Melka- Werer Altitude: 785m.a.s.l Latitude: 9.7^0N Longitude: 39.9^0E

Year	T-Min (°C)	T-Max (°C)	R.H (%)	W.S (km/day)	S.S.H (hr/day)	RFF (mm)	E.Pan (mm/day)
1994	18.74	33.85	51.27	367.50	8.58	613.10	6.99
1995	19.52	34.72	52.48	373.09	8.17	500.66	7.00
1996	19.02	34.40	51.05	347.42	1.47	680.64	6.32
1997	19.68	34.38	48.29	336.15	0.00	622.88	5.77
1998	20.33	34.40	54.32	341.42	8.05	582.20	6.86
1999	19.16	34.48	36.40	277.84	6.71	876.42	5.41
2000	18.84	34.42	48.84	387.66	8.78	563.16	6.83
2001	18.96	34.66	50.03	371.74	8.53	588.50	7.14
2002	19.89	35.38	45.91	10.46	8.68	269.14	8.56
2003	19.80	35.28	50.31	16.07	8.45	547.30	8.39
2004	19.38	34.65	51.73	14.79	8.71	685.92	7.92
2005	19.31	34.53	52.84	134.21	8.56	773.40	7.64
2006	20.12	34.45	53.63	130.85	8.32	720.05	7.53
2007	19.01	34.54	52.25	127.47	8.50	641.86	7.19
2008	18.47	34.29	50.15	120.74	8.90	470.63	7.84
2009	19.98	35.10	48.53	129.41	8.80	437.70	8.71
2010	19.84	34.28	55.24	115.46	7.96	773.60	6.63
2011	21.76	35.30	48.86	137.87	8.28	499.29	7.37
2012	19.74	35.16	47.39	144.35	8.61	540.62	7.93
2013	20.19	34.98	50.31	124.06	7.58	513.40	7.55
2014	19.24	34.82	46.17	126.48	7.15	462.60	6.53
2015	15.14	35.91	59.56	77.38	5.42	301.11	6.66
2016	13.83	31.90	76.70	128.87	6.12	840.80	4.59
2017	14.20	33.10	60.92	134.37	8.13	897.46	6.74
2018	19.99	34.31	59.41	129.54	4.22	1258.80	6.06
Ava.g	18.96	34.53	52.10	184.21	7.31	626.45	7.05

Where, T-Min=Minimum Temperature T-Max= Maximum Temperature, R.H=Relative Humidity, S.S.H=Sunshine Hours,W.S= Wind Speed, RFF=Rainfall and E.Pan=Pan Evaporation

Appendix table 2: Mean monthly climatic parameters of years (1994 to 2018)

Month	T-Min (°C)	T-Max (°C)	R.H (%)	W.S (km/day)	S.S.H (hr/day)	RFF (mm)	E.Pan (mm/day)
January	15.35	31.59	56.13	153.44	7.80	20.31	5.70
February	16.70	33.87	50.13	165.51	8.40	12.23	7.05
March	19.45	35.28	51.01	179.39	7.81	74.90	7.77
April	20.48	36.27	51.12	183.40	7.55	60.76	7.38
May	21.18	37.68	45.86	192.21	7.62	33.85	8.11
June	23.25	38.32	42.55	235.23	7.89	26.70	9.25
July	21.44	35.00	56.67	292.62	6.82	146.00	7.80
August	20.88	33.51	60.18	219.57	5.72	160.90	6.02
September	20.81	34.54	56.05	184.33	5.83	47.66	6.26
October	17.80	34.05	51.01	138.37	6.89	23.59	6.87
November	15.45	32.61	52.07	128.73	7.94	17.54	6.27
December	14.50	31.47	52.72	132.64	7.57	4.20	6.03
Average	18.94	34.52	52.12	183.79	7.32	52.39	7.04

Appendix table 3: The percentage of clay, silt, and sand and soil textural type

Fields	Soil sample depth (cm)							
	0 to 30 cm				30 to 60 cm			
	%Clay	% Silt	% Sand	Texture	% Clay	% Silt	% Sand	Texture
KA4	36.80	47.20	16.00	SiCL	31.60	49.20	19.20	SiCL
KA8	37.60	43.20	19.20	SiCL	27.60	53.20	19.20	SiCL
KD4	28.40	65.20	6.40	SiCL	36.40	57.20	6.40	SiCL
KB1	27.60	41.20	31.20	CL	27.60	41.20	31.20	CL
KB3	33.60	45.20	21.20	CL	27.60	37.20	35.20	CL
KA6	27.60	41.20	31.20	CL	39.60	39.20	21.20	CL
KD2	11.60	7.20	81.20	SL	11.60	3.20	85.20	SL
KA10	18.80	29.20	52.00	SL	19.60	25.20	55.20	SL
KA2	22.80	61.20	16.00	SiL	22.00	58.00	20.00	SiL
KD8	26.40	53.20	20.40	SiL	24.40	75.20	0.40	SiL
KD9	22.40	55.20	22.40	SiL	20.40	65.20	14.40	SiL

Where, SiL=Silt loam, SL=Sandy loam,CL=Clay loam and SiCL=Silty clay loam

B. Appendix Figures

Appendix figure 1: Furrow irrigation method in Kesem Sugar Project farm

Appendix figure 2: Hydro flumes irrigation method in kesem Sugar Project

Appendix figure 3: Main canal of kesem Sugar Project at weir site

Appendix figure 4: Main canal of kesem Sugar Project at "Alibete site"