SCHEME LEVEL WATER DISTRIBUTION AND PRODUCTIVITY EVALUATION OF FRE LEKATIT SMALL-SCALE IRRIGATION IN EASTERN ZONE, TIRGAY, ETHIOPIA.

BY:

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DECLARATION

I, Berhe Araya, hereby present for consideration by **the Institute** of Water and Environment at Mekelle University, my dissertation in partial fulfillment of the requirement for the Degree of Masters in Irrigation Engineering and Management entitled 'Scheme Level Water Distribution And Productivity Evaluation of Fre-lekatit Small Scale Irrigation'. I sincerely declare that this thesis is the product of my wife, Tsigeahiwet Yemane, and my Relative Ftsum G.hiwet, including me efforts. No other person has published a similar study which I might have copied, and at no stage will this be published without my consent and that of the Institute of Water and Environment.

Name of the student: Berhe Araya____ Signature_____________ Date _________

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ABSTRACT

This study was conducted in the drought-prone Woreda of Hawzen, Hatset Kebelle, located in the Eastern Zone, Tigray National Regional State, Ethiopia. The research aimed to evaluate the performance of the Fre-lekatit irrigation scheme using selected performance indicators. Specifically, the study assessed the reservoir's current water use, irrigation scheme productivity, water distribution, and allocation efficiency. Water applications and velocities were monitored using a Parshall flume, a V-notch weir, and the floating technique at different locations: farm level, secondary canals, and the main canal. A total of 45 measurements were taken at selected points in the head, middle, and tail sections of the command area using a Parshall flume. Soil samples were collected using an auger, while climatic and agronomic data from both primary and secondary sources were analyzed using the CROPWAT model to determine crop water requirements.

The findings show that during the 2018 irrigation season over 125 days (January–June), the total amount of water diverted to the field applied and through the main canal were, 56199.4 m3/ha (1,251,516 m3) or 192.2 l/s and respectively. The distribution of water based on the locations of the irrigated land shows that the total volume of water applied per hectare per season for the irrigation scheme was measured to be 8005.7 m3, 7894.4.m3, and 7789.4 m3 for upper, middle, and lower sides of the command area respectively. The WDC ratio value was 1.2, indicating that the system capacity does not constrain the agricultural water demands, whereas the RWS and RIS values were 1.91 and 1.95, respectively. The upper section of the command area received more water compared to the middle and lower sections.

To improve water use efficiency and crop yields, it is recommended that farmers receive intensive hands-on training in irrigation management and best farming practices. Additionally, regular maintenance of the weir structure and off-take channels is necessary to minimize seepage and prevent excess water loss downstream.

Keywords: water productivity, water distribution, and scheme level evaluation irrigation on a small scale.

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LIST OF ABBREVIATIONS AND ACRONYMS

A	Area of field
Bd	Bulk Density
CWR	Crop Water Requirement
DA’s	Development Agent
Du	Duration of Irrigation event (sec)
Ec	Conveyance Efficiency
ET_o	Reference Evapotranspiration
ET	Evapotranspiration
ET_C	Crop evapotranspiration
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GO’s	Government Organizations
Ha	Hectares
ICID	International Commission on Irrigation and Drainage
ILRI	International Livestock Research Institute
IWMI	International Water Management Institute
IWR	Irrigation water Requirement
Kc	Crop Coefficient
Ky	Yield reduction factor
CoSAERT	Commission for Sustainable Agricultural and Environment Rehabilitation of Tigray
REST	Relief society of Tigray
HWoARD	Hawzen- Woreda office Agriculture and Rural Development
HWoWRME	Hawzen- Woreda office Water Resource Mines and Energy
SSI	Small Scale Irrigation
MoA	Ministry of Agriculture
FDRE	Federal Democratic Republic of Ethiopia
MOWR	Ministry of Water Resources

MWRGI	Ministry of water resource Government of India
NGO's	Non-governmental Organizations
O &M	Operation and Maintenance
Qa	Average Discharge (l/sec)
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SARET	Sustainable agriculture and Environmental Rehabilitation Tigray
SCS	Soil Conservation Service
SGVP	Standardized Gross Value of Production
GRDP	Gross Regional Domestic Product
SSI	Small-Scale Irrigation
TAW	Total Available Water
Pe	Effective rainfall
WC	Water Committee
WUA	Water use association
WDC	Water diverted Capacity
PWP	Permanent Wilting Point
TVIW	Total volume of Irrigation Water applied to the selected fields (m^3)
TWRB	Tigray Water Resource Bureau
A.S.L	Above sea level
Total-DDD	Total Dam Draw Down
Total-Released-V	Total Released Volume
GPS	Global positioning system
CSA	Central Statistical Authority
CHW	Community Hand Dug Well
PHW	Private Hand Hug Well
DDD	Dam Draw Down

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CHAPTER 1: Introduction

1.1 Background

Ethiopia is predominantly an agrarian country with the vast majority of its population directly or indirectly involved in agriculture. Agriculture in the country is mainly rainfall dependent, traditional and subsistence with limited access to agricultural technologies and institutional support services (Desta, 2004).

Agriculture in Ethiopia the basic of the country's economy; it accounts for 46% of the nation's gross domestic product (GDP), 85% of the export, and 80% total employment (WAE, 2008) (Makombe G. K., 2007) Both industry and services depend strongly on the performance of agriculture, which provides raw materials, and generates foreign currency to import essential inputs and food for the fast-growing population.

While Ethiopian agriculture remains a crucial tool for sustainable development and the fight against poverty, irrigation is becoming increasingly expected in the twenty-first century (Haile and Kasa, 2015). While agriculture has shown to be exceptionally effective at reducing poverty, it will not be sufficient on its own to do so. The majority of the countries in Sub-Saharan Africa are agriculturally based, and these nations depend heavily on agriculture and related businesses to prosper, combat widespread poverty, and provide food security. However, a lack of water could make it increasingly difficult to produce enough food to fulfill the growing demands of the global population. Enhancing the scheme level water distribution and productivity of the current irrigation schemes could be one way to protect this limited resource (Gebrehaweria, 2007).
Ethiopia has an estimated 2.6 billion m3 of potential ground water and 12 river basins, including man-made and natural lakes, with an annual runoff volume of 122 billion m3 of surface water. With 83 million people living there in 2008, Ethiopia is the second most populated country in Africa after Nigeria, and it ranks among the world's poorest nations. Rain-fed agriculture is the main source of food insecurity in the nation, which has been brought on by poverty, poor

institutions, poorly functioning markets, and inconsistent policy (Awulachew.et.l, 2010). Ethiopia has always used irrigation, and it is still a vital component of the country's agricultural today. Ethiopia has a substantial amount of water resource potential. About 80-90% of the potentially available water resource is found in four river basins namely, Abay (Blue Nile), Tekeze, Baro Akobo and Omo-Gibe in west and south western parts of the country, where the population is not more than 30 to 40% (Water, 2002) .Even though, Ethiopia is endowed with ample water resources in central, western and south western parts, most of north eastern and eastern parts of the country are relatively dry (Seleshi, 2010). The water resources in the eastern and south eastern parts are relatively low and only 10 to 20% of the potentially available water resources are found in these basins where the population is over 60 % of the total population (Ministry of Water, 2002).

Irrigation has contributed significantly to poverty reduction, food security, and improving the quality of life for rural population. However, the sustainability of irrigated agriculture is being questioned, both economically and environmentally. According to Awulachew (2010), Ethiopia has an estimated 5.3 million ha of potentially irrigable land of which 3.7 million ha is from surface water (small, medium and large scale) while the remaining 1.6 million ha is from rainwater harvesting technologies and groundwater. The current irrigated land is estimated at 1,304,493 ha (CSA, 2020) .

The development of small-scale irrigation is one of the major intervention areas to boost agricultural production in the rural parts of the country. According FAO, 2003 small scale irrigation is found to help farmers to overcome rainfall and water constraint by providing a sustainable supply of water for crop production and livestock, strengthen the base for sustainable agriculture, provide increased food security to poor communities and contribute to the improvement of human nutrition.

Improving the water utilization of the scheme, which requires improving the management skills of the users, is one challenge to be tackled to ensure the sustainability of the schemes. In the country water development for agriculture is a priority, but poorly designed and planned irrigation undermines efforts to improve livelihoods and exposes people and environment to risks. Recent estimates indicate that the total irrigated area in Ethiopia is 640,000 ha around 4 to 5 % of the existing cultivated area and 12% of its irrigation potential (Seleshi et al., 2010).

Moreover, scheme performance is estimated to be an average of 36 percent below design, implying a further loss of about 230 thousand hectares of irrigated land; about 1.9 billion metric tons of topsoil is lost annually, which negatively affects water and land resources and agricultural productivity. Salinity is already an issue in some large-scale irrigation (LSI) much of the increase in irrigated area had come because of expansion of small-scale irrigation. Yet, the existing irrigation development in Ethiopia, as compared to the resource the country has, is negligible (Seleshi et al., 2010).

Poor management of irrigation water is one of the principal reasons for the low water use efficiency in irrigation. As available water resources become scarce, more emphasis is given to efficient use of irrigation water for maximum economic return and water resources sustainability. This requires measuring and evaluating how efficiently water is extracted from a water source to produce crop yield. The inadequate and often unreliable water deliveries in the main system cause farmers to face regular shortages in the water supply, resulting in reduced yields and incomes as well as in much smaller areas being irrigated than originally planned. At field level, inappropriate field layout and mismanagement also lead to further water losses and reduced yields.

Some irrigation projects in Ethiopia and the Rift Valley Lake Basin have struggled to achieve sustainable impacts due to various limitations, including a lack of integration with local socio-economic practices, weak institutional frameworks, and technical and policy deficiencies (IFAD, 2020). This indicates the need for a more comprehensive approach to irrigation management that transcends disciplinary silos. According to Gebremedhin and Peden (2021), operational inefficiencies, rather than design flaws, are often the primary reasons for the underperformance of small-scale irrigation systems in Ethiopia.

Drawing lessons from Large-Scale Irrigation Systems (LISs), the Kenyan government has been focusing on promoting commercial small-scale irrigation projects to better exploit the country’s irrigation potential (Kenya, 2021). Similarly, Ethiopia has embraced a shift towards more community-driven, small-scale irrigation projects (MoWR, 2020). This transition reflects the consensus that SSISs have higher chances of success due to their more manageable scale, community involvement, and integration into local social structures (Amon, 2021). Small-scale irrigation schemes are spread throughout Ethiopia and are characterized by both traditional technologies and modern irrigation practices, providing valuable lessons in the integration of indigenous knowledge into irrigation practices (Orodho, 2020).

However, poorly managed irrigation schemes continue to undermine efforts to improve livelihoods in Ethiopia, making it crucial to reassess how irrigation water is managed under the constraints of limited water and land resources. In some areas, the challenges of erratic rainfall, such as delayed rainy seasons and poor distribution, highlight the importance of developing irrigation systems to stabilize agricultural production (WBoARD, 2023). The need for further investigation into the expansion of small, medium, and large-scale irrigation systems in Ethiopia is clear, particularly in regions facing water and land management challenges.

This study will evaluate the current performance, opportunities, and challenges related to the development and management of small-scale irrigation schemes in Hawzen Woreda, aiming to provide insights into assess the overall performance of the irrigation scheme in the region.

1.2 Statement of the Problem

According to FAO (2006), institutions responsible for low water use efficiencies induced by area-based water allocation, poor field efficiency performance and the sustainability of the irrigation scheme. But few of the institutions responsible for irrigation are adequately structured and lack of qualified personnel is another cause of poor management performance irrigation systems in Africa (FAO, 1996). In Ethiopia, scheme performance is estimated an average of 36% below design capacity. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010a; 2010b).

Tigray region is one of the regions in Ethiopia with vast potential for irrigation development. The erratic nature of rainfall and number of population increases from time to time in the region. This has a contribution for computation of users of water resources in the region. Dr. Mintesinot

Behailu and Dr. Nata Tadesse (2004), assessed report that in micro dams based on the performance of many irrigation schemes in Tigray region is far below their potential, mainly due to inefficient irrigation water management and poor repair or rehabilitation. Failure and unsustainability of irrigation projects in Tigray Region has been institutional and management deficiencies.

Fre-lekatit small-scale irrigation is found in this region and characterized with erratic rainfall events. It is established for surrounding farmers who applying irrigation. Poor understanding of farmers' priorities, lack of clear and sustainable water share among users, low level of ownership of the scheme, due to lack of awareness and frequent training for water delivery and management, as a result, farmers, particularly those at the tail end of the irrigation system, appear lack of water deficiencies more compared to those located nearer to the upper water users. Poor water management, including water losses from the reservoir to field level and misuse of irrigation water, has been commonly observed. There has been no comprehensive performance evaluation of the scheme to assess water distribution and productivity, despite the need for better management practices.

This study will provide valuable insights for farmers, researchers, and local/regional decision-makers in designing better strategies for sustainable irrigation need to maintenance the Fre-lekatit irrigation scheme.

1.3 General objectives:

To assess the overall performance of the Fre-lekatit irrigation scheme by evaluating water utilization, distribution efficiency, and water productivity using irrigation water supply indicators.

1.3.1 Specific objectives

- To evaluate the water utilization performance of the water within the dam
- To evaluate the scheme level water distribution performances
- To evaluate the scheme level water productivity using irrigation water supply indicators

1.4. Research Questions

- How efficient is the water utilization within the dam Fre-lekatit irrigation scheme and what are the key factors affecting its performance?
- What is the effectiveness of the water distribution across different sections of the Fre-lekatit irrigation scheme, and how does it impact farmers, particularly the tail end users?
- How does the water productivity at the scheme level contribute to food security, and what improvements are needed for sustainable management of the irrigation scheme?

1.5. Scope of the research

The scope of this research was conducted to assess technical performances of Fre-lekatit small-scale irrigation scheme in Hawzen Woreda and identify options to improve overall irrigation performance. Therefore, the overall objective of the study was to evaluate the scheme level of performance of Fre-lekatit small scale irrigation system under the existing farmers' irrigation management practices using selected performance indicators and starting from the reservoir dam until farm field. Additionally, the study's findings can be applied to the creation of irrigation water application strategies that raise the irrigation system's scheme level. It can offer a better platform for system management WUA committee, farm staff, and policy water usage rule and regulation making.

CHAPTER 2: Literature Review

2.1 Dam structure

Dam structure: Dams are among the most significant civil engineering structures not only because they are expensive to build but also because of their significance in a variety of interdisciplinary social and economic ideals. By constructing dams, reservoirs, irrigation and diversion canals, and hydropower plants, Ethiopia is aggressively utilizing its water resources. The advantages of the dams extend beyond hydroelectricity. Numerous dams are multifunctional structures that are intended to supply water for irrigation, livestock, flood control, and other uses. The cost of building a dam can be significantly less per gallon of water stored than that of a dugout (University tewenten, 2014).

Compared to dugouts, most dams are shallower and have a substantially larger surface area. Dams consequently have lower water quality and greater evaporation losses than dugouts. The future safe operation and cost-effective optimization of dams, especially embankment dams, depend on the proper monitoring of construction quality. In order to attain high levels of embankment stability, an earth fill dam is predominantly made of engineering soils that have been consistently and intensely compacted (Irrigation, 2010).

Ever since humans began using water to increase crop yields, the scheme level evaluation has been a crucial component of irrigation. The scheme level evaluation of surface irrigation has been particularly significant, and in the last few decades, excellent studies have contributed to the active fields of relevant study. Numerous strategies and techniques have been devised to evaluate irrigation applications from various angles. Enhancing the productivity of current irrigation schemes has gained growing attention due to the limited availability of water and land resources needed for the necessary growth in food production globally.

The scheme level irrigation assessment's ultimate goal was to maximize resource utilization by offering pertinent management at the field feedback. Consequently, it could help the system management determine whether the production and distribution of water are sufficient and, if not, what needs to be done differently or corrected in order to make things better. In order to maintain sustainable water consumption, the current small-scale irrigation schemes would need to incorporate a water application strategy into their operations.

2.2 Irrigation development in Ethiopia

According to (MoWR2001), the country's water resources should be developed and farmers' irrigation systems should be expanded in order to increase agricultural productivity and output. This is in line with Ethiopia's water policy. The policy places a strong emphasis on helping farmers implement small-scale irrigation using various water abstraction technology choices in order to combat intermittent droughts and irregular rainfall.

Throughout the 1950s, the first official irrigation schemes were established in the upper and lower Awash Valley by private concessionaires who ran farms for the production of commercial crops such cotton, sugarcane, and horticultural crops. Irrigated farming was extended throughout the Lower Rift Valley and the entirety of the Awash Valley throughout the 1960s. Due to the water management made possible by the building of the Koka dam and reservoir, which provided benefits like as flood control, hydropower, and a guaranteed supply of irrigation water, the awash valley had the greatest expansion. Furthermore, the Awash Valley became accessible to export markets and ready customers in the hinterland once the asphalt Addis-Assab road was built (Directorates,2011a). This was due to taking an advantage of the construction of Koka dam aimed as a reservoir irrigation water supply, flood control and hydropower generation. During the mid-1970s, windmills and hand pumps were introduced to lift water from groundwater for drinking water supply, domestic and gardening purposes (Directorates, 2011a).

According to the Ethiopian Ministry of Agriculture, there were modern water storage and water management systems for irrigation purposes. This includes water diversion schemes, water storage dams, micro irrigation systems, rainwater harvesting and shallow ground water harvesting techniques. These systems make use of different water drawing irrigation technologies for lifting, conveying and applying irrigation water for irrigation uses. Night water storage facilities, Treadle pumps for lifting water, smallholder drip systems and micro- sprinklers for irrigation application are used among others (MoA, 2011a)

2.3 Irrigation development in Tigray

Tigray's irrigation development: Except the SNNPR, Tigray has one of the worst economies and levels of food insecurity in the nation (FDRE, 1999). In the Tigray regional state, agriculture provides a living for 85% of the inhabitants. Although we have a plenty of water resources, this sector is mostly dependent on rain, yet the rains in Tigray are inconsistent and unpredictable (REST, 2003). One of the main policy goals of the Ethiopian government, as well as the regional government of Tigray, is the decrease of poverty in the country. Everyone agreed that adopting technologies that raise soil moisture to use greater productivity and intensifying agriculture would be the primary ways to increase agricultural production and reduce poverty.

The use of productivity enhancing inputs (such as fertilizer and high yielding variety) depends much on availability of moisture in which case, investment in irrigation becomes crucial. Despite the role of irrigation in easing the effect of rainfall uncertainty on agricultural performance, with an immense irrigation potential, the region has remained dependent on rain-fed and less productive agriculture, which resulted in food insecurity and sever poverty. To this end, the Ethiopian government in general and the regional government of Tigray in particular have focused on rural investment on small-scale irrigation as a key poverty reduction strategy. Since the establishment of the Commission for Sustainable Agricultural and Environment Rehabilitation of Tigray (CoSAERT) in 1995, 54 micro-dams; 106-river diversion; and a number of spate irrigation projects were constructed with a total irrigation capacity of 3700 hectares benefiting 19,000 households (Abraha, 2003).

In addition to the government's effort, non-governmental organizations such as Relief Society of Tigray (REST) have invested in irrigation projects. According to Abraha study (year 2003), a micro-dam project, with capacity of 100 hectares, is estimated to cost about 5.84 million Birr while a river diversion project that can irrigate 45 hectares costs 1.17million Birr, in which case investment per hectare is estimated at 58,390 and 25,896 Birr, in dam and river diversion projects, respectively (Gebregziabher, 2007).

2.4. Performances of small scale irrigation in Ethiopia

In Ethiopia, small-scale irrigation is seen as a fundamental tactic for mitigating the effects of climate change, reducing poverty, and ensuring food security. The Ethiopian government places particular emphasis on boosting agricultural productivity through the development of small-scale irrigation schemes because it is crucial to the sector's overall growth. Converting the rainfall-dependent rain-fed agricultural system to an irrigation-and rain-fed combination agricultural system is beneficial. This is thought to be the nation's most well-known approach to sustainable development. To truly understand the history of irrigation's emergence and subsequent changes, it is necessary to look into how irrigation methods have developed in Ethiopia. Improved access to irrigation and irrigation development intervention make rural food security, poverty alleviation and adaptation to climate change (Sileshi et.al, 2010).

Irrigation development is expected to contribute to the national economy in several ways. At the micro level, irrigation could lead to an increase in yield per hectare and subsequent increases in income, consumption and food security (Lipton et al., 2003; Hussain and Hanjra, 2004). Furthermore, Hussain and Hanjra (2004), based on their studies in Ethiopia, indicated that irrigation benefits the poor through higher production, higher yields, lower risks of crop failure, and higher and year round farm and non-farm employment. Irrigation enables smallholders to adopt more diversified cropping pattern, and to switch from low value subsistence production to high-value market-oriented production (Hagos et al., 2007). Macro level impacts manifest themselves through agricultural impacts on economic growth. At the aggregate level, irrigation investments act as production and supply shifters, and have a positive effect on economic growth. Studies in Ethiopia show that agricultural growth serves as an “engine” of economic growth, and irrigation-led technological changes are the key drivers behind productivity growth in the agricultural sector (Hussain and Hanjra 2004; Alagh, 2001).

Other effects of irrigation on changes in the environment and other social impacts have been reported. These include on the economic value of wetlands (Barbier and Thompson, 1998) employment impact of irrigation (Berck and Hoffman, 2002) and non-farm sector benefits from irrigation investment (IWMI, 2010).

Small-scale irrigation demand projected poses huge challenge for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services. Development in agriculture over the last 30 years has brought significant increases in global production, partly because of expansion of cropland, partly through challenge in technology over time with objective of seeing positive effect of small-scale irrigation on agricultural production and food security of the economy country.

As expected, access to irrigation was found to have positive and significant impact on household food security. It contributed to household food security at least in three ways.

i) Access to irrigation-enabled households to utilize farm resources (land, labor and oxen) more efficiently during off-season that otherwise would have underutilized.
ii) Access to irrigation enabled irrigation users increase cropping intensity (grows, crops more than once in year) there by not only increase output but also contributed to stabilize consumption.
iii) It helped farmers to be engaged in high value crops production that could be marketed in the off-season when prices are at their peak.

2.5. Water productivity of small-scale irrigation

Water productivity is defined as the ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits. Alternatively, water productivity deals with the amount of crops production (mass or monetary equivalent) per water supplied to the scheme during the irrigated season. As an irrigation engineer, it might mean the ratio of the amount or the value of crops produced in a farm to the supplied water .In its broadest sense it reflects the objectives of producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to a use or depleted by a use. Put simply, it means growing more food or gaining more benefits with less water.

Physical water productivity is defined as the ratio of the mass of agricultural output to the amount of water used, while economic productivity is defined as the value derived per unit of water used. Water productivity is also sometimes measured specifically for crops (KATRIEN, 2010).

2.6. Water distribution of small-scale irrigation

Water distribution is the main issue in any irrigation schemes. The most important performance indicators in the distribution of irrigation water include adequacy, timeliness and equity in the supply of water. Two types, method of water distribution are continuous and rotation on irrigation farm land. Water rotation is one of the water distributions methods of the order crop watering based on the timetable designed for equitable distribution of irrigation water. Water rotation implies the order of water delivery in accordance with the schedule where water delivery day, time, and duration are specified.

2.7 Water supply indicators

Molden et al. (1998), states that the water supply indicators (relative water supply, relative irrigation supply, and water delivery capacity) are better suited to place the irrigation system in its physical and management context. Higher values of these indicators indicate a more generous supply of water. In this case, productivity to land may be more important. Where the water supply indicators show a lower value it indicates a situation of a more constrained water supply and values of productivity per unit of water are more important.

According to Boss et al. (1994), these indicators deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity.

2.8 Soil water Availability

Soil water availability refers to the capacity of a soil to retain water and make available to plants. After heavy rainfall or irrigation, the soil will drain until field capacity is reached. Field capacity is the amount of water that a well-drained soil should hold against gravitational forces, or the amount of water remaining when downward drainage has markedly decreased. The total available water in the root zone is the difference between the water content at field capacity and wilting point (Allen et al., 1998).

2.9. Crop Water Requirement

Crops will transpire water at the maximum rate when the soil water is adequate. Broner (2003) cited by Adeniran et al. (2010), reported that knowing seasonal crop water requirements is crucial for planning crop planting mixture especially during drought years. The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel, 2004). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha, 2000).

2.9.1 CROPWAT model description

CROPWAT model is a software program for the computation of crop water demand and irrigation programming. Moreover, the software provides options for the design of diverse water supply scenarios and the computation of a number of water supplies for several crop patterns (Allen et al., 1998). Normally, the computation of crop CWR and irrigation schedules in CROPWAT is based on the required information prepared by the user which whether can be directly typed into the software or uploaded from other sources.

2.9.2 CROPWAT program structure

The program is subdivided into eight distinct modules, five of which are for data entry and three for computations. The entry to the modules is through a menu in the toolbar or alternatively using the navigation bar at the left-hand side of the main view (Allen et al., 1998). The data entry modules include climate/ETo, Rain, Crop type (dry crop or rice), soil, and crop pattern. The computation modules are CWR, schedules, and scheme, for the calculation of crop water requirement, irrigation schedule, and scheme supply, respectively (Allen, 1998).

CHAPTER 3: Materials and Methods

3.1 Description of the study area

Fre-lekatit small-scale irrigation project is located in, Eastern zone of Tigray, Hawzen Woreda, Hatset Kebelle. The dam site is located between 555552 E 1553745 N and 555734 E 1553637N at an elevation of 2340 m.a.s.l. The command area has an elevation range of 2278-2317 meters above sea level. Fre-lekatit dam is a tributary of the Suluh valley which is one of the tributaries of the Tekeze basin. In the East a weather road of from Hawzen town to Hatset Kebelle delineates and divides the command area as the weather road of having 12 km of distance to North east. The project area is located about 100 km from Mekelle city Town and 861 km far north of Addis Ababa.

Fre-lekatit irrigation the earthen embankment dam which has 21 m dam height that the crest reach at elevation of 2335 m.a.s.l, 115 m the length of the weir water body that stretch, and 12.728 million m^3reservoir volume capacities. The reservoir surface area at full supply level is predicted to be 250 ha, whereas the catchment area upstream of the dam is 111.48 km^2. Though just 100 ha have been created for irrigation, the gross irrigable area is estimated to be 350 ha. The actual area under irrigation season 2018 is 125.25 hectares, nevertheless, because the infrastructure is now in less than ideal condition.

The project is an earthen dam irrigation system studied by the Tigray Regional Water Resource and Energy Bureau, with funding provided by its budget and design consultancy by Mekelle University. The development of the irrigation scheme began in the dry season of (Tigray Bureau of Water, 2011). The main canal is in a relatively good working condition and has a rectangular top section in the lined upper most reaches from the off take the first water collection point of the canal is rectangular. The methods of on-farm water application are border irrigation for maize farms, and furrow irrigation coupled with traditional water application using same to the others (Tigray Bureau of Water, 2011).

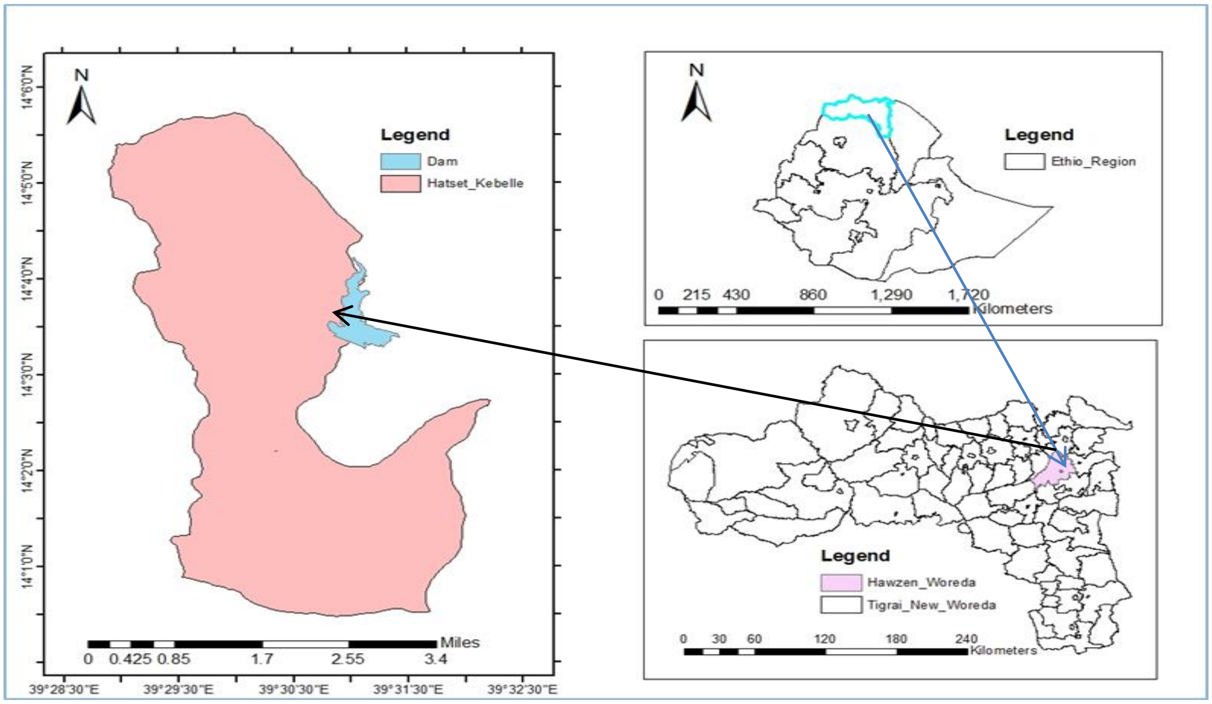


Figure 3. 1 Location map of the study area

The irrigation method commonly practiced by farmers is furrow type of surface irrigation method. The furrows are made traditionally by using oxen pulled ploughs. Almost all of the farmers irrigate some selected crops maize, potato and barley. Of all, maize is the dominant irrigated crop in this irrigation scheme. The lengths of the commonly used furrows in the selected maize fields generally average 50 meters.

The study area receives an annual monthly average rainfall ranging from 0.59 mm in January to a maximum of 186.89 mm in July, with an average annual total of 531 mm. However, the rainfall is highly erratic and unevenly distributed. The mean monthly relative humidity of the area varies between 32.6 to 71.2 % and the average is 46.6%. The mean daily wind velocity varies between 1.01 and 2.3 km/day in the months of November and August occurs. The mean daily sunshine hours varies from 4.2 in the month of January to 9.5 in July. The average monthly minimum and maximum temperatures were observed as 6.8˚C and 25.5˚C occurring in the month of December and may occurs. Climate data was obtained from nearby Sinkata meteorological stations (Table 3.1).

The dominant soil type of the command area is sand clay loam and sand clay. Seasonal soil water holding and drying are observed in the irrigation scheme. According to USDA soil texture classifications, results from the soil laboratory analysis show that Sandy Clay loam (59%) and, Sandy clay (41%) are the dominant soil textures respectively. The irrigated area has generally a gentle slope of 0.1- 5%. The command area is located downstream of the dam.

Table: 3. 1 Data of precipitation of the study area

Table 3. 1 Data of precipitation of the study area

Months	average monthly Rain fall mm from 2003-2017	Eff. Rain Mm
January	0.59	0
February	9.48	0
March	27.36	6.4
April	41.34	14.8
May	33.43	10
Jun	35.21	11.1
July	186.89	125.5
August	150.00	96
September	21.40	2.8
October	7.18	0
November	14.19	0
December	4.14	0
	531.21	266.7

Source: National Meteorology Agency of Ethiopia (2003-2017)

3.1.1. Socio-economic conditions

Hawzen woreda lies to the east of Tsaeda Emba woreda, Kolla- Tembien woreda to the west, Ganta Afeshum woreda and Ahferom to the north, and Kilte Awlaelo to the south, constitute a shared boundary. Its total area Hawzen Wereda coverage is 80,949.80 hectares, with 24 rural kebelles, 3 urban kebelles, and 81 kushets and states that the population is 111236, consisting of 52956 males and 58280 females according to Hawzen Wereda, finance sector 2018.

According to socio economic of Hatset Kebelle also has a total population of 4663, consisting of 2262 males and 2401 females, respectively. The beneficiaries in irrigation scheme comprised 287 heads of family, of which 192 were headed by men and 95 by women, but my specific sample farmers are select only 45 out of 287 farmers that sowing only measured maize in study time.

3.1.2. Water resources

Water resources data on irrigation potential transactions is sourced According to the Hawzen Woreda both Agricultural Rural Development Offices and the Water resource and Energy sectors were obtained. A few water harvesting irrigation facilities, including CHW 1000, PHW 1200, Check dam -54, Diversion -13, and Micro Dam -2, are presently in operation. Additionally, there are some naturally occurring river Suluh, and the ground water potential is very close to the surface and subsurface as physical feasibility on the study area. The Woreda Hawzen total irrigated area during the 2018 off-irrigation season was 2173 hectares coverage, as Hawzen Wereda reported 2017 (sectors, 2017). The Fre-lekatit earthen dam is 125 ha current irrigated and the remain ha are not now irrigated out of 274.489 ha of irrigated land in Hatset Kebelle covered with 564 beneficiaries. The exist Fre-lekatit reservoir water body is shown in below

Figure 3. 2 Fre-lekatit Dam Reservoir body

3.1.3 Water Distribution and Management System

WUAs were grouped in five groups under the Fre Lekatit irrigation program, where farmers are allowed to irrigate until they have had enough water. The five groups use a rotational irrigation water distribution system, with the farmers allowed to continue irrigation until they had adequate water in the schedule time. Depending on the crop's growth stage, the scheme's irregular irrigation intervals range average from 7 to 11 days. Throughout the year, a representative farmer who is assigned by the water user association works to manage the gate and divert water at the head of the main canal.

The scheme was designed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season. Actual water delivery service to irrigators was certainly rotational; irrigation water was managed by Water User Association (WUA), who had the overall authority to administer and control the irrigation water management and utilization. The main water user association had six members in with one chairman, one vice chairman and the others secretary while each secondary canals had sub water user associations to control on their locations. There is one main canal, five secondary canals and many tertiary field canals which are operated by the WUA water distributers locally called “Water Committee” who had been elected by the beneficiaries from upper, middle and tail end of the scheme based on the proximity to the water source.

The Water Committee has the authority to provide water for each farmer based on the time schedule condition. Which is local name“Abo may” could decide who should first irrigate among the individual farmers within a group. Water Committee has also the responsibility to control and manage time of water diverted to the selected group and to negotiate with other Water Committee on behalf of the group. The farmers paid a total fee of 120 Birr per year for the water used to irrigate their farmland. The canals are maintained by the farmers at the end of rainy season and after completing canal cleaning the gate is opened until the end of the season. Each plot holder is responsible to operate the scheme during his turn. He was supposed to check the distribution field ditch starting from his plot to the outlet. Farmers usually used to irrigate their fields every weekly depending on the time schedule rotational irrigation system.

3.2 Methods

3.2.1 Measurement points, crop selection, and field layout

To evaluate irrigation water use, scheme-level water distribution, and productivity performance at the field level, stratified random sampling was conducted. Farmers were stratified based on their location in the command area as head, middle, and tail-end users of the water source.

A total of 45 farmers' fields, cultivated with the selected maize crop (Melkasa-2), were included in the study. Nine farmers were selected from each position—head, middle, and tail-end—within the irrigation scheme. The selected plots varied in irrigated area size but had similar soil characteristics, furrow layout, and management practices, such as weeding, insect protection, and fertilizer application (as shown in Figure 3). Using ArcGIS 10.3, a detailed map of the Fre-Lekatit irrigation system's command zones was delineated, and schematic maps were plotted to display discharge measurement points for the 45 selected fields.

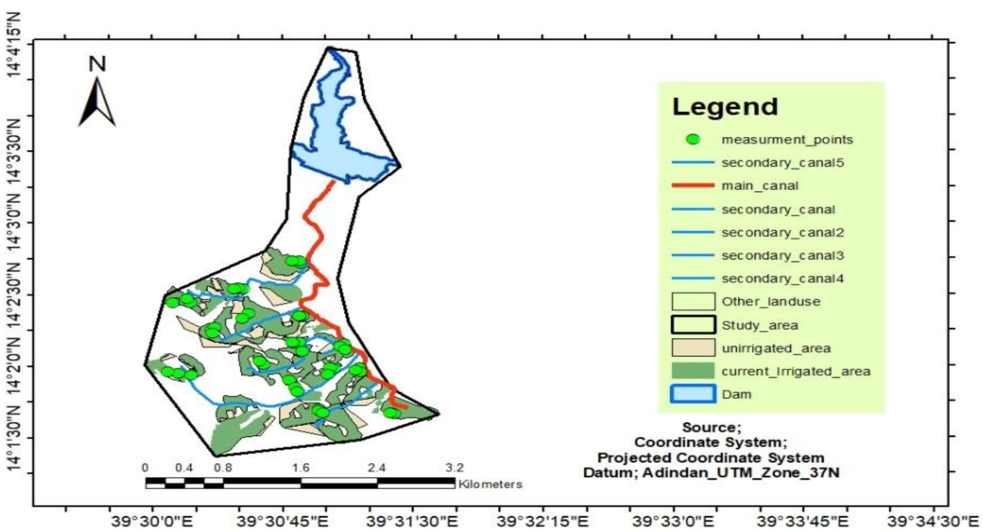


Figure 3. 3 Map of Fre-lekatit irrigation scheme and Canals layout with measurement points

3.2.2 Agronomy of melkasa-2 maize crop variety

To assess and evaluate the impact of water distribution, water productivity and the overall performance parameters on crop yield, the yield of selected irrigated productive sample plots were collected through same distributed questionnaires separately from head, middle and tail end the locations of the scheme. The irrigator farmers were practiced in the area. The total yield obtained from the selected plot was also measured and converted to hectare basis. The dominant cultivated crops the dry irrigation season cover were maize, potato and barley during time research and, the major crop covered 46% of the cultivated land.

The remaining coverage was 42 % by potato and 12% is barley during the irrigation period. The Earthen dam structures were also used to provide supplementary irrigation for rain fed crops. According to the FAO CROPWAT software database, maize variety (melkasa-2) has a total length of growth period of 135 days, which is divided into 22 days of Initial Stage, 38 days of Development Stage, 45 days of Mid-season stage and 30 days of Late Season stage with Crop Coefficients of 0.50, 1.20 and 0.60 for each stages of the crop life cycle, respectively (FAO, 1978)

Figure 3. 4 Maize growing first stages

3.2.3 Data Collection methods

The investigation was carried out while the crops were being irrigated during the dry season. The study began in January and run through June of 2018. Regular inspections and observations were conducted during the study period to evaluate the study sites' water management procedures and the manner in which water was applied. In order to meet the goals of the research, both primary and secondary data were gathered. The primary data were collected from field by direct measurement such as discharge, water surface elevation, soil samples (laboratory), field plot dimensions, socioeconomic data collected questionnaires and field observation of irrigation infrastructures. Whereas, secondary data from different offices and design documents.

3.2.3.1 Primary data

Primary Data collection methods include a survey, semi-structure and interview the selected irrigator farmers. The field survey was carried out to inspect physical conditions of the scheme level components, water distribution, water productivity activities and including water management situation.

Repeated field visits were made to investigate method of water applications and closely observe practices related to water management techniques used by irrigators. Primary data at field level were collected from farmer’s field from irrigated (the head, middle, and downstream water user) of the study area.

Socioeconomic data: were also collected in survey, with the assistance of an enumerator, was conducted during the harvest period at the irrigation scheme as well as all sample farmers from the study area participated in the survey. They were focus asked 45 the initial cost of seeds, fertilizer, pesticides, as plot, and other related data’s as well as the amount of maize harvested, recorded in number of standard sacks not as object but it is supported. If the farmers grew any other crops, but, they were no asked the amount of profit received from the sale of this additional crop. When a farmer harvested and the survey had been completed, an area measurement of the corresponding sample plots was also performed.

Soil textural class: to determine soil texture of each farmer's field, a total 27 soil samples or nine composite from each position (i.e. nine composite samples at nine different depths from each of head, middle and tail-end locations) were taken. The textural analysis was done using the hydrometric method. Based on the percentage of composition, the soil textural class was determined by USDA soil textural triangle method.

Field Capacity (FC), Permanent Wilting Point (PWP) and Total available water (TAW): For the determination of soil moisture content at FC and PWP of the soils in the irrigation scheme; 27 soil samples at three different depths (0-30 cm, 30-60 cm and 60-100cm) from all positions (head, middle and tail-end users) were taken and analyzed using pressure plate apparatus at 1/3 and 15 bars, respectively.

TAW is the amount of water that a crop can extract from its root zone, and its magnitude depends on the type of soil and the rooting depth. The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water (Allen et al.1998).
TAW which is an estimate of the amount of water, which a crop can use from the soil for the selected fields, was computed from the moisture content in volume percent at field capacity and permanent wilting point (Equat3.1)

$$TAW\ (mm/m)\ 10 * [(\theta Fc\ (\%)\ (\theta Pwp\ (\%)]Zr \ \ldots\ldots\ldots\ldots\ldots\ldots..\ldots..\ldots\ldots\ Equation{:}\ 3.1$$

Where: TAW the total available soil water in the root zone (mm),

Θ_{Fc} (%) the water content at field capacity volume basis (%),

Θ_{Pwp} (%) the water content at wilting point volume basis (%), and

Zr is the effective root depth (cm)

Soil moisture: To determine the soil moisture content, soil samples were taken to the laboratory in the irrigation growth stage of the maize crop (initial, developmental, mid and late stages) after irrigation by considering field capacity of the soil at three depths (0-30 and 30 cm-60 cm and 60-100cm) per test pit using core samplers to preserve moisture loss during travel.

It is presumed that this depth is the effective root zone of the irrigated vegetable crops. The maximum effective root zone of crop variety, maize is 1m according to (FAO irrigation book No.56). The moisture content of the collected soil samples were determines using gravimetric method. The gravimetric moisture content of volume base is calculated using the equation (3. 2).

The aforementioned formula was used to calculate the total available water (TAW) for plant usage in the root zone (Allen et al., 1998). The Total Available Water (TAW) for plant usage in the root zone was also calculated by James (1993) as the moisture content difference between field capacity and permanent wilting point.

The difference between the weights before heating and after heating was giving the moisture content of the soil sample. The water contents were determined on weight and volume basis as described by (Michael, 2008):

$$\Theta m = \frac{(Ww - Wd) * 100}{Wd} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots \text{Equation: } 3.2$$

Where,

Θm is gravimetric soil moisture content (% volume bases), Ww is wet weight of the soil (g), Wd is dry weight of the soil (g), and Bd- soil bulk density (g/cm^3).

The amount of moisture stored in the root zone of the crop was calculated by subtracting the moisture content before irrigation from moisture content after irrigation. The purpose of calculating the amount of moisture in the root zone of the crop was determining the water application efficiency, storage efficiency and distribution efficiency of the irrigation schemes.

The Equation is as show below:

$$\Theta v = \theta m * Bd \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Equation: } 3.3$$

Where,

θv is volumetric water content, θm is moisture contents and Bd is bulk density. Recommended sample sizes range from 10 to 100g (Australian Water Resources Council, 1974), but 50 to 100g is preferable for most samples.

To locate the boundary of the command area, actual canals network and location of canal structures, transverse survey was made with GPS (global positioning system). This was done by walking around the boundary of the command area and along canals and taking point data.

3.2.3.2 Secondary data

Secondary data for the irrigation scheme were collected from past reports and files responsible organizations such as the Hawzen Wereda Bureau of Agriculture and Rural Development Office, Hawzen Wereda Water Resource Energy and, Kebelle office of Hatset Sinkata Meteorological Station, Tigray regional water resource bureau and, other published and unpublished sources. They include climate data, irrigated crop, actual command areas, designed features of the scheme in the design document are major data which were utilized in the study.

3.2.5. Determination of Crop Water and Irrigation Water Requirement

Calculating the Need for Irrigation and Crop Water to find out how much of the applied irrigation water is used by the crop, it is necessary to determine the water requirements of the crop. The crop water requirement (CWR) of the major irrigated crops grown in the irrigation scheme was estimated using CROPWAT 8.0 windows computer program. The determination of the CWR by the model depends on the determination of the reference evapotranspiration value using the available climatic data.

The fifteen years mean climatic data for the nearest station (Sinkata) was used (Table 4.10). Based on CROPWAT 8.0 data for major crops grown in the study areas including growing stages and stage lengths (days), crop coefficients (Kc), rooting depths (Zr), depletion levels (P), yield response factors (Ky) and planting date were obtained from FAO guidelines (Doorenbos et al., 1986; Allen et al., 1998). But practically measured start from the planting date until harvesting date almost has finished the same as FAO guidelines.

Crop evapotranspiration (ET crop or ETc) is estimated as the reference evapotranspiration (ETo) multiplied by a crop coefficient.

(Kc).$ETc = Kc * ETo$ ………………………………………………..……………. $Equation: 3.4$

Where, ETo is reference evapotranspiration (mm) calculated with CROPWAT 8 program (FAO, 1992) and Kc is the crop coefficient developed for the main crops using FAO guidelines (Doorenbos and Kassam, 1986) and adjusted for regional conditions (Sener, 2004).

The irrigation water requirement (IR) was computed after estimation of effective rainfall by the CROPWAT model using the water budget equation.

$IR = ETc - Peff$ …………………………………………………………….……….. $Equation: 3.5$

Where, ETc is crop evapotranspiration (mm/season), and Peff is effective rainfall (mm/season). Net irrigation requirement is the quantity of water necessary for the crop growth. Crop water requirement (ET crop) is defined as the depth (amount) of water needed to meet the water loss through evapotranspiration. In other words it is the amount of water needed by various crops to grow optimum. The crop thus reaches its full production potential under the give environment.

3.2.6 Reservoir Operation Studies

This study proposes to describe estimating reservoir inflow and outflow from source observation using the necessary daily measured drawdown records through the installed graduated reading rod. To estimate the water balance components in order to identify the actual released volume of water starting from the reservoir body until the irrigated applied field was measured using different discharge methods (Maureen, 2007).

In order to determine the relations between water bodies of the dam (h-v) volume, it was necessary to have the measured daily drawdown records of the reservoir outflow volume of water. For the reservoir, the Fre-lekatit earthen dam, there was complete data available on the design document (Area-Elevation-Capacity-Curve).

A reservoir is used to manage water resources, and its inflow and outflow hydrographs are critical to reservoir planning for agricultural water uses A reservoir water budget is associated with many different hydrological processes, such as direct deposit of rainfall, surface drainage from upstream areas (inflow), and seepage, evaporation, water release through off take (outflow). The total losses include evaporation, transpiration, seepage losses, daily animal consumption and other leakages such as filling losses (Maureen, 2007).

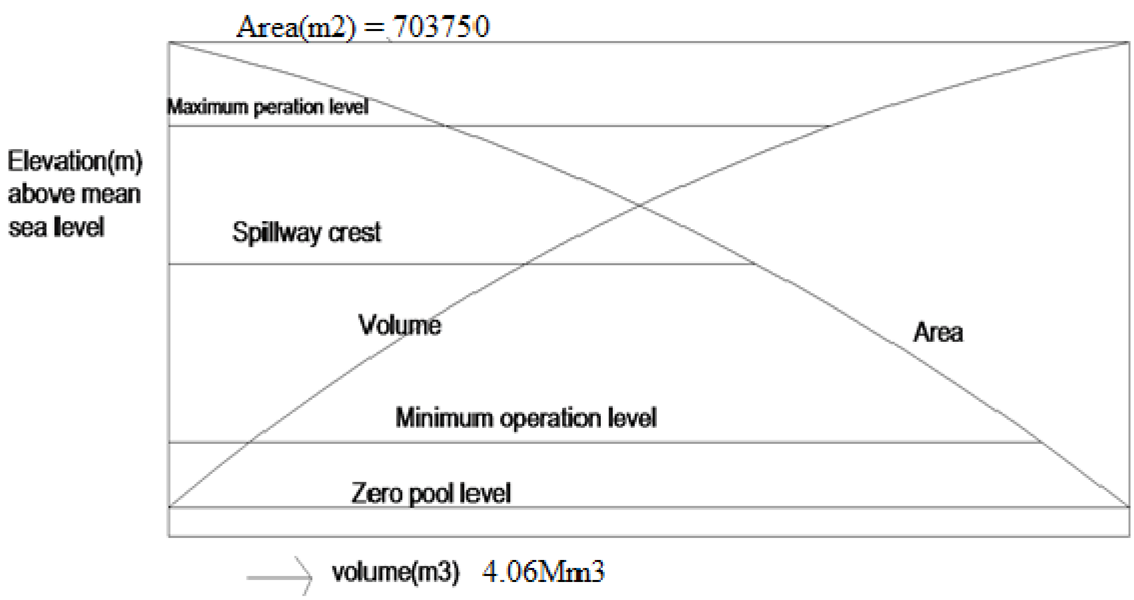


Figure 3. 5 Area- Elevations – Capacity Curve of Fre Lekatit dam

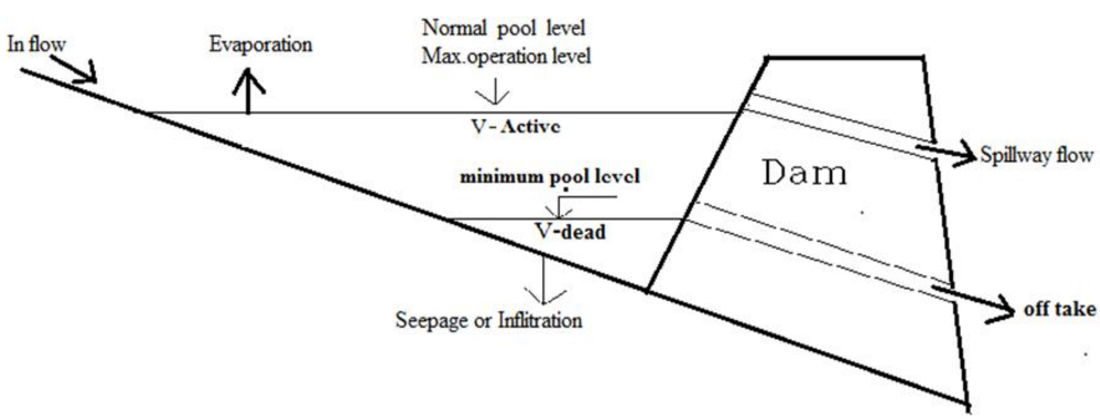


Figure 3. 6 Storage characteristics of the reservoir

The dependency on irrigation area requires some analyses of the water balance base on known and unknown variables perspectives (Maureen, 2007). To identify the water balance may have described on estimating inflow and out flow measured discharges perspective.

i) .Monthly dam drawdown water level recorder devices daily measured (by installing graduated rod) where placed at head work to measure decreased head (m) and corresponding released volume water (m3).
ii) The sum of daily measurements of irrigation supply to the scheme was being made by using vertical graduated reading rod (gauge) (V-h) relationship base line on the design counter lines at the headwork released volume water starting at fixed point.
iii) . Estimating the total dam head recovered through rainfall around reservoir area upstream
iv) . Estimate the total diverted volume water passed through main canal and secondary canals supplied to the actual irrigated area.
v) . Estimate the total losses from dam until tail end or irrigated field

3.2.6.1 Reservoir Water Balance

According to Burt (1999), a water balance can be defined as an accounting of all water volumes entering and leaving a three dimensional space over the study period of the time. This implies that spatial boundaries have to be defined, and that the water crossing the boundaries needs to be measured volumetrically. This is best achieved through measuring flow rates at selected points in the distribution system over a known period of time. A complete water balance is not limited to only irrigation water supply, rainwater or ground water, and all losses (seepage, Evaporation and others, but includes all water that enters and leaves the spatial boundaries (Maureen, 2007).

The water balance equation, which involves the inflow and outflow volume of water starting from a reservoir to specific field plots or farms, is used. The relationship between the equations describe in 3.5 and 3.6 can be used to define water balance. seasonal continuity the overall a water balance problem and quantity reservoir inflow and out flow using the estimate calculate as displayed in Equation 3.5.The reservoir water budget can be described using the concept of water storage mass balance, expressed as follows.

$$ds/dt = I - 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3.6$$

$$ds/dt = Inflow - outflow \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3.7$$

$$ds/dt = PP + Rc - (Se + Ev + Rr) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3.8$$

1. Inflow = PP + RC or (Seasonal inflows into the reservoir)

Where:

I = Inflow

O = outflow

ds = storage

•PP= Precipitation or Rain fall (mm) using unit conversion into (m^3)

•Rc = Reservoir capacity from design document curve or

Reservoir storage volume at the starting time (m^3)

2. Out flow = Se + Ev + Rc

Where:

Out flow = Dam drawdown (DDD) Released water through main canal

Se= Seepage (m^3)

Ev = Seasonal Evaporation (m^3)

- Rr = Released water to irrigated through main canal

(Irrigation Supply for the Seasonal (Jan- Jun) in m^3

$$Outflow = Se + Ev + R \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3.9$$

Where S is the amount of water stored in a reservoir (m^3), this is the amount of water entering the reservoir (m^3/s), and O is the amount of water going out of the reservoir (m^3/s). Equation 3.6 can be expanded with detailed. Mass balance equation

ds /dt = I- 0 ⟶ ds/dt = (PP + Rc) - (Se + Ev + Rr) as mention above

- Two unknown variables; Seepage and Evaporation as losses variables
- Known variables is: S-- Reservoir storage water from water level

I --- Total inflow

O-- Total out flow

Rc--- Reservoir inflow from design document

R --- Rain fall or Precipitation

Rr ---- Reservoir out flow

The overall to estimated water balance of the dam is expressed by this the above equation. Because water abstraction from the reservoir as in terms of inflows and outflow into the reservoir are both of changeable, operation research necessitates iterative computation. With this method, all losses were calculated as the total of irrigation application losses at the micro level. The majority of the measurable quantities in the equation above were all direct and directed. The result is estimated depended on known variables field measurement on the study area (Jung-Hun Song1, 2020).

3.2.7. Discharge flow Measurements

Measurements of discharge flow measuring in irrigation flow were one of the essential variables for water distribution evaluating of irrigation performance. In this investigation, discharge measurements were made using three different techniques. These included a V-notch weir, a calibrated 2-inch Parshall flume, and the use of the float technique

3.2.7.1 Float method

The float approach water flow has been used to measure the volume of water at several locations of the scheme. These is the one main canal flow measuring starting from off take the source to the main canal at different locations (upper, middle, and tail- end) field sites that have been chosen for measurement. Due to a lack of flow measuring structures, the flow rates at the main and secondary canals were measured by flow velocity, and the V-notch weir in the canals had to be estimated in order to determine their discharges. This allowed for the assessment of the irrigation scheme conveyance efficiency.

Irrigation efficiencies are determine at scheme or farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down at lined main canal, to determine the overall irrigation efficiency (Jadhav et al. 1993). For modern schemes water losses in the processes of conveyance were low (24%), while the significant proportion of water (76%) was lost on the farm. In view of this evidence, we concluded that irrigation schemes in Ethiopia, regardless of their typology, have low water delivery performance. As every scheme has shown its own strength and weakness, concluding sustainability in terms of typology is misleading and this suggests that policy directions should be based on composite sustainability indices according to (Agide, 2016).

Main canal Dimension: the width (b) and depth (h) of the canals were measured with a measuring tape. These dimensions were used for calculating the cross-sectional area of flow. Wetted Cross-sectional area of flow, A = b*h

Where: A-cross-section area of flow (m2),

b- Width of the of canal (m)

h- Depth of canal (m)

A reduction factor of 0.8 (JICA, 2004) was used to convert the surface velocity to mean flow velocity.

$$Mean\ flow\ velocity, v\ (m/s) = 0.8 * L/t.(m/sec)\ --------- Equation\ 3.10$$

$$Discharge\ (m3/sec)\ = V\ (m/sec)\ * A\ (m2)\ \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Equation\ 3.11$$

Where: Q is the Discharge in m3/s;

V is the Average Flow Velocity in m/s; and

A is the area in m^2 of the Wetted Cross-section.

The irrigation water discharge was also measured at the main canal intake during the study period to determine the actual discharge through off take the scheme. Measured data's are taken 30 days during the irrigation season at head and tail end when the main gate was opened.

Figure 3. 7 Existed Lined Main Canal of Fre-lekatit irrigation scheme

3.2.7.2 V notch weir discharge (for Secondary canal)

Discharge from V-notch weirs (for every secondary canal) was measured in order to partially gather the flow data determined, flow measurements were made on each of the five secondary canals that are situated at the head-in-take reach secondary canals of the irrigation system. It was determined using a V-Notch weir of the average daily discharges (in the morning and afternoon). Calculated online equations and guidelines for water flow discharge passed through V-notch weir was computed based on the (Jimenez, 1999-2015). The discharge is directly related to the water depth above the crotch (bottom) of the V; this distance is called head (h).

V-Notch (Triangular) Weir Calculator Discharge and Head Calculations, Equations, and Guidelines for water flow measurement in streams and open channels

I applied the recent the below equation on line calculated Kindsvater-Shen Equation

$$Q = 4.28\, C \tan\left(\frac{angle}{2}\right) * (h + k)^{2.5} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3.12}$$

Where: Q = discharge over weir in m3/sec or l/ sec

C = discharge coefficient,

θ = notch angle,

h = head (m) and

k = head correction factor (m).

C and k can be estimated most of as constant.

The basic data required to measure discharge using v-notch weir are:

- Datum starting from zero ground 35 height
- H.max above the v-notch angle is 25cm (constant)
- Average height flow pass at different measured in cm
- Calculate discharge result through v-notch online measured.
- S I Units V-notch weir calculation: converted in to m3=cubic meter, s=second

Figure 3. 8 Discharge measuring using V-notch weir in April

3.2.7.3. Measurement of Water Applied Depth (WAD) to fields

Understanding water application depth, which is the amount of water applied to field in irrigation event, is important indicator for evaluation of water management in the irrigation scheme. To determine the amount of water applied by the irrigators to the fields at every growth stage (initial, developmental, mid and late stages) of the crop (maize), Parshall flumes (2 inch) were installed at the entrance of test plots every irrigation interval when the farmers are irrigating the test plots.

When the irrigator completed irrigating the test plot, the average depth of irrigation water passing through the flume, and the irrigation duration time (total flow time) were recorded for each test plot irrigated. The discharges of the water applied were taken from the respective recommended discharge table (Annex 5). Then, the depths of water applied to the fields were estimated by dividing the average total volume of water applied to the fields by the areas irrigated.

The discharge passing through the Parshall flume was computed using the free flow discharge measuring formula through a two inch throat width (Bos, 1989; Merkley, 2004; Gertrude, 2006). Since it is free to flow, only upstream measurement point which located within 2/3 section of the converging section was used converging inlet section it is intended primarily for use of irrigation purposed (Johnson, 1966).

The amount of inflow passed through Parshall flumes to irrigated plots was computed as follows:

$Qt\ = AD, OR\ D = \ (Qt)/A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; Equation\ 3.13$

Where V= Qt, OR = AD

Q= Discharge of the par shall flume (1/s)

t= Time taken to irrigated (Second)

A= Area of irrigated plot (m2)

D= Depth of irrigation water applied (mm)

$$Q = KHa^{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; Equation\ 3.14$$

Where; Q = free flow rate (m3/sec)

K = flume discharge constant (varies by flume size)

Ha=depth at point of measurement (cm)

n= discharge exponent (depends upon flume size)

The value of calibration parameters for a metric unit, K and n of a two-inch Parshall flumes value are 0.1207 and 1.55, respectively (Merkley, 2004).

Figure 3. 9 Discharge measuring using 2" Parshall flume at farm

3.2.8. Irrigation water use performance indicators

Measurements of discharge flow measuring in irrigation flow were one of the essential variables for water productivity evaluating of irrigation performance as water indictors.

The assessment of water use performance was conducted using three different types of indicators: water delivery capacity (%), relative irrigation supply (RIS), and relative water supply (RWS) (Levine, 1982; Perry, 1996). For the 2018 Cropping season (Jan-June) in Fre-lekatit, the net irrigation needs (IR) and the net crop water requirements (CWR) were calculated for each irrigated crop. To determine the crop water need for each crop variety, the CROPWAT 8 computer program's crop coefficients were utilized.

Input data include monthly temperature (maximum and minimum), humidity, sunshine, and wind speed. Crop water requirements (ETc) over the growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on a well established procedures. The updated values of crop coefficients are determined from (Allen et al., 1998).

Crop water demand (m3) is the potential crop evapotranspiration (ETp) or the actual evapotranspiration (ETc) when the entire crop water requirement is met, where total water supply (m^3) is the sum of diverted water for irrigation plus rainfall. The crop demands take into account seepage losses and deep percolation. The crop ETc less the effective rainfall was the irrigation demand (m3), and the irrigation supply (m3) was made up of surface diversions and net groundwater draws for irrigation. The CROPWAT program was used to calculate the net crop water needs and irrigation requirement (FAO, 1992).

3.2.8.1 Relative water supply (RWS) and Relative irrigation supply (RIS)

Relative water supply (RWS) and relative irrigation supply (RIS) are used as the basic water supply indicators. Both relate supply to demand, and give some indication as the condition of water abundance or scarcity and how tightly supply and demand are matched. Relative water supply and relative irrigation supply were estimated using equation 3. 15 and, 3. 16 respectively.

$$Relative\ water\ supply = \frac{Total\ water\ supply}{Crop\ demand\ (CRW)} \dots\dots\dots\dots\dots\dots\dots\dots..Equation\ 3.15$$

Where:

- Total water supply sum of irrigation plus rainfall.
- Crop demand = potential crop ET, or
- The ET under well-watered conditions. When maize was considered, deep percolation and seepage losses were added to crop demand.

$$Relative\ irrigation\ supply = \frac{(irrigation\ supply}{Irrigation\ demand\ (IR)} \dots\dots\dots\dots\dots\ Equation\ 3.16$$

Where:

- Irrigation demand (IR) = CWR- Peff
- Peff is effective rainfall (mm/season)
- Irrigation supply = only the surface diversions and net groundwater draft for irrigation.
- Irrigation demand = the crop ET less effective rainfall.

Both RWS and RIS, by relating supply to demand, give some indication as the condition of water abundance or scarcity and how tightly supply and demand are matched.

3.2.8.2. Water delivery capacity (WDC)

The water delivery capacity ratio indicates whether the system design was in anyway a constraint to meet the maximum crop water requirement (MULETA, 2013). Values much greater than 1 indicate that their capacity is not a constraint to meeting crop water demands. Values close to 1 indicate that there may be difficulties meeting short-term peak demands. Oftentimes, additional capacity is designed (at additional cost) to allow for more flexible water deliveries, or to ease management. WDC was estimated using equation 3. 16. According to (Molden D. J., 1990) and water delivery capacity ratio can be expressed as:

$$Water\ delivery\ capacity\ (\%)\ = \frac{(Canal\ capacity\ to\ deliver\ water\ at\ \ head}{Peak\ consumptive\ demand} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.17$$

Where: Capacity to deliver water at the system head

= the present discharge capacity of the canal at the system head, and

Peak consumptive demand

= the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

3.2.9. Conveyance efficiency

The conveyance efficiency was measured on the main canal by measuring discharges at two different points. The discharges were calculated from the velocities of the water flowing in the main canal using floating materials. The method of discharge measurement is called floating method as floating materials being used for velocity measurement. The discharge measurement was conducted in the upper position of the main canal.

Floating material was put on the upper end of the canal section and the time it took to reach the marked section of the same canal was registered. This test was replicated five times and the average time it took was taken to calculate the discharges. The cross sectional area of the canal was also estimated by measuring the average depth and width of the same canal section. The average velocity and the rate of flow (discharge) were calculated by dividing the distance with the average time, and by multiplying the cross sectional area with the average flow velocity, using equations 3.10 and 3. 11, respectively.

The second measurement was taken at a fixed distance above the downstream end of the main canal. The same procedure was followed to that of the upper parts of the canal to estimate the discharge at the outlet (the downstream end) so that the amount of conveyance loss was known and the conveyance efficiency was determined. The measurements for both positions were taken twice. The conveyance efficiency was calculated by using equation 3. 18.

The irrigation water discharge was also measured at the main canal intake during the study period to determine the actual discharge of intakes in the scheme. Measured data's are taken monthly at head end when the main gate was opened. These flow data`s were utilized for computation of canal delivery performance indicators.

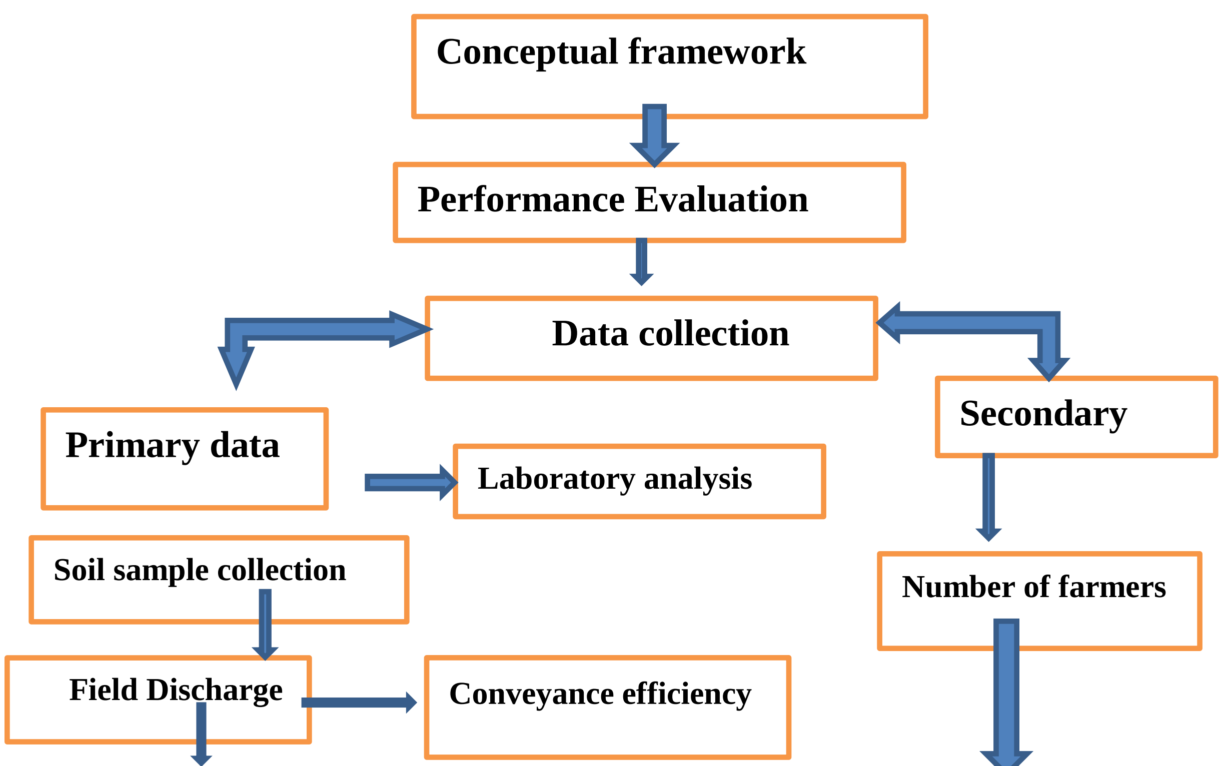
$$Ec\ (\%)\ = (Vf\,/\,Vt) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3.18$$

Where, Ec = Conveyance efficiency (%)

Vf = Volume of irrigation water that reaches at secondary canal` or field (m3/se)

Vt = Volume of irrigation water diverted from the water source (m^3/se)

3.2.10 Organizational setups of performance the Fre-lekatit irrigation scheme



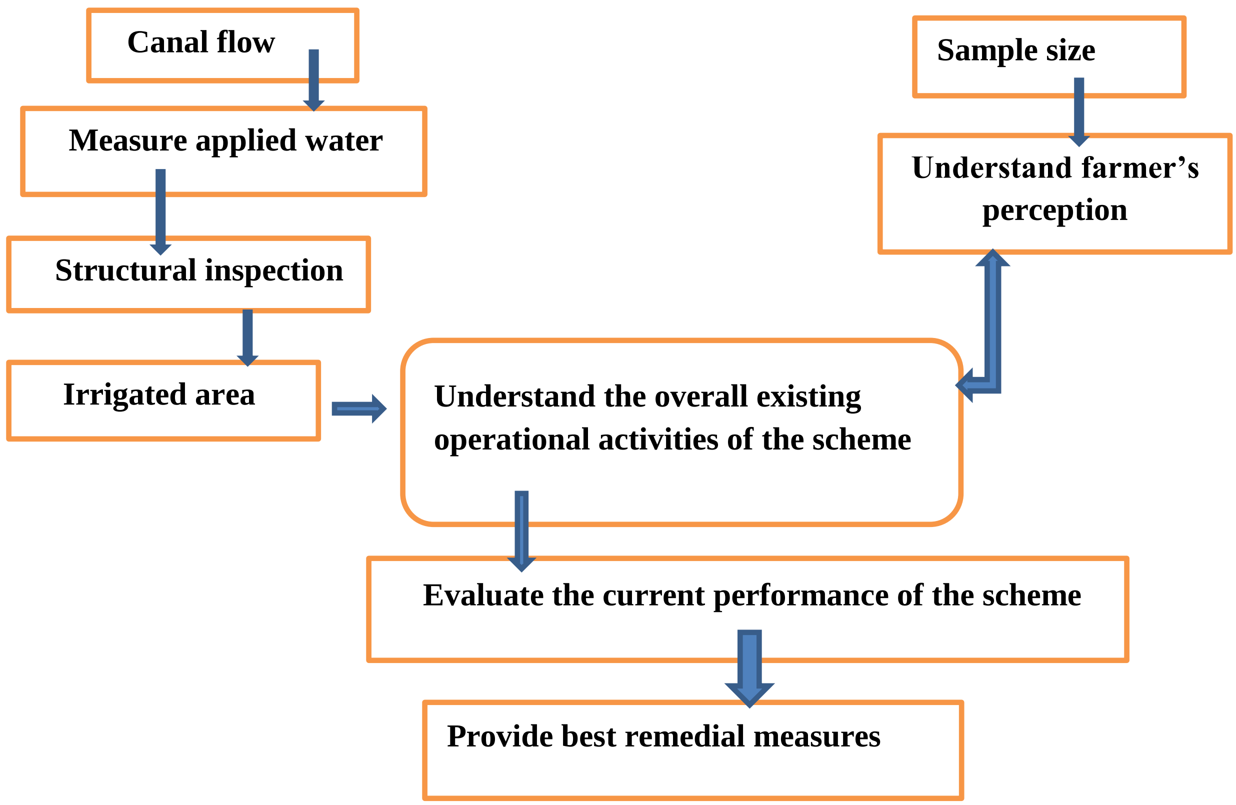


Figure 3. 10 Framework allocations performance irrigation system components

According to the framework is founded on the premise that the optimal irrigation, as measured from the irrigation source, contributes to the command area, the extracted point downstream, and either the consumed fraction or the non-consumed fraction. In order to apply this framework to irrigation areas, typical system components of water infrastructure are outlined under various conceivable conditions. Water entering a farm can be used for direct irrigation enters the farm's water distribution system, or help with storage changes in farm dam.

3.2.11. Methods of Data Analysis

Data Analysis Techniques utilizing both qualitative and quantitatively measurable data, the information gathered through surveys, transect walks, and official and informal discussions were examined and interpreted. The Statistical Package for Social Science (SPSS, Version-20) program, a soil lab, Google Earth, a CROPWATCROPWAT 8 model, and were all used in the data analysis process. Qualitative approaches and descriptive statistics were used to assess the quantitative and qualitative data that was gathered from the primary sources. Software from SPSS was used to analyze the quantitative data. Ultimately, the results of the statistical analysis were examined through the use of means, frequencies, percentages, tabulation, and cross-tabulation.

Both water distribution and water productivity evaluated at scheme level were used to water indicators performances to determine the efficacy of the Fre-lekatit irrigation scheme. Additional relevant findings are also provided and discussed. The criteria needed to assess the farmer practice's water utility at the field level, i.e., the properties of the soil, were established.

3.2.12 Materials used

The materials which were used in this study were: Graduated reading rod on the dam weir and V-notch weir discharge on secondary canal (constructed using sheet metal canals 2” Parshall) Par shall flume consist of a converging inlet section, a throat section with straight parallel sides, and a diverging outlet section valuable.

CHAPTER 4: Results and Discussions

This chapter presents quantitative results from the findings are part of the study aimed to identifying major constraints of the scheme level water distribution and productivity in the Fre-lekatit irrigation scheme. The analysis was among 45 HHs farmers which are randomly selected in the study area; from each secondary canal 9 irrigator farmers (head, middle and tail end) are irrigation water applied from the irrigation scheme. In addition to evaluate the existing reservoir water utility of the Fre-lekatit Irrigation scheme.

4.1. Soil data Analysis of the Study Area

To investigate some of the physical properties of soil in the site (moisture content at field capacity (FC) and permanent welting point (PWP), moisture content after irrigation, texture, and bulk density), for the purpose of understanding the general feature of the irrigated soil type, different field observations were taken and analyzed.

4.1.1 Soil texture of the study Area

Generally the study area dominated soil was cover based on the soil laboratory analysis resulted soil type were Sandy Clay loam (59.26%), Sandy clay (40.74%) had been resulted respectively.

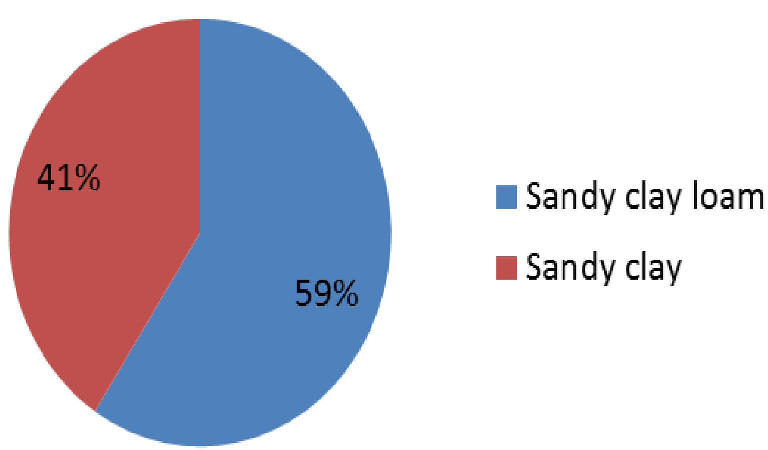


Figure 4. 1 soil texture of the study area

According to the USDA textural classification, the soil texture of irrigation scheme was determined based on the particle size distribution. As a result, percent sand clay loam takes the highest proportion in the study area [figure 4.4]. Accordingly, the textural class was sand clay loam at all depths and positions or locations (Head, Middle and Tail-end) as presented in Table 4.1. As seen in Table 4.1 the bulk density varied from the minimum as 1.333 g/cm3 to high of 1.559 g/cm3 at the scheme's middle and top location obtain respectively. According to Miller and Donahue (1995), recommended soil bulk density below 1.4gm/cm^3 for clays and 1.6gm/cm^3 nearly for sands in order to get better plant growth. The current result is in agreement with the classification suggested by (Miller and Donahue, 1995). Hence, the soil of the study area found to be suitable for plant growth.

The top surface 0-30 cm had an average bulk density of 1.438 g/cm3 whereas; the middle surface and subsurface (30-60 cm) and (60-100 cm) had an average bulk density of result 1.459g/cm^3 and 1.52 g/cm^3 as well as scheme's position average varied from 1.466 to 1.546 g/cm^3 increased respectively result.

The results of the soil sample were dominant. Because they have less total pore space than silty or clayey soils (not applicable to red clayey soils and volcanic ash soils), sand followed by clay soils had relatively high bulk densities. Generally, bulk density rises with soil depth. Texture often affects bulk density. The available water capacity of a particular soil is generally reduced by high bulk densities. For optimal plant growth, Miller and Donahue (1995) suggested a soil bulk density of less than 1.4g/cm^3 for clay soils and 1.6g/cm^3 for sand then the range density of sand and clay soils are to get better plant growth.

The bulk density values of the soils at the irrigation scheme were low as per the bulk density rating of Jones et al.,(2003), indicating that there was no compaction that could limit infiltration of water into and through the soil and root penetration.

Table 4. 1 Soil textural classes of the study area

	Upper locations						
	Soil depth(cm)	% Sand	% Silt	% Clay	Textural class	Bulk Density(g/cm^3)	Sample plot
Plot-1	0-30	77	1	22	Sandy clay loam	1.516	Head plots
	30-60	69	5	26	Sandy clay loam	1.532	
	60-100	59	9	32	Sandy clay loam	1.545	
Plot-2	0-30	65	3	32	Sandy clay loam	1.455	
	30-60	55	5	40	Sandy clay	1.523	
	60-100	55	5	40	Sandy clay	1.533	
Plot-3	0-30	57	7	36	Sandy clay	1.516	
	30-60	55	7	38	Sandy clay	1.524	
	60-100	49	7	44	Sandy clay	1.578	

		Middle locations					
Plot-1	0-30	57	7	36	Sandy clay	1.33	Middle-Plots
	30- 60	51	9	40	Sandy clay	1.36	
	60-100	57	9	34	Sandy clay loam	1.44	
Plot-2	0-30	67	3	30	Sandy clay loam	1.35	
	30- 60	57	9	34	Sandy clay loam	1.37	
	60-100	53	11	36	Sandy clay	1.50	
Plot-3	0-30	59	11	30	Sandy clay loam	1.36	
	30- 60	63	5	32	Sandy clay loam	1.41	
	60-100	53	11	36	Sandy clay	1.51	

		Tail -end locations					
Plot-1	0-30	65	7	28	Sandy clay loam	1.543	Tail-end Plots
	30- 60	53	11	36	Sandy clay	1.559	
	60-100	67	9	24	Sandy clay loam	1.566	
Plot-2	0-30	67	9	24	Sandy clay loam	1.429	
	30- 60	57	13	30	Sandy clay loam	1.436	

	60-100	53	11	36	Sandy clay	1.458	
Plot-3	0-30	69	7	24	Sandy clay loam	1.443	
	30- 60	63	9	28	Sandy clay loam	1.424	
	60-100	57	9	34	Sandy clay loam	1.554	

4.1.2. Soil moisture content at field capacity and permanent wilting point

The selected soil physical characteristics of (Bulk density, Field capacity, Permanent wilting point, and Total available water) at Fre-lekatit irrigation schemes were presented in (Table 4.4). The volumetric moisture content retained at field capacity varied from 30.38 % to 50.13 % by volume, while the soil moisture at permanent wilting point varied from a minimum value of 26.2 % to the maximum value of 37.77.9 %m3/m3 on volume basis (Table 4.4). Similarly, the value of total average available water varied from the lower value of from the lower value of 108mm/m to higher value of 127 mm/m.

The value of FC, PWP and TAW were found to be in the range given by FAO (1998) (Table 4.4). The value of total available water ranged from 108 mm/m at subsurface (middle reach) to the high value of 127.20 mm/m at the surface (upper reach) for sandy clay loam and sandy loam of the selected fields at Fre-lekatit irrigation scheme. The total available water (TAW) is directly related to variation in Fc and Pwp. The results obtained indicate as the sampling depth increase the total available water decrease in the root zone. However, the water holding capacity or the total water available of the soils at irrigation scheme was good as described in [Annex 7]. Generally, the water holding capacity of the soil depends on its texture, bulk density, and soil structures.

Increase the water holding capacity of the soil, improvement of irrigation practice is necessary, such as appropriate tillage practice, soil conservation, crop rotation, and addition of organic matter (Solomon, 2016)

(Bulk density, field capacity, permanent wilting point and total available water)

Table 4. 2 Selected Soil physical characteristics of the study area

		Location Upper Location							
	Farmer-1			Farmer-2			Farmer-3		
Field code	Plot-1			Plot-2			Plot-3		
depth unit (cm)	0-30	30-60	60-100	0-30	30-60	60-100	0-30	30-60	60-100	
θmFc(%)	30.3	28.8	30.6	30.9	32.8	32.7	32.2	30.6	31.2	
ΘvFc%	45.93	44.12	47.28	44.96	49.95	50.13	48.82	46.63	49.23	
θmPwp(%)	19.7	19.2	20.6	21.6	24.8	25	22.6	24	27.1	
ΘvPwp%	29.87	29.41	31.83	31.43	37.77	38.33	34.26	36.58	37.70	
Bd (g/cm3)	1.516	1.532	1.545	1.455	1.523	1.533	1.516	1.524	1.578	
TAW (%)	16.070	14.707	15.450	13.532	12.184	11.804	14.554	10.058	6.470	
TAW (mm)	48.21	44.12	46.35	40.59	36.55	35.41	43.66	30.18	19.41	
TAW (mm/m)	160.70	147.07	154.50	135.32	121.84	118.04	145.54	100.58	64.70	127.59

			Middle location							
	Farmer-1			Farmer-2			Farmer-3			
Field code	Plot-1			Plot-2			Plot-3			
depth unit (cm)	0-30	30-60	60-100	0-30	30-60	60-100	0-30	30-60	60-100	
θmFc(%)	31.1	30	30.1	31.5	32.1	28.6	31.2	30.2	30.7	
ΘvFc (%)	41.46	40.68	43.19	42.40	43.91	42.81	42.34	42.61	46.42	
θmPwp(%)	22.6	24.9	21.5	22.5	21.6	19.6	20.6	20.6	22.7	
ΘvPwp%	30.13	33.76	30.85	30.29	29.55	29.34	27.95	29.07	34.32	
Bd (g/cm3)	1.33	1.36	1.44	1.35	1.37	1.50	1.36	1.41	1.51	
TAW (%)	11.33	6.92	12.34	12.11	14.36	13.47	14.38	13.55	12.10	
TAW (mm)	33.9915	33.3	42.4	33	31.5	36	37.8	28.8	32	
TAW	113.31	69.16	123.41	121.14	143.64	134.73	143.84	135.46	120.96	122.85

(mm/m)										

			Tail-end location							
	Farmer-1			Farmer2			Farmer3			
Field code	Plot-1			Plot-2			Plot-3			
depth unit (cm)	0-30	30-60	60-100	0-30	30-60	60-100	0-30	30-60	60-100	
θmFc(%)	27.6	22.4	19.4	25	29.9	33.8	24.6	27.8	32.1	
ΘvFc%	42.59	34.92	30.38	35.73	42.94	49.28	35.50	39.59	49.88	
θmPwp(%)	19.3	17.5	19.2	20	19.4	22.3	19.1	18.4	21.5	
ΘvPwp%	29.78	27.28	30.07	28.58	27.86	32.51	27.56	26.20	33.41	
Bd (g/cm3)	1.543	1.559	1.566	1.429	1.436	1.458	1.443	1.424	1.554	
TAW (%)	12.807	7.639	0.313	7.145	15.078	16.767	7.937	13.386	16.472	
TAW (mm)	38.421	22.917	0.940	21.435	45.234	50.301	23.810	40.157	49.417	
TAW (mm/m)	128.069	76.391	3.132	71.45	150.78	167.67	79.365	133.856	164.72	108.38

θmFc %, θvFc% is the moisture water content of the soil at field capacity on a weight basis (%) and on a volume basis (%) respectively. θmPwp %, θvPwp% is moisture water content of the soil at a permanent wilting point on a weight basis (%) and on a volume basis (%) respectively, Bd is a bulk density of the soil and TAW is total available water.

4.2 Evaluating the existing utilization of reservoir water

Using a graded reading rod installed on the headwork of the structure, the water balance of the Fre Lekatit irrigation scheme was measured every day, commencing with dam water discharged through the off take structure. When measuring practically, assessing or keeping an eye on the water released for irrigation based on conventional benchmark red color on headwork a reference. One of the most crucial factors to take into account when utilizing this component of water balance was the duration of the computations. An area's reliance on irrigation necessitates some water balance analysis. Water balance may have been explained using four different viewpoints in phrases and (Table 3).

Using the existing counter maps, the original reservoir elevation-area-capacity curve at a dam site can be created. Using the following formula, the difference in volume between any two consecutive contour heights and the reservoir's live capacity were determined. The reservoir's water surface area and water storage capacity were determined by the elevation of the water level reading. This function was represented by the area and capacity curve as shown in (Table.3).

Figure 4. 2 daily measuring dam drawdown

Table 4. 3 Area- Elevation-Capacity- curve

Month	Reading Elevation	Absolute elevation (m)	Corresponding area (m^2)	Corresponding volume(m^3)	Monthly draw down(m^3)	Water released events	Monthly Volume released(m^3)	Monthly draw down (m)
Benchmark	2330	19	657837.97	3354623.0	0			

Jan	2329.58	18.58	622923.42	3095788.3	258834.66	21	12325.46	0.42
Feb	2329.1	18.1	583021.07	2799977.3	295811.04	24	12325.46	0.48
Mar	2328.66	17.66	547795.16	2561393.6	238583.72	22	10844.71	0.44
Apr	2328.198	17.198	510807.97	2310880.7	250512.91	22	11386.95	0.462
May	2327.718	16.718	470993.63	2086282.5	224598.20	24	9358.26	0.48
Jun	2327.498	16.498	452745.39	1983341.6	102940.84	12	8578.40	0.22
Total-DDD	2.502	2.502	205092.58	1371281.4	1371281.37	125		2.502
Dam recovered					43157.7			
Total-Released-Volume(m3)					1414439.05			

i) (A). The total draw down of the dam from Jan.to June 2018 was 2.5m and from the elevation –area-capacity curve the total volume of water release during that time was about 1,371,281m^3.

ii) (B). The dam recovered 43157 m3 of volume water, (4.7 cm higher head) during the irrigation season, as a result of a decline in 40mm rainfall in the upstream catchment area according to result (table 4.1).

iii) (C). During the irrigation season a total of 1251516 m^3 and 1053645m^3 water diverted through the main and secondary canal results, respectively.

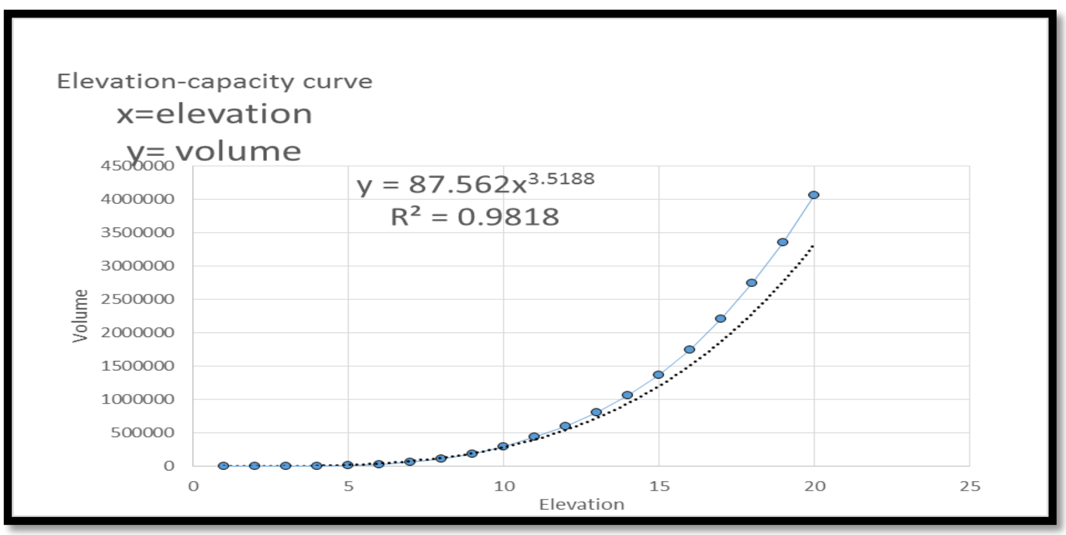
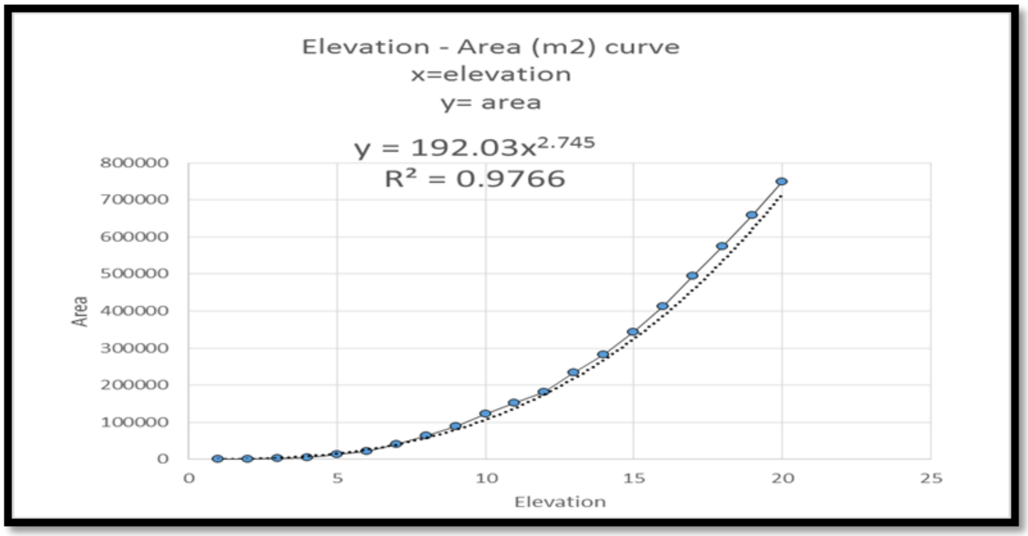


Figure 4. 3 Elevation –Storage curve

Source data: from Design document Fre-lekatit dam (2011)



Source data: from Design document based Elevation -Area-Capacity Curve

Figure 4. 4 Elevation-Area curve

(D). Using lined canal, the estimate released quantities of irrigation water to the command area for the whole irrigation seasonal (Jan- Jun) through the main and secondary canals were 1,251,516 m^3 and 1,0536,45 m^3 results respectively. Compare among the main canal to; secondary canals, and at field spots the conveyance efficiency results are 84.2% and 61.70% resulted respectively. The outcome shows that the main canal to secondary canal is efficient. If the entire system is lined, the conveyance efficiency can reach up to 86 % according to the (Singh2, 2018)

Then the total conveyance losses based on the estimated reservoir outflow calculating irrigation water released through main canal; to secondary canals and field spots comparative described specially is 197870 m^3 (15.9 %), and 476919 m^3 (38.3%) result respectively, not only these but also consider all losses in this study area in the 125-days period over irrigation season according to (Table 4. 2).

Table 4. 4 Results of seasonally released volume of water from the dam to the Secondary canals

Monthly	Released water from the source (Reservoir)m^3	Total diverted water through main canal(m^3)	Total delivered water through	Total loss of water(main -2rd	Total loss of water (D- 2nd	Conveyance efficiency, (Dam - 2nd canal) %	Conveyance efficiency, (Main -2nd) %

			Secondary canals (m^3)	canals) in m^3	canal) inm^3		
Jan	258834.7	230568.7	151875.3	78693.3	106959.3	58.7	65.9
Feb	295811	260621.9	205543.5	55078.3	90267.5	69.5	78.9
Mar	238583.7	220595.8	209368.4	11227.3	29215.3	87.8	94.9
Apr	250512.9	240595.8	215538.8	25057	34974.1	86	89.6
May	224598.2	210649.9	208607.1	2042.8	15991.1	92.9	89
Jun	102940.8	90325	62712.2	27612.8	40228.7	60.9	69.4
Total	1371281.4	1253356.9	1053645.4	199711.6	317636	76.8	84.1
Conveyance efficiency of Main canal to sum of secondary canals (%)				84.1			
Conveyance losses of Main canal to sum of secondary canals (%)				15.9			
Conveyance efficiency Dam -secondary canals (%)				76.84			

4.3. Socioeconomic results

The easiest way to evaluate the overall effects of irrigation is to compare similar agro-environments where household differences in summary data were reported for all factors, including seasonal and practical farm management irrigation and other associated aspects (Annex-6). Approximately the entire 45 household's only focuses on the questionnaire sample plots were farmers who used irrigation maize crop variety. In other words, irrigation allows farmers to choose high-value crops and cultivate their land extensively rather the rain fall productive.

According to questionnaire statically data collect the average age of the household head is approximately 53 years and the minimum and maximum age of the household head is between 35 and 71 years respectively. Gender of the household head is one of the determinant factors for agricultural commercialization. From the sample survey, majority of the household heads are

male-headed households cover (60%) the rest household heads are female-headed. Furthermore, 64% of the male-headed households have access to irrigation while 36% of the female headed households have access to participate in the irrigation system.
Finally result from the suggest that even though access to irrigation have positive impacts on farm households market participation, the irrigation scheme impacted in food security on that community exists.

According to the Woreda Agri. Dev.t Sector Report (2018), the average crop yield in the Fre-lekatit irrigated areas for the irrigation season were 18, 15 and 20 quintals/ha for Maize, Potato and Barley respectively, but according to the standard harvesting productive 28, 24 and 24 respectively. The same manure, 100 kg DAP/ha, sold 1444 Birr and 100 kg urea/ha, sold 1407 Birr, were utilized. According to farmers' information, improved seed, supplied at 630 Birr/25 kg, was also widely used by farmers to increase agricultural productivity and replenish soil fertility. Particularly, depending on the appropriate soil types, it was not advised to change from location to location, while weed control twice at growing and till erring handed weeding continues as necessary throughout the growing season to improve the crop production.

4.4 Evaluation of water distribution performances

The parameters assessed for water distribution performance evaluation of Fre-lekatit small-scale irrigation scheme were include the following. Conveyance efficiency at main canal, water application in the secondary canals, and water applied at field level are the parameters that evaluated in this scheme. Institutional and support service evaluation was also conducted to incorporate local knowledge and perspective on the irrigation system.

4.4.1. Main canal water conveyance efficiency

The conveyance efficiency, Ec measures the percentage of discharge entering the system that is recorded as having been allocated to the water management units. Conveyance efficiency of the systems was computed considering the total flow delivered by conveyance system and total inflow into the system (Table 4.5). During the study period, average conveyance efficiency of the main canal from main intake up to the tail end considering different measuring locations of discharge using floating method or area-velocity method. The results from the table below illustrate the averages discharge utilizing the floating approach at 40-meter intervals based on primary field measurements.

Table 4. 5 Average discharge measured using floating method at main canal

Canal	**Segme nt**	**Distance b/n**	**Inflow**	**Out flow**	**Conveyance loss**	**Losses /length**	**Conveyan ce**
Type	No.	points (m)	(l/s)	(l/s)	(l/s)	(l/s/m)	efficiency %
Lined main	1	40	225.85	179.26	46.58733	1.16468	0.79373
Canal	2	40	223.66	176.33	47.33304	1.18333	0.78837
	3	40	229.16	174.545	54.61584	1.36540	0.76167
	4	40	215.242	172.24	43.00681	1.07517	0.80019
		Average	218.274	166.154	47.88575	1.19714	0.78599
			192.214				78. 6

According to the table 4.9, the estimated average value of inflow, outflow, and water conveyance efficiency as well as water conveyance losses for different sections of the main canal is in my study when compared to the findings of Jadhav et al. (1993). Who reported about 24% average loss and 76 % have conveyance efficiency from lined main canals which was also lower than my result values. The measured value in my research is water conveyance efficiency for main canal varied from 79.4 to 80.1% with average value of 78.6%.The values of conveyance efficiency and lost were proportional value relatively to (Jadhav et al. 1993).Therefore, the values of water conveyance efficiency the study area is related to the others researchers based on results. The water conveyance losses per 40 m length varied from 19.98 l/s/40 m to 23.83 l/s/40 m with average value equal to 21.43 l/s/ (40 m).

The loss would have been avoidable with canal lining or minimized with proper maintenance like where with concrete lined canal and other protect losses and animal drinking.

4.4.2 Seasonal released volume water through secondary canals

The discharge was measure using v-notch weir (90^{o}) at head (intake) of the each secondary canals and there are five secondary canals present in the irrigation scheme. The discharge delivered to the secondary canals and the v-notch weir was measured on line frequently during each irrigation event at the point where, allocated the flow head water. The discharge measured was combined with the duration of the discharge (application time) to determine the total delivered volume water applied during the study period starting (Jan.-June) in each canals have resulted below.

Table 4. 6 Sample Data Sheet of Triangular (90o) V-Notch weir online discharges measuring

	Solve for:	Result	Unit
1	Discharge, Q	0.01430988	M3/sec
2	Head, h:	0.1606	M
3	Notch Angle, θ:	90 degree	Degree
4	Discharge Coefficient, C:	0.57798489	M
5	© 2015LMNO Engineering,	0.000884687	Reference

The amount of irrigation released volume water measures through each secondary canals in the study area varied from 201,612.4 m^3 to 225,989.7 m^3 corresponding irrigated area range 21.2ha-30.35 ha respectively, measured divert water to the irrigated based on selected field plots in irrigation season.as the result see below the total delivered volume water to all these secondary canals is 1053645.4m^3 (84.2%) of the diverted volume water passed through main canal was delivered on.

Table 4. 7 Seasonal released volume water through secondary canals

Months	Canal-1	Canal-2	Canal-3	Canal-4	Canal-5	Total
	V(m3)	V(m3)	V(m3)	V(m3)	V(m3)	Released

						volume (m3)
Jan	30901.3	30242.3	30565.3	30125.6	30040.8	151875.3
Feb	39643.9	39981.4	41997.7	40175.9	43744.7	205543.5
Mar	38485.8	42440.1	42064.8	39338.4	47039.2	209368.4
Apr	40253.1	41997.5	43007.9	43137.1	47143.2	215538.8
May	39098.1	40909.8	41592.5	41413.7	45593.0	208607.1
Jun	13230.1	12904.5	12342.1	11798.7	12436.8	62712.2
Sum	201612.4	208475.6	211570.3	205989.4	225997.7	1053645.4

4.4.3. Water applied at field level

The result of this analysis scheme level water distribution can be allocated day rotation or for specific period (days interval) within a week. As far as the schedule of irrigation water allocation is for the peasant associations he belongs, farmers have the right to apply the water as much as he wants. That means there is no any restriction how much water a farmer can divert for his field regardless of the size of his farm, especially for head end users. From field observation and results of the observation data, compared due to unwise use of water by the head end users and tail end user faced water shortages frequently. This result agrees with the study held by (HASSEN, 2004) in the case of upper awash river valley Ethiopia, the study identified that the beneficiaries had low knowledge on the irrigation scheduling (how and when to apply). The overall result of this analysis indicates that the technical support from experts was poor and farmers irrigate their farms on guess or on their own perceptions. The study has ensured that the beneficiaries have low knowledge of irrigation scheduling (interval, time and duration). The average irrigation applied water for the Fre-lekatit irrigation scheme was different as locations of the irrigator farmers.

The application time mostly depends on the discharge received at a given point. Table 3.6 shows the time used to irrigate the sample plots area ranging from 0.1107 ha to 0.1885 ha. In general, the application time is linearly related to the discharge amount. The average irrigation water depth of the sample plots for selected maize melkasa-2 crop variety ranged based on secondary canal locations range from 47.76 mm to 56.94 mm as (Annex: 5). This shows that there is much difference on the practice framer amount of irrigation water applied during the study period as comparative to water demand.

Table 4. 8 Seasonal Average irrigation applied depth water of the sample 45 plots

Secondary Canal Location	Total Spot area in (m2)	Total applied gross volume of water (m3)	Applied depth of irrigation water (mm)	Total no. of irrigation events	Total irrigation water applied (mm)	Total gross irrigation applied (m3/ha/season
Canal -1	11396.2	600.9	52.7	16.0	843.7	8437.1
Canal -2	11798.7	612.7	51.9	16.0	830.9	8308.7
Canal -3	11167.0	572.0	51.2	15.0	768.4	7683.8
Canal -4	11433.0	558.8	48.9	15.0	733.2	7331.7
Canal -5	11433.0	552.9	48.4	16.0	773.7	7737.2
Average			50.5	78.0	789.6	7896.4

The results showed that the average water applied depths for selected fields per irrigation event were 51.55mm, 50.55 mm and 49.55 mm for the upstream, middle and tail end fields respectively for Fre-lekatit irrigation scheme (Annex 4.10). The amount of irrigation water applied per hectare in one irrigation season and corresponding applied volume water to the selected fields at the Fre-lekatit irrigation scheme was 800.51 mm (8005. m^3/ha), 789.44 mm (7894.4 m^3/ha), and 778.9mm (7789 m^3/ha) in upstream, middle and tail end locations respectively. The average amount of irrigation water applied per hectare per season in the irrigation scheme is 789.6 mm (7896 m3/ha) according to (Table: 4.8).

All locations were found to irrigate above the optimum value obtained from the CROPWAT8 (545mm) for maize crop for the cropping season 2018.

The average water application depth variation was observed among the selected fields due to variation in irrigation intervals, and depth application per irrigation. The upper field was more irrigated water comparing to the middle and lower fields irrigated farmers, because they are nearest to the water source they could divert the water to their fields, as they want as they like (they did not transfer to the next users at a time).

In addition to the total average water applied depths for selected fields per irrigation and corresponding applied volume water to the selected fields described details on the above (Annex :5). Farmers minimized water losses by using deficit irrigation and by transferring water immediately to the next plot. On the other hand, over-irrigation and high water losses were observed on.

According to the Table 4.8, the average applied irrigation water base on location secondary canal-l field's selected plots are received more irrigation than the other secondary canal-5 of the fields' plots, have 52.8m and 48.4 mm respectively resulted, while the secondary canal-5 field's selected plots received the least amount of water application. The remaining secondary canals demonstrate that there was little variation in the quantity of irrigation water used during the research period. According result to table 4.8 the average irrigation water applied depth as the scheme is 50.50 mm. The scheme's irrigation interval was determined based on a rotating basis.

Irrigation of fields is also not uniform. Some farmers start irrigation from the downstream side of the field while others start from the top part of the field from which they get water as Joshua W. Faulkner (2006). But all farmers responded in interviews on their method as the most convenient way. As the furrow size is small, most furrows receive a discharge beyond their capacity. Consequently, water may spill over furrows and flow to a part of the field that has already been irrigated.

4.5 Water logging problem occurrence in Fre-lekatit irrigation scheme

There is an excess accumulation of waterlogging in the irrigated land, due to misuse of farmer-irrigated water. This can adversely affect the beneficial characteristics of the soil strata, as the soil is unable to absorb the water as it should. It occurs when there is insufficient oxygen in the pore space for plant roots to be able to respire adequately. Waterlogging can also be caused by the rising of the water table to the point that the soil pores in the crop root zone get clogged. In summary, waterlogging and saturation, leading to soil suffocation and obstruction of oxygen circulation, are created due to application beyond the water-holding capacity of the soil.

4.6 Determination of Crop Water Requirement and Irrigation Water Requirement

The crop water requirement and irrigation water requirement computed from the climatic data were used for the purpose of estimation of crop water productivity in terms of water consumed, and also utilized as cross check for the irrigation requirement obtained from soil moisture analysis. Crop water requirement for each crop was determined using CROPWAT 8.0 computer program and a summary is presented in Table 4.10 In absence of reports on maize, potato and barley irrigation water requirements for the 2018 production year with the average irrigation interval practiced by farmers. The calculation was made by taking the crop coefficient (Kc) and critical depletion fraction (p) values of crop and asparagus respectively, as an input data to run the program.

Table 4. 9 Crop water and Irrigation requirement of maize the irrigated scheme

Crop type	Area coverage (ha)	Area coverage (%)	Planting date	Harvesting date	Irrigation interval (days)
Maize	57.6	46	22-Jan	5-Jun	7
Potato	52.6	42	20-Jan	2- Jun	8
Barley	15	20	12-Feb	14-May	10
Total	125.2	100			

Table 4. 10 Monthly CWR and IR of crops maize grown in the irrigation scheme

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	3	Init	0.3	1.17	10.5	0	10.5
Feb	1	Init	0.3	1.22	12.2	0	12.2
Feb	2	Deve	0.37	1.55	15.5	0	15.5
Feb	3	Deve	0.57	2.56	20.5	0.1	20.4
Mar	1	Deve	0.78	3.7	37	1.4	35.6
Mar	2	Deve	1.01	5.07	50.7	2.1	48.6

Mar	3	Mid	1.18	5.92	55.1	3	52.1
Apr	1	Mid	1.19	5.96	59.6	4.4	55.5
Apr	2	Mid	1.19	5.97	59.7	5.5	54.1
Apr	3	Mid	1.19	5.98	59.8	4.8	55
May	1	Late	1.17	5.91	59.1	3.7	55.4
May	2	Late	0.95	4.8	48	3.1	44.9
May	3	Late	0.66	3.21	35.3	3.3	32
					545	32	513.1

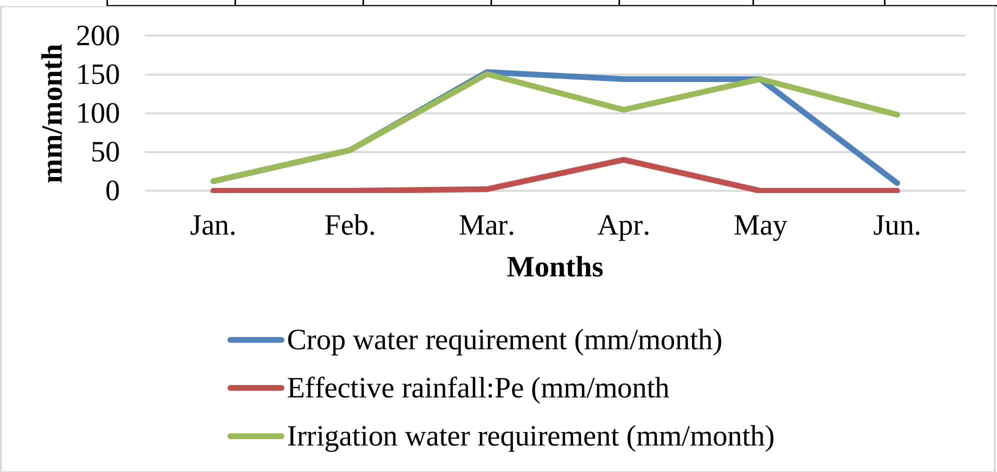


Figure 4. 5 CWR, Eff. rainfall and Irrigation requirement for Maize

The value of the computation of CWR, IR and rain fall for variety crop were planted (transplanted) toward the end of January, its anticipated crop water demand is 545 mm; however, irrigation is only needed for 513.1 mm, since 32 mm of the water needed is supplied by (effective) rainfall. Potatoes planted at the start of January require 566.6 mm of water, of which 31.6 mm come from rainfall and the remaining 535 mm come from irrigation. The water requirement of barley planted March is 487.1mm of which 458.3 mm need to deliver through irrigation, the rest (28.8 mm) is from rainfall according to (Table.4.11)

The result of a computer program was the average climate data of 15 years (2003 to 2017) ETo CROPWAT8 output was indicated in Tables 4.10. The details of the crop water requirement and irrigation requirements of the crops (Maize, potato, and barley) for the Fre-lekatit irrigation scheme was indicated in Tables 4.9 and Annex 10. The infiltration value for basic soil types for CWR determination was taken from FAO recommendation since there was no available material at that time and details were described in Annex: 10. From Table 4.9, which was calculated with Cropwat8, the maximum irrigation requirements of the crop maize with 7 days interval at Fre-lekatit irrigation scheme was only 55.5 mm depth of water. This value can be used for the whole farmers' fields for their similar characteristics required to determine the crop water requirements of the site. But the average actual required water applied by the farmers with 7 days interval varied from 47.6mm to 56.95mm at Fre-lekatit (Table 4.6) the result was the estimated value up and down. This showed that the farmers were applying different water relatively to the actual required at the study area.

Table 4. 11 Crop water requirement and irrigation requirement of Fre Lekatit irrigation scheme

Crop type	Area cover in (ha)	Crop water requirement	Eff. Rainfall	Irrigation Requirement	Total net Crop demand	Total net Irrigation Requirement
		(mm/season)	(mm/season)	(mm/season)	(mm/season)	(mm/season)
Maize	57.62	545	32	513.1	250.7	236.05
Potato	52.63	566.6	31.6	535.1	238.1	224.9
Barley	15	487.1	28.8	458.3	58.34	54.9
Total	125.2	1598.7	92	1507	547.15	516

Based on the above table 4.11 resulted total crop water requirement for the growing season of Fre Lekatit irrigation scheme was determined as below.

CWR maize *area maize)/area total) + (CWR potato* area potato)/area total) + (CWR barley *area barley)/area total)

Where:

NCWR crop is the water requirement of a crop calculated and taken from Table 4.11, area crop is irrigated areas of the respective crops taken from the same Table 4.9 and irrigated total area is (125.25 ha).

The result is 547.14 mm/season. To change the depth to volume of NCWR multiply it by the total irrigated area, i.e.125.25× 104× 547.14 *10-3 m3 = 685,295.5 m3/season. The total irrigation requirement is calculated in the same way and the result is 515.86 mm/dec mm/season i.e. 125.25 m2× 104×515.85 m*10-3 = 646,114.7m3/season.

The net crop water requirement and net irrigation requirement for the season of 2018 production year of the Fre Lekatit irrigation scheme result was 547.15 mm/ dec and 516 mm/season had 685,295.5 m3/season and 646,114.65m3/season had resulted respectively.

The total volume of water diverted the Fre-lekatit irrigation project during the irrigation season (Jan.-June), with an average discharge of 192.21lit/sec was continuous flows and 1,251,516.4m3 through main canal result respectively, with an average operation time 11.5 hours per day flow. In addition to the total volume of water delivered to the secondary canals intakes were measured 1053646 m^3 in off irrigation season. There is consider water losses between main canal and secondary canals water release for the period of irrigation seasonal.

The amount of water or depth of water diverted during the whole season for Fre-lekatit irrigation was calculated as: volume of water diverted divided by total irrigated area. The result is 1,251,516.37 m3/125.25*104 m2)*1000 = 999.22 mm was average applied irrigation depth through the scheme and the total rained fall during the study cropping season (Jan-June) 2018 is rain fall 40 mm appeared in the study area.

Based on the above results showed both of the totals NIR of the study area cropping season is 516 mm/season is irrigation demand and the total diverted water is 999.22 mm irrigation supplied according to the irrigation scheme farmers' practical measured result. Then there is more irrigation applied or excess water irrigated than crop water requirement according to the result CROPWAT8 in study area.

4.7. Evaluating of water productivity performance

4.7. 1 Determination of Relative Water Supply and Relative Irrigation Supply

Table 4. 12 Summary results of maize crop production in 2018 year to estimate CWR and IR

Scheme	Area	Irrigation diverted water in		CWR	IR	Effective	Total rainfall
	Coverage,	(m^3	(mm)	mm	mm	RF(mm)	RF,mm

	ha						
Fre-lekatit	125.25	1,251,516.4	999.2	545	513.1	32	40

Based on the data table 4.13, the water use performance indicators (RWS and RIS) were calculated as below. These values also imply relationship between water supply and crop water demand was less than from the point of water distribution in the scheme.

1. Relative water supply = (Irrigation diverted + Total rainfall)/ (CWR)

= (999.22+ 40)/ (545) = 1.91

2. Relative irrigation supply = (Irrigation diverted)/ (IR)

= (999.22)/ (513) = 1.95

The results of the practical measurements of, relative irrigation supply, and water supply are displayed below. According to Table 4.13, the scheme's average relative water supply and relative irrigation supply were 1.91 and 1.95, respectively. Comparative performance indicator: Relative water supply, reflecting the availability of water in relation to crop demand, was 1.95 indicating that the total water applied was similar to the crop needs. According to the US Bureau of Reclamation's method (Smith, 1992). RWS and RIS values indicate whether there is an adequate supply done or not to cover the demand. RWS and RIS values of 1 or higher indicates adequate while the values smaller than 1 indicate inadequate supply of irrigation (Kemal, 2007).

Table 4. 13 Summary of results for RWS and RIS

Scheme	*Relative water supply*	*Relative* irrigation *supply*
Fre Lekatit	1.91	1.95

Then the calculated values of both shows that the irrigation system had an appropriate RWS and RIS values were calculated as 1.91 and 1.95 respectively. This value implies that there is not a constraining water availability situation during in the 2018 irrigation season for total demand of the Fre-lekatit irrigation scheme. For instance, RWS and RIS values alone in this study indicate that water demand of the crops in the scheme is satisfied. However RWS and RIS values should be decreased in order to meet the requirement in the project area where crops suffer from the lack of water due to increasing maize land. Similar results were also obtained from many researches around the world (Ray et al., 2002; Bandara, 2003). The calculated RWS and RIS for Fre Lekatit irrigation scheme is summarized in below.

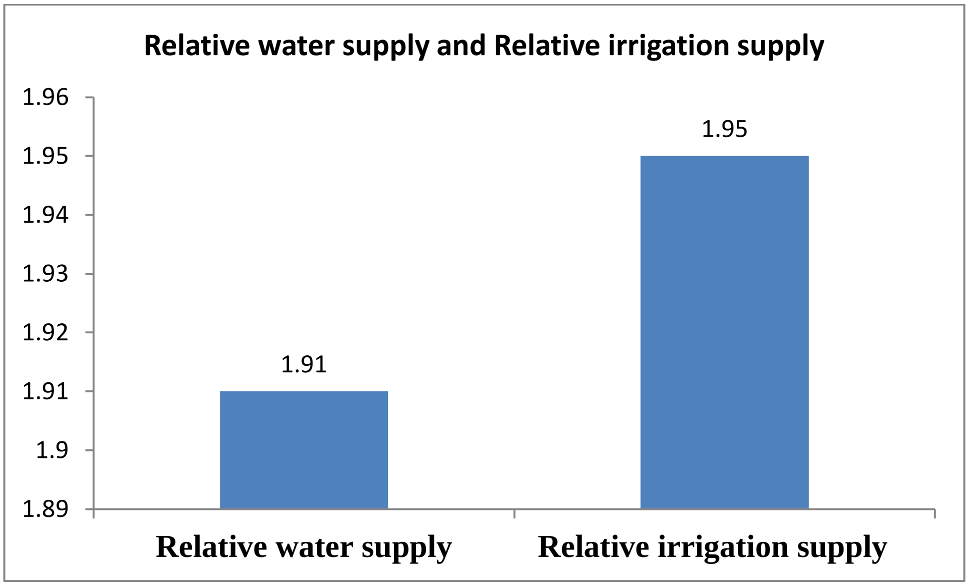


Figure 4. 6 Water supply indicators both of the RWS and RIS

4.7.2 Determination of Water Delivery Capacity Ratio (WDC)

The ratio of the actual volume of water delivered to the intended volume of water delivered is used to calculate the water delivery performance. The intended volume of water, as determined by the design document, was 560 lit/sec; however, the actual supplied volume through the average discharge between the inflow and outflow main canal is 192 lit/sec. The average measurement result throughout the survey was 192 l/sec (conveyance efficiency: 78.6%) for the actual delivered volume of water. Equation (3.8) is used to calculate the water delivery performance, which is meaning that 34% (192.21/560) the capacity of the design is use.

It showed that because the scheme's water distribution diverts around 1/3 of the planned water volume to the field, the actual water provided is significantly less than the intended water volume. It implies that ideal volume of the scheme higher than the actual irrigated volume released water through main canal. Because most of the commands are not irrigated by two cases; rested land and not accessed canal available to irrigated land.

The projects' irrigation requirements were calculated (Table 4.14) with Cropwat8 using climatic data, planting pattern, planting dates and the area coverage of individual crop for the cropping season of 2018 (Jan.-June). And the results were:

Table 4. 14 Peak IR of Fre-lekatit irrigation projects

Months	Jan	Feb	Mar	Apr	May	Jun
Irrigation .req. for actual area (l/s/ha)	0.04	0.2	0.55	0.63	0.49	0.04

The peak irrigation requirements of Fre-lekatit irrigation as a whole for 2018 cropping season occurred in April the value that was, 0.63 lit/sec/ha. This is for continuous flow, and for 11.5 hours discharge flow running time in a day then the peak consumptive demand will be:

Peak demand is 0.63*cropped area for that month* 24/11.5

= 0.63 *125.25 *2.087 = 164.7 lit/sec.

The peak irrigation requirement (164.7 lit/sec) was determined for the irrigated area of 125.25 ha when the crops covering the area were taken from Table 4.9, for their respective area coverage ratio. The actual discharge capacity of the main canal at the system head was 192.2

Lit/sec, this was the total discharge of the Fre-lekatit irrigation season.

This value was taken because for the Fre Lekatit irrigation scheme to satisfy the water demand of the crops even if the designs discharge higher than the actual canal capacity discharge less.

1. Water Delivery Capacity = $\frac{\text{Actual canal capacity at head}}{\text{Peak demand}}$

= 192.21 l/s /164.7 = 1.2

It is clear from the computations above at the April had the highest irrigation water need (164.7 lit/sec). If maize crop is the only crop farmed under the irrigation plan, the canals would need to be built with a flow large enough to provide the entire land with a net discharge of (164.7 lit/sec). In another way, the month of peak water availability was crucial for planning an irrigation project. The average irrigation water applied in relation to the demanded water as the research area's Fre Lekatit irrigation scheme's ultimate outcome because the design discharge (560lit/se) of the scheme above the currently measured discharge. The WDC ratio value that was found 1.2

according to (Molden, 1998)) state that the value obtained suggests that crop watering was not restricted by system capacity there is enough water supply in the reservoir.

CHAPTER 5: Conclusions and Recommendations

5.1 Conclusions

For improvement of irrigation scheme and the irrigation practices, frequent performance evaluation is very important.

There was sufficient water in the dam reservoir throughout the study period, even during dry spells. Additionally, a high capacity flow in comparison to the irrigated and low irrigated areas, the chance to apply more water than the crops need. More water is lost from dams as a result of downstream seepage through weirs, evaporation, and other factors.

The amount of water applied depth during the maize crop growing season was more than the crop's requirement, which indicated that much amount of water was being wasted due to poor irrigation water management practice with low application efficiency as scheme. From the results of water use distribution analysis, the highest value was obtained at the head users followed by the middle and tail-enders, since the average water application of the all water users were greater than to gross irrigation requirement. From this, it can be concluded that the irrigation efficiency in general and, the water use distribution in particular can be improve by minimizing water losses and applying water according to crop water requirement. To achieve this, farmers should be given training on irrigation water use and management aspects as per crops.

Based on the analysis results, RWS, RIS and WDC ratio values results of the Fre-lekatit irrigation scheme the capacity volume is not a limitation for irrigation purpose during the study period.

Even the WUA of the scheme are not strong enough to manage the irrigation farm based on rules and regulations of the water management of the scheme.

5.2. Recommendations

Based on the above findings, recommendations for scheme level evaluation of water distribution and productivity the irrigation performance of Fre Lekatit irrigation scheme include:

a) The existing reservoir body contains enough water, according to the study area, to irrigate the remaining unirrigated area during the study period.

b) The gate and dam weir should be requiring maintenance on time, and some wastage water through canals should be protecting like animal drinking, canal overflow areas and other losses.

c) Increasing conveyance efficiency by establishing a closed conduit canal system.

d) All stakeholders should assist farmers in applying proper irrigation depth and interval, as well as enhancing the scheme's physical infrastructure, and then structures should be built for future sustainable use.

e) The irrigation scheme water within and among farmers at different locations, as well as at the same were not selected same crops variety at field level, were practically applied depth water with itself farmer management should equal application for scheme level water distribution and productivity.

f) Water pricing must be based on accurate water flow data as well as equitable, adequate and reliable water distribution rules governed by the water user associations.

g) In order to improve water productivity of these system, farmers, water users associations and development agents should receive training on canal water management, crop water requirement, and equitable and efficient water distribution.

h) Should be reduce water logging problems on the study area through;

- Practice good drainage system
- Minimizing seepage inflow
- Proper irrigation management
- Alternating farming methods'

Farmers should apply irrigation before or at the time when the readily available soil water is depleted. They should also avoid over irrigation by applying irrigation to a depth smaller than or equal to the root zone depletion. This will improve field water application and the scheme's overall water productive.

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APPENDICES

ANNEXES 1. Irrigation Schedule of maize

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	mm/day	%	mm	mm	mm	mm	l/s/ha
22-Jan	1	Init	0	1	1.2	59	18.1	0	0	40.3	4.67
23-Jan	2	Init	0.2	1	1.2	6	0	1.8	0	0	0
24-Jan	3	Init	0	1	1.2	11	0	3.6	0	0	0
25-Jan	4	Init	0	1	1.2	16	0	5.4	0	0	0
26-Jan	5	Init	0	1	1.2	20	0	7.2	0	0	0
27-Jan	6	Init	0.2	1	1.2	24	0	8.8	0	0	0
28-Jan	7	Init	0	1	1.2	28	0	10.6	0	0	0
29-Jan	8	Init	0	1	1.2	32	0	12.4	0	0	0
30-Jan	9	Init	0	1	1.2	35	0	14.2	0	0	0
31-Jan	10	Init	0	1	1.2	39	0	16	0	0	0
1-Feb	11	Init	0	1	1.2	42	0	17.9	0	0	0
2-Feb	12	Init	0	1	1.2	45	0	19.8	0	0	0
3-Feb	13	Init	1	1	1.2	46	0	20.7	0	0	0
4-Feb	14	Init	0	1	1.2	49	0	22.5	0	0	0
5-Feb	15	Init	0	1	1.2	52	0	24.4	0	0	0
6-Feb	16	Init	0	1	1.2	54	0	26.2	0	0	0
7-Feb	17	Init	1	1	1.2	55	27.2	0	0	60.3	6.98
8-Feb	18	Init	0	1	1.2	4	0	1.9	0	0	0
9-Feb	19	Init	0	1	1.2	7	0	3.7	0	0	0
10-Feb	20	Init	0	1	1.2	11	0	5.6	0	0	0
11-Feb	21	Init	0	1	1.6	15	0	7.8	0	0	0
12-Feb	22	Init	0	1	1.6	18	0	10.1	0	0	0
13-Feb	23	Dev	1.4	1	1.6	20	0	11	0	0	0
14-Feb	24	Dev	0	1	1.6	23	0	13.3	0	0	0
15-Feb	25	Dev	0	1	1.6	27	0	15.5	0	0	0
16-Feb	26	Dev	0	1	1.6	30	0	17.8	0	0	0
17-Feb	27	Dev	1.4	1	1.6	31	0	18.7	0	0	0
18-Feb	28	Dev	0	1	1.6	34	0	20.9	0	0	0

19-Feb	29	Dev	0	1	1.6	37	0	23.2	0	0	0
20-Feb	30	Dev	0	1	1.6	40	0	25.5	0	0	0
21-Feb	31	Dev	0	1	2.6	44	0	28.8	0	0	0
22-Feb	32	Dev	0	1	2.6	48	0	32	0	0	0
23-Feb	33	Dev	2.4	1	2.6	49	0	32.9	0	0	0
24-Feb	34	Dev	0	1	2.6	52	0	36.2	0	0	0
25-Feb	35	Dev	0	1	2.6	56	39.5	0	0	87.7	10.15
26-Feb	36	Dev	0	1	2.6	5	0	3.3	0	0	0
27-Feb	37	Dev	2.4	1	2.6	6	0	4.1	0	0	0
28-Feb	38	Dev	0	1	2.6	10	0	7.4	0	0	0
1-Mar	39	Dev	0	1	3.8	16	0	11.9	0	0	0
2-Mar	40	Dev	0	1	3.8	21	0	16.3	0	0	0
3-Mar	41	Dev	3.6	1	3.8	22	0	17.1	0	0	0
4-Mar	42	Dev	0	1	3.8	28	0	21.5	0	0	0
5-Mar	43	Dev	0	1	3.8	33	0	25.9	0	0	0
6-Mar	44	Dev	0	1	3.8	38	0	30.4	0	0	0
7-Mar	45	Dev	3.6	1	3.8	38	0	31.2	0	0	0
8-Mar	46	Dev	0	1	3.8	43	0	35.6	0	0	0
9-Mar	47	Dev	0	1	3.8	48	0	40	0	0	0
10-Mar	48	Dev	0	1	3.8	52	0	44.4	0	0	0
11-Mar	49	Dev	0	1	5.1	58	50.2	0	0	111.6	12.92
12-Mar	50	Dev	0	1	5.1	7	0	5.8	0	0	0
13-Mar	51	Dev	4.6	1	5.1	8	0	6.9	0	0	0
14-Mar	52	Dev	0	1	5.1	14	0	12.7	0	0	0
15-Mar	53	Dev	0	1	5.1	20	0	18.5	0	0	0
16-Mar	54	Dev	0	1	5.1	26	0	24.3	0	0	0
17-Mar	55	Dev	4.6	1	5.1	27	0	25.4	0	0	0
18-Mar	56	Dev	0	1	5.1	33	0	31.2	0	0	0
19-Mar	57	Dev	0	1	5.1	39	0	37	0	0	0
20-Mar	58	Dev	0	1	5.1	44	0	42.8	0	0	0
21-Mar	59	Dev	0	1	5.9	50	0	49.3	0	0	0
22-Mar	60	Dev	0	1	5.9	56	55.2	0	0	122.6	14.19
23-Mar	61	Mid	5.4	1	5.9	6	0	5.9	0	0	0

24-Mar	62	Mid	0	1	5.9	12	0	11.8	0	0	0
25-Mar	63	Mid	0	1	5.9	18	0	17.7	0	0	0
26-Mar	64	Mid	0	1	5.9	24	0	23.5	0	0	0
27-Mar	65	Mid	5.4	1	5.9	24	0	24	0	0	0
28-Mar	66	Mid	0	1	5.9	30	0	29.9	0	0	0
29-Mar	67	Mid	0	1	5.9	36	0	35.8	0	0	0
30-Mar	68	Mid	0	1	5.9	42	0	41.7	0	0	0
31-Mar	69	Mid	0	1	5.9	48	0	47.6	0	0	0
1-Apr	70	Mid	0	1	5.9	54	0	53.5	0	0	0
2-Apr	71	Mid	0	1	5.9	60	59.4	0	0	131.9	15.27
3-Apr	72	Mid	6.4	1	5.9	6	0	5.9	0	0	0
4-Apr	73	Mid	0	1	5.9	12	0	11.8	0	0	0
5-Apr	74	Mid	0	1	5.9	18	0	17.7	0	0	0
6-Apr	75	Mid	0	1	5.9	24	0	23.6	0	0	0
7-Apr	76	Mid	6.4	1	5.9	23	0	23	0	0	0
8-Apr	77	Mid	0	1	5.9	29	0	28.9	0	0	0
9-Apr	78	Mid	0	1	5.9	35	0	34.8	0	0	0
10-Apr	79	Mid	0	1	5.9	41	0	40.7	0	0	0
11-Apr	80	Mid	0	1	5.9	47	0	46.6	0	0	0
12-Apr	81	Mid	0	1	5.9	53	0	52.5	0	0	0
13-Apr	82	Mid	7.4	1	5.9	52	0	51	0	0	0
14-Apr	83	Mid	0	1	5.9	58	56.9	0	0	126.6	14.65
15-Apr	84	Mid	0	1	5.9	6	0	5.9	0	0	0
16-Apr	85	Mid	0	1	5.9	12	0	11.8	0	0	0
17-Apr	86	Mid	7.4	1	5.9	10	0	10.3	0	0	0
18-Apr	87	Mid	0	1	5.9	16	0	16.2	0	0	0
19-Apr	88	Mid	0	1	5.9	22	0	22.1	0	0	0
20-Apr	89	Mid	0	1	5.9	28	0	28	0	0	0
21-Apr	90	Mid	0	1	5.9	34	0	33.9	0	0	0
22-Apr	91	Mid	0	1	5.9	40	0	39.8	0	0	0
23-Apr	92	Mid	6.8	1	5.9	39	0	39	0	0	0
24-Apr	93	Mid	0	1	5.9	45	0	44.9	0	0	0
25-Apr	94	Mid	0	1	5.9	51	0	50.8	0	0	0

26-Apr	95	Mid	0	1	5.9	57	56.7	0	0	126	14.59
27-Apr	96	Mid	6.8	1	5.9	6	0	5.9	0	0	0
28-Apr	97	Mid	0	1	5.9	12	0	11.8	0	0	0
29-Apr	98	Mid	0	1	5.9	18	0	17.7	0	0	0
30-Apr	99	Mid	0	1	5.9	24	0	23.7	0	0	0
1-May	100	Mid	0	1	5.8	30	0	29.4	0	0	0
2-May	101	Mid	0	1	5.8	36	0	35.2	0	0	0
3-May	102	Mid	5.9	1	5.8	35	0	35.1	0	0	0
4-May	103	Mid	0	1	5.8	41	0	40.9	0	0	0
5-May	104	Mid	0	1	5.8	47	0	46.7	0	0	0
6-May	105	Mid	0	1	5.8	53	0	52.5	0	0	0
7-May	106	End	5.9	1	5.8	53	0	52.4	0	0	0
8-May	107	End	0	1	5.8	59	58.2	0	0	129.3	14.97
9-May	108	End	0	1	5.8	6	0	5.8	0	0	0
10-May	109	End	0	1	5.8	12	0	11.6	0	0	0
11-May	110	End	0	1	4.6	16	0	16.2	0	0	0
12-May	111	End	0	1	4.6	21	0	20.8	0	0	0
13-May	112	End	5.4	1	4.6	20	0	20	0	0	0
14-May	113	End	0	1	4.6	25	0	24.6	0	0	0
15-May	114	End	0	1	4.6	30	0	29.3	0	0	0
16-May	115	End	0	1	4.6	34	0	33.9	0	0	0
17-May	116	End	5.4	1	4.6	33	0	33.1	0	0	0
18-May	117	End	0	1	4.6	38	0	37.7	0	0	0
19-	118	End	0	1	4.6	43	0	42.3	0	0	0

May											
20-May	119	End	0	1	4.6	47	0	46.9	0	0	0
21-May	120	End	0	1	3	50	0	50	0	0	0
22-May	121	End	0	1	3	54	0	53	0	0	0
23-May	122	End	5.5	1	3	51	0	50.5	0	0	0
24-May	123	End	0	1	3	54	0	53.6	0	0	0
25-May	124	End	0	1	3	57	0	56.6	0	0	0
26-May	125	End	0	1	3	60	0	59.6	0	0	0
27-May	126	End	5.5	1	3	58	0	57.1	0	0	0
28-May	127	End	0	1	3	61	0	60.2	0	0	0
29-May	128	End	0	1	3	64	0	63.2	0	0	0
30-May	129	End	0	1	3	67	0	66.2	0	0	0
31-May	130	End	0	1	3	70	0	69.3	0	0	0
1-Jun	131	End	0	1	1.9	72	0	71.2	0	0	0
2-Jun	132	End	0	1	1.9	74	0	73.1	0	0	0
3-Jun	133	End	3.4	1	1.9	72	0	71.5	0	0	0
4-Jun	134	End	0	1	1.9	74	0	73.4	0	0	0
5-Jun	End	End	0	1	0	74					

ANNEXES 2

Taking Floating Q by 40 m Distances interval (in flow and out flow) Starting From (Jan.-June)

				Inflow					
Segment	Average time (Sec)	Length(m)	Width(m)	Depth(m)	Surface velocity	Average velocity	Wetted cross-section	Discharge(flow rate)	Q in (L/s)
1	95	40	0.9	0.745	0.4211	0.3368	0.6705	0.2259	225.8526
2	94	40	0.9	0.73	0.4255	0.3404	0.6570	0.2237	223.6596
3	93	40	0.9	0.74	0.4301	0.3441	0.6660	0.2292	229.1613
4	95	40	0.9	0.71	0.4211	0.3368	0.6390	0.2152	215.2421
5	95	40	0.9	0.72	0.4211	0.3368	0.6480	0.2183	218.2737
									222.4379

				outflow					
Segment	Average time (Sec)	Length(m)	Width(m)	Depth(m)	Surface velocity	Average velocity	Wetted cross-section	Discharge(flow rate)	Q in (L/s)
1	98	40	0.9	0.61	0.408	0.327	0.549	0.179	179.265
2	98	40	0.9	0.6	0.408	0.327	0.540	0.176	176.327
3	99	40	0.9	0.6	0.404	0.323	0.540	0.175	174.545
4	102	40	0.9	0.61	0.392	0.314	0.549	0.172	172.235
5	104	40	0.9	0.6	0.385	0.308	0.540	0.166	166.154
									173.705

ANNEXES 3 Summarized discharge measuring through floating method

Canal	Segment	Distance b/	Inflow	Out flow	onveyance loss		Conveyance
type	No.	points (m)	(l/s)	(l/s)	(l/s)	(l/s/m)	efficiency %
Lined main	1	40	225.85263	179.26531	46.58733	1.16468	0.79373
Canal	2	40	223.65957	176.32653	47.33304	1.18333	0.78837
	3	40	229.16129	174.54545	54.61584	1.36540	0.76167
	4	40	215.24211	172.23529	43.00681	1.07517	0.80019
		Average	218.27368	166.15385	47.88575	1.19714	0.78599
			192.214				78.599
			192.214l/sec				78.59

ANNEXES 4. Discharge seasonal measured using V- notch weir

Discharge seasonal measured using V- notch weir

Discharge Calculations

V-Notch Weir

University of Pennsylvania

prepared by Rafael A. Jimenez

reviewer: Tony Sauder

Q= 4.28 C tan (angle/2)(h+k)^2.5

C= 0.607165052 - 0.000874466963(angle) + 6.10393334*10^-6(angle^2)

K= 0.01444902648 -0.00033955535(angle) + 3.29819003*10^-6(angle^2) - 1.06215442*10^-8(angle^3)

angle	90	
angle/2	45	
C	0.583	
K	0.0029	0.00088514(m)
tan (ang	1	

I was measured at two in-takes for each 2 nd canals

H-max Above V-notch angle

P B/n zero and V-notch Angle

AVe. H=height flow pass

	Dist. From Datum (cm	H-max / H max	H (cm) Point-1	H(m)	H (cm) Point-2	H(m)	K(m)	h1+k (n point-1	h2+k (m point-2	C	point-1(4.28 C(l Av. Q n	point-2(4.28 C(l Av. Q m^3/s	sum of (Q1+Q2	Total Q (l/se)	Av. Time	Volume in (m3)	Canal s	Irrigati on
Jan	35	25	21.56	0.2156	20.76	0.208	9E-04	0.216	0.2085	0.583	0.0544	0.0495	0.1039	103.87	1380	34401.4	Canal-1	4
	35	25	21.25	0.2125	21.25	0.213	9E-04	0.213	0.2134	0.583	0.0525	0.0525	0.1049	104.9	1350	42485.5	Canal-2	5
	35	25	21.45	0.2145	20.15	0.202	9E-04	0.215	0.2024	0.583	0.0537	0.046	0.0996	99.64	1362	40712.8	Canal-3	5
	35	25	21.75	0.2175	21.75	0.218	9E-04	0.218	0.2184	0.583	0.0556	0.0556	0.1112	111.16	1350	45018.2	Canal-4	5
	35	25	21.85	0.2185	20.45	0.205	9E-04	0.219	0.2054	0.583	0.0562	0.0477	0.1039	103.89	1320	41140	Cananl	5
Feb	35	25	21.75	0.2175	20.35	0.204	9E-04	0.218	0.2044	0.583	0.0556	0.0471	0.1027	102.67	1380	42506.4	Canal-1	5
	35	25	21.45	0.2145	21.45	0.215	9E-04	0.215	0.2154	0.583	0.0537	0.0537	0.1074	107.38	1350	43488	Canal-2	5
	35	25	21.75	0.2175	21.55	0.216	9E-04	0.218	0.2164	0.583	0.0556	0.0543	0.1099	109.89	1360	35868.9	Canal-3	4
	35	25	21.76	0.2176	21.56	0.216	9E-04	0.218	0.2165	0.583	0.0556	0.0544	0.11	110.02	1320	43567.4	Canal-4	5
	35	25	21.55	0.2155	21.45	0.215	9E-04	0.216	0.2154	0.583	0.0543	0.0537	0.108	108	1362	44130.1	Cananl	5
Mar	35	25	21.76	0.2176	20.76	0.208	9E-04	0.218	0.2085	0.583	0.0556	0.0495	0.1051	105.13	1338	33760.5	Canal-1	4
	35	25	21.75	0.2175	20.25	0.203	9E-04	0.218	0.2034	0.583	0.0556	0.0465	0.1021	102.1	1350	41349.9	Canal-2	5
	35	25	21.16	0.2116	20.15	0.202	9E-04	0.212	0.2024	0.583	0.0519	0.046	0.0979	97.851	1380	40510.2	Canal-3	5
	35	25	21.25	0.2125	20.15	0.202	9E-04	0.213	0.2024	0.583	0.0525	0.046	0.0984	98.402	1350	31882.2	Canal-4	4
	35	25	21.16	0.2116	20.45	0.205	9E-04	0.212	0.2054	0.583	0.0519	0.0477	0.0996	99.572	1338	31974.7	Cananl	4
Apr	35	25	20.75	0.2075	21.35	0.214	9E-04	0.208	0.2144	0.583	0.0494	0.0531	0.1025	102.5	1350	33210.1	Canal-1	4
	35	25	21.56	0.2156	20.15	0.202	9E-04	0.216	0.2024	0.583	0.0544	0.046	0.1003	100.33	1362	32795.1	Canal-2	4
	35	25	21.75	0.2175	20.55	0.206	9E-04	0.218	0.2064	0.583	0.0556	0.0483	0.1038	103.83	1350	33641.9	Canal-3	4
	35	25	21.75	0.2175	21.26	0.213	9E-04	0.218	0.2135	0.583	0.0556	0.0525	0.1081	108.09	1362	35332.7	Canal-4	4
	35	25	21.15	0.2115	20.45	0.205	9E-04	0.212	0.2054	0.583	0.0518	0.0477	0.0995	99.511	1380	32958.2	Cananl	4
May	35	25	21.75	0.2175	20.76	0.208	9E-04	0.218	0.2085	0.583	0.0556	0.0495	0.1051	105.07	1350	42553.3	Canal-1	5
	35	25	21.85	0.2185	21.25	0.213	9E-04	0.219	0.2134	0.583	0.0562	0.0525	0.1087	108.67	1350	35208.3	Canal-2	4
	35	25	20.26	0.2026	21.15	0.212	9E-04	0.203	0.2124	0.583	0.0466	0.0518	0.0984	98.417	1290	38087.2	Canal-3	5
	35	25	21.75	0.2175	21.75	0.218	9E-04	0.218	0.2184	0.583	0.0556	0.0556	0.1112	111.16	1362	45418.4	Canal-4	5
	35	25	21.36	0.2136	21.45	0.215	9E-04	0.214	0.2154	0.583	0.0531	0.0537	0.1068	106.82	1374	44030.7	Cananl	5
Jun	35	25	21.25	0.2125	21.15	0.212	9E-04	0.213	0.2124	0.583	0.0525	0.0518	0.1043	104.29	1350	16895	canal-1	2
	35	25	20.26	0.2026	21.25	0.213	9E-04	0.203	0.2134	0.583	0.0466	0.0525	0.099	99.029	1380	16399.2	canal-2	2
	35	25	21.25	0.2125	21.55	0.216	9E-04	0.213	0.2164	0.583	0.0525	0.0543	0.1068	106.77	1350	25944	Canal-3	3
	35	25	21.16	0.2116	21.56	0.216	9E-04	0.212	0.2165	0.583	0.0519	0.0544	0.1063	106.28	1266	16145.6	canal-4	2
	35	25	21.05	0.2105	21.45	0.215	9E-04	0.211	0.2154	0.583	0.0512	0.0537	0.1049	104.92	1350	16997	canal-5	2
																1053646		125

ANNEXES 5. The 45 Sample plots measuring discharge using 2’’ pars hall flume

	plot code	Av. PF head in m	Respective Q in (m3/s)	Time take (min)	Sample Area (m2)	applied gross water (m3)	Gross irrigation depth (mm)	Total No. of irrigation events	Total irrigation water appied (mm)	Total irrigation water
Canal-1	UF1	0.1665	0.0075	231	1884.70	103.95	55.15	16	882.47	8824.75
2	UF2	0.1664	0.00749	140	1112.56	62.92	56.55	16	904.81	9048.11
3	UF3	0.1595	0.00721	135	1107.00	58.40	52.76	16	844.10	8440.98
4	MF1	0.1525	0.00664	172	1234.70	68.52	55.50	16	887.99	8879.86
5	MF2	0.1525	0.00654	155	1162.56	60.82	52.32	16	837.08	8370.77
6	MF3	0.1485	0.00628	169	1207.20	63.68	52.75	16	843.99	8439.92
7	LF1	0.1455	0.00618	175	1254.70	64.89	51.72	16	827.48	8274.81
8	LF2	0.1455	0.00608	179	1232.56	65.30	52.98	16	847.66	8476.56
9	LF3	0.1453	0.00607	177	1200.21	64.46	53.71	16	859.36	8593.62
Canal-2	UF1	0.1655	0.00743	218	1852.00	97.18	52.48	16	839.61	8396.06
2	UF2	0.1655	0.00743	135	1112.56	60.18	54.09	16	865.51	8655.07
3	UF3	0.1585	0.00695	142	1107.21	59.21	53.48	16	855.69	8556.86
4	MF1	0.1525	0.00655	166	1234.70	65.24	52.84	16	845.39	8453.94
5	MF2	0.1525	0.00654	188	1462.56	73.77	50.44	16	807.04	8070.36
6	MF3	0.1475	0.00621	179	1307.21	66.70	51.02	16	816.34	8163.39
7	LF1	0.145	0.00625	165	1254.70	61.88	49.31	16	789.03	7890.33
8	LF2	0.145	0.00605	169	1250.56	61.35	49.06	16	784.89	7848.90
9	LF3	0.1449	0.00604	175	1217.21	63.42	52.10	16	833.64	8336.44
Canal-3	UF1	0.1635	0.00729	161	1236.70	70.42	56.94	15	854.14	8541.45
2	UF2	0.1635	0.00729	149	1240.56	65.17	52.53	15	788.02	7880.22
3	UF3	0.1575	0.00688	159	1217.21	65.64	53.92	15	808.84	8088.40
4	MF1	0.1525	0.00654	168	1235.00	65.92	53.38	15	800.69	8006.87
5	MF2	0.1525	0.00654	184	1420.00	72.20	50.85	15	762.69	7626.93
6	MF3	0.1485	0.00628	173	1307.20	65.19	49.87	15	748.01	7480.08
7	LF1	0.1435	0.00595	178	1223.00	63.55	51.96	15	779.39	7793.87
8	LF2	0.1425	0.00589	165	1164.30	58.31	50.08	15	751.24	7512.37
9	LF3	0.1449	0.00604	148	1123.00	53.64	47.76	15	716.41	7164.10
Canal-4	UF1	0.1575	0.00688	172	1421.00	71.00	49.97	15	749.49	7494.89
2	UF2	0.1575	0.00688	157	1321.00	64.81	49.06	15	735.92	7359.15
3	UF3	0.1574	0.00687	175	1463.00	72.14	49.31	15	739.59	7395.93
4	MF1	0.1474	0.00621	145	1121.00	54.03	48.20	15	722.93	7229.30
5	MF2	0.1475	0.00621	168	1263.00	62.60	49.56	15	743.43	7434.30
6	MF3	0.1475	0.00621	150	1165.00	55.89	47.97	15	719.61	7196.14
7	LF1	0.1425	0.00589	169	1203.00	59.72	49.65	15	744.70	7446.96
8	LF2	0.1375	0.00557	190	1326.00	63.50	47.89	15	718.30	7183.03
9	LF3	0.1375	0.00557	165	1150.00	55.14	47.95	15	719.26	7192.57
Canal-5	UF1	0.1652	0.00741	163	1421.00	72.47	51.00	16	815.99	8159.86
2	UF2	0.1625	0.00722	150	1321.00	64.98	49.19	16	787.04	7870.40
3	UF3	0.1575	0.00688	192	1463.00	79.26	54.17	16	866.80	8667.95
4	MF1	0.165	0.00739	142	1121.00	62.96	56.17	16	898.67	8986.66
5	MF2	0.162	0.00719	154	1263.00	66.44	52.60	16	841.62	8416.23
6	MF3	0.1575	0.00688	135	1165.00	55.73	47.84	16	765.36	7653.63
7	LF1	0.145	0.00605	159	1203.00	57.72	47.98	16	767.64	7676.41
8	LF2	0.135	0.00542	195	1326.00	63.41	47.82	16	765.18	7651.76
9	LF3	0.1575	0.00688	153	1150.00	63.16	54.92	16	878.73	8787.26
					57227.9	65.48566667	50.480	15.6	32161.700	321617.00

ANNEXES 6.Upper location 15 sample Plots

		The samples area of average Water Applied Depth Each Farmers							
	plot code	Av. PF head in m	Respective Q in (m3/s)	Time take (min)	Sample Area (m2)	applied gross volume water (m3)	Gross irrigation depth (mm)	Total No. of irrigation events	Total irrigation water appied (mm)	Total irrigation water applied (m3)
Canal-1	UF1	0.1665	0.0075	231	1884.7	103.95	55.15	16	882.47	8824.75
2	UF2	0.1664	0.00749	140	1112.56	62.92	56.55	16	904.81	9048.11
3	UF3	0.1595	0.00721	135	1107	58.4	52.76	16	844.1	8440.98
Canal-2	UF1	0.1655	0.00743	218	1852	97.18	52.48	16	839.61	8396.06
2	UF2	0.1655	0.00743	135	1112.56	60.18	54.09	16	865.51	8655.07
3	UF3	0.1585	0.00695	142	1107.21	59.21	53.48	16	855.69	8556.86
Canal-3	UF1	0.1635	0.00729	161	1236.7	70.42	56.94	15	854.14	8541.45
2	UF2	0.1635	0.00729	149	1240.56	65.17	52.53	15	788.02	7880.22
3	UF3	0.1575	0.00688	159	1217.21	65.64	53.92	15	808.84	8088.4
Canal-4	UF1	0.1575	0.00688	172	1421	71	49.97	15	749.49	7494.89
2	UF2	0.1575	0.00688	157	1321	64.81	49.06	15	735.92	7359.15
3	UF3	0.1574	0.00687	175	1463	72.14	49.31	15	739.59	7395.93
Canal-5	UF1	0.1652	0.00741	163	1421	72.47	51	16	815.99	8159.86
2	UF2	0.1625	0.00722	150	1321	64.98	49.19	16	787.04	7870.4
3	UF3	0.1575	0.00688	192	1463	79.26	54.17	16	866.8	8667.95
					11396.2	612.9	51.6			

ANNEXES 7.Middle location 15 sample plots

		The samples area of average Water Applied Depth Each Farmers							
	plot code	Av. PF head in m	Respective Q in (m3/s)	Time take (min)	Sample Area (m2)	applied gross water (m3)	Gross irrigation depth (mm)	Total No. of irrigation events	Total irrigation water appied (mm)	Total irrigation water applied (m3)
Canal-1	MF1	0.1525	0.00664	172	1234.7	68.52	55.5	16	887.99	8879.86
2	MF2	0.1525	0.00654	155	1162.56	60.82	52.32	16	837.08	8370.77
3	MF3	0.1485	0.00628	169	1207.2	63.68	52.75	16	843.99	8439.92
Canal-2	MF1	0.1525	0.00655	166	1234.7	65.24	52.84	16	845.39	8453.94
2	MF2	0.1525	0.00654	189	1462.56	74.16	50.71	16	811.33	8113.29
3	MF3	0.1475	0.00621	179	1307.21	66.7	51.02	16	816.34	8163.39
Canal-3	MF1	0.1525	0.00654	168	1235	65.92	53.38	15	800.69	8006.87
2	MF2	0.1525	0.00654	184	1420	72.2	50.85	15	762.69	7626.93
3	MF3	0.1485	0.00628	173	1307.2	65.19	49.87	15	748.01	7480.08
Canal-4	MF1	0.1474	0.00621	145	1121	54.03	48.2	15	722.93	7229.3
2	MF2	0.1475	0.00621	168	1263	62.6	49.56	15	743.43	7434.3
3	MF3	0.1475	0.00621	150	1165	55.89	47.97	15	719.61	7196.14
Canal-5	MF1	0.165	0.00739	142	1121	62.96	56.17	16	898.67	8986.66
2	MF2	0.162	0.00719	154	1263	66.44	52.6	16	841.62	8416.23
3	MF3	0.1575	0.00688	135	1165	55.73	47.84	16	765.36	7653.63
					11798.7	617.7	50.4			

ANNEXES 8.Lower location 15 sample plots

		The samples area of average Water Applied Depth Each Farmers								
	plot code	Av. PF head in m	Respective Q in (m3/s)	Time take (min)	Sample Area (m2)	applied gross water (m3)	Gross irrigation depth (mm)	Total No. of irrigation events	Total irrigation water appied (mm)	Total irrigation water applied (m3)
Canal-1	LF1	0.1455	0.00618	175	1254.7	64.89	51.72	16	827.48	8274.81
2	LF2	0.1455	0.00608	179	1232.56	65.3	52.98	16	847.66	8476.56
3	LF3	0.1453	0.00607	177	1200.21	64.46	53.71	16	859.36	8593.62
Canal-2	LF1	0.145	0.00625	168	1254.7	63	50.21	16	803.38	8033.79
2	LF2	0.145	0.00605	179	1250.56	64.98	51.96	16	831.33	8313.33
3	LF3	0.1449	0.00604	185	1217.21	67.04	55.08	16	881.28	8812.81
Canal-3	LF1	0.1435	0.00595	178	1223	63.55	51.96	15	779.39	7793.87
2	LF2	0.1425	0.00589	165	1164.3	58.31	50.08	15	751.24	7512.37
3	LF3	0.1449	0.00604	148	1123	53.64	47.76	15	716.41	7164.1
Canal-4	LF1	0.1425	0.00589	169	1203	59.72	49.65	15	744.7	7446.96
2	LF2	0.1375	0.00557	190	1326	63.5	47.89	15	718.3	7183.03
3	LF3	0.1375	0.00557	165	1150	55.14	47.95	15	719.26	7192.57
Canal-5	LF1	0.145	0.00605	159	1203	57.72	47.98	16	767.64	7676.41
2	LF2	0.135	0.00542	185	1326	60.16	45.37	16	725.94	7259.37
3	LF3	0.1575	0.00688	153	1150	63.16	54.92	16	878.73	8787.26
					11433	582.8712	49.55			

ANNEXE 8. Seasonal Released Volume water through secondary Canals

Months	Canal-1	Canal-2	Canal-3	Canal-4	Canal-5	Total Released volume (m3)
	V(m3)	V(m3)	V(m3)	V(m3)	V(m3)	
Jan	30901.3	30242.3	30565.3	30125.6	30040.8	151875.3
Feb	39643.9	39981.4	41997.7	40175.9	43744.7	205543.5
Mar	38485.8	42440.1	42064.8	39338.4	47039.2	209368.4
Apr	40253.1	41997.5	43007.9	43137.1	47143.2	215538.8
May	39098.1	40909.8	41592.5	41413.7	45593.0	208607.1
Jun	13230.1	12904.5	12342.1	11798.7	12436.8	62712.2
Sum	201612.4	208475.6	211570.3	205989.4	225997.7	1053645.4
More released water Sequencs orders are					C5>C3>C2>C4>C1	

ANNEXE 9. Summary of the essential parameters on the Scheme Performance Indicators

Summarized of the essential parameters the Scheme Performance Indicators					
Scheme	Designed Command	Actual irrigated	seasonal Irrigation diverted		Crop water consumed
Fre-lekatit	area, in ha	area in ha	in (m3)	in (mm)	m3/season
	350	125.25	1,251,516.37	999.22	997,001.51

ANNEXE: 10 seasonally cropping area Coverage 2018 in the Irrigation Scheme

potato	Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
				coeff	mm/day	mm/dec	mm/dec	mm/dec
	Jan	3	Init	0.5	1.95	17.6	0	17.6
	Feb	1	Init	0.5	2.04	20.4	0	20.4
	Feb	2	Deve	0.52	2.21	22.1	0	22.1
	Feb	3	Deve	0.68	3.07	24.6	0.1	24.4
	Mar	1	Deve	0.88	4.16	41.6	1.4	40.2
	Mar	2	Mid	1.08	5.42	54.2	2.1	52.1
	Mar	3	Mid	1.14	5.73	63	3	59.9
	Apr	1	Mid	1.14	5.73	57.3	4.4	52.9
	Apr	2	Mid	1.14	5.74	57.4	5.5	51.9
	Apr	3	Mid	1.14	5.75	57.5	4.8	52.7
	May	1	Late	1.09	5.52	55.2	3.7	51.4
	May	2	Late	0.96	4.85	48.5	3.1	45.4
	May	3	Late	0.82	3.99	43.9	3.3	40.6
	Jun	1	Late	0.73	3.47	3.5	0.1	3.5
	total					566.6	31.6	535.1

Barley	Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
				coeff	mm/day	mm/dec	mm/dec	mm/dec
	Jan	3	Init	0.3	1.17	10.5	0	10.5
	Feb	1	Deve	0.33	1.36	13.6	0	13.6
	Feb	2	Deve	0.62	2.64	26.4	0	26.4
	Feb	3	Deve	0.92	4.16	33.3	0.1	33.2
	Mar	1	Mid	1.13	5.39	53.9	1.4	52.5
	Mar	2	Mid	1.14	5.72	57.2	2.1	55.1
	Mar	3	Mid	1.14	5.73	63	3	60
	Apr	1	Mid	1.14	5.73	57.3	4.4	52.9
	Apr	2	Mid	1.14	5.74	57.4	5.5	51.9
	Apr	3	Late	1.04	5.21	52.1	4.8	47.3
	May	1	Late	0.74	3.74	37.4	3.7	33.7
	May	2	Late	0.44	2.24	22.4	3.1	19.3
	May	3	Late	0.26	1.29	2.6	0.6	2.6
						487.1	28.8	458.9

ANNEXE: 11 Seasonal Average irrigation applied depth water of the sample 45 plots

Secondary Canal Location	Total Sample plot Area in (m2)	Total applied gross volume of water in (m3)	Applied depth of irrigation water in (mm)	Total no. of irrigation events	Total irrigation water applied (mm)	Total gross irrigationa pplied (m3/ha/season
Upper location	20280.5	1040.74	51.32	15.6	800.551	8005.5
Middle	18669.13	944.75	50.61	15.6	789.440	7894.4
Tail end	18278.24	912.67	49.93	15.6	778.939	7789.4
Average			50.50			7896.4

ANNEXE: 12

Descriptive Statistics	N	Minimum	Maximum	Mean	Std. Deviation		
Sex HH	45	1	2	1.67	0.477		
Age HH	45	1	4	2.6	0.915		
Irrigation access	45	1	1	1	0		
House hold size	45	1	3	1.8	0.661		
Marital status	45	2	4	2.31	0.633		
Education formal	45	1	4	2.2	0.726		
HH occupation	45	2	2	2	0		
Total agri. land in ha	45	2	3	2.49	0.506		
Total irrigated.in 2018 ha	45	1	3	2.51	0.549		
Distance homestead in km	45	1	2	1.11	0.318		
Irrigated maize in ha	45	2	3	2.53	0.505		
Product maize in KG	45	1	2	1.89	0.318		
Birr gain maize	45	1	3	2.89	0.383		
Improve seed in KG	45	1	3	1.13	0.405		
fertilizer in KG	45	1	11	1.98	1.438		
Valid N (list wise)	45						
Sex	GHH	MS	IRR	Education formal	Farm experience	HH Size	Active age
famel=1	30-40=1	single=1	acess=1	never attended=1	1-2=1	1-3=1	20-30=1
Male=2	41-50=2	married=2	Un acess=2	primary school=2	3-4=2	4-6=2	31-44=2
	51-60=3	divorced=3		secondary=3	5-6=3	7-10=3	45-55=3
	>71=4	widower=4		other=4	>7=4		>56=4
HH occupation	Total agri la	Total irr 2018 in	Distance hon	Improved seed in kg	Organic fertilizer in kg		
cultivated land=2	0.25-0.5=1	0.125-0.25=1	0.5-1=1	1=50-100	1=50-100		
herding=1	0.51-0.75=2	0.26-0.5=2	1-2=2	2=101-150	2=101-150		
other paid work=3	0.76<= 3	0.51-0.75=3	2-5=3	3=>150	3=>150		
student=4		0.76<=4	3<=4				
Amount money taken in bi	Irr maize	Product maize	HH				
	in ha	in kg	consumptio	Sold maize in birr	Birr gain maize		
1=>0	0.125-0.25=	1=1000-2000	1=1000-2000	1=200-300	1=200-300		
2=1001-2000	0.26-0.5= 2	2=2001-3000	2=2001-3000	2=301-400	2=301-400		
3=2001-4000	0.51-0.75= 3	3=3001-4000	3=3001-4000	3=301-500	3=301-500		
	0.76<= 4	4=>4000	4=>4000	4=>500	4=>500		

ANNEXE 13.Current all irrigator farmers in Canal -1

S/No	Name of Farmers	Gender	Plots code or Canal1	GPS Location X	Y	Total Command Area in ha	maize area (ha)	potato area (ha)	barley area (ha)	toata irrigated area	unirrigated area	Remark
										0		
1	Keshi Tsegay Kahsay	M	Upper	555545	1552614	0.626939	0.1884.7	0.2359	0.122		0.123	Samples
2	Tsehanesh Zeweldu	F	Upper	555562	1552544	0.274589	0.1112.56	0.149		0.149		Samples
3	G/silasie W/gerima	M	Upper	555454	1552618	0.868905	0.1107	0.148	0.12	0.268	0.600905	Samples
4	W/silasie G/silasie	M	Upper	555445	1552551	0.658072	0.300072	0.158		0.158	0.500072	
5	Keshi G/rufael Welu	M	Upper	555394	1552586	0.350255	0.125255	0	0.125	0.125	0.225255	
6	Kesh Kidanu Hagos	M	Upper	555392	1552659	0.516231	0.150231	0.266		0.266	0.250231	
7	G/gergis Girmay	M	Upper	555450	1552708	0.825288	0.029712	0.225	0.11	0.335	0.490288	
8	Brhan Etay	F	Upper	555346	1552732	0.423799	0.249799	0.174		0.174	0.249799	
9	Tsegab Etay	M	Upper	555331	1552531	0.568282	0.026718	0.2	0.125	0.325	0.243282	
10	G/gergis Gofan	M	Upper	555279	1552586	0.585829	0.140029	0.2658		0.2658	0.320029	
11	Kahsay Girum	M	Upper	555296	1552644	0.694128	0.300128	0.194		0.194	0.500128	
12	Aleganesh Alemayo	F	Upper	555266	1552689	0.465064	0.250064	0.215		0.215	0.250064	
13	Foten Hiben	F	Upper	555135	1552685	0.796794	0.120094	0.2967		0.2967	0.500094	
14	G/silasie G/medihin	M	Upper	555195	1552657	0.693886	0.268006	0.29388	0.132	0.42588	0.268006	
15	G/gergis Girmay	M	Upper	5554909	1552189	0.497137	0.250137	0.247		0.247	0.250137	
16	FTC	M	Upper	554859	1552183	1.261956	0.2106	0.125	0.12	0.245	1.016956	
17	Brhan Hadera	M	Middel	554895	1552114	0.586086	0.180086	0.236		0.236	0.350086	
18	Brhan G/mariam	M	Middel	554850	1552114	0.47803	0.15603		0.122	0.122	0.35603	
19	G/medinh Hadera	M	Middel	554797	1552153	0.246924	0.126924	0.12		0.12	0.126924	
20	T/mariamG/medihin	M	Middel	554738	1552021	0.575239	0.251	0.175239	0.21	0.385239	0.19	
21	Teklay Hagos	M	Middel	554758	1551957	0.438599	0.217599	0.221		0.221	0.217599	
22	G/medihn wneh	M	Middel	554845	1551960	0.658385	0.078385	0.12	0.16	0.28	0.378385	
23	Brhane Tesfay	M	Middel	554738	1552220	0.554794	0.226794	0.028		0.028	0.526794	
24	G/her Kasa Gedam	M	Middel	554682	1552220	0.642671	0.300671	0.142		0.142	0.500671	
25	Hailay Gezahay	M	Middel	554657	1552167	0.473474	0.153474	0.22		0.22	0.253474	
26	Mahlet Hadera	F	Middel	554618	1552228	0.538715	0.22915	0.178	0.11	0.288	0.250715	
27	Brhan Hadera	F	Middel	554643	1552125	0.621826	0.090826	0.12	0.211	0.331	0.290826	
28	Girmay Zewelu	M	Middel	554833	1552361	0.58898	0.17818	0.112	0.1288	0.2408	0.34818	Samples
29	Hadis Seged	M	Middel	554770	1552340	0.811268	0.390268		0.121	0.121	0.690268	Samples
30	G/her Asgedom	M	Middel	554784	1552296	0.713482	0.213482			0	0.713482	Samples
31	Hailay Hintsa	M	Middel	554515	1552018	0.487832	0.317832			0	0.487832	
32	Kesh G/hanis G/silasie	M	Middel	5544489	1552178	0.319149	0.150149		0.169	0.169	0.150149	
33	Etay Welu	M	Middel	554433	1552083	0.483163	0.23163	0.21	0.11	0.32	0.163163	
34	G/medihin Abreha	M	Middel	554411	1552192	0.549303	0.149303	0.2		0.2	0.349303	
35	Hailu Kahsay	M	Middel	554358	1552139	0.494777	0.144777	0.25		0.25	0.244777	
36	Kidan G/mariam	F	Middel	554296	1552153	0.568762	0.280762	0.188		0.188	0.380762	
37	G/medihin Hadera	M	Middel	554319	1552225	0.411068	0.221068	0.19		0.19	0.221068	
38	Teklay Hagos	M	Middel	554184	1552273	0.438004	0.038012	0.25		0.25	0.188004	
39	Brhan Hadera	F	Lower	554891	1552119	0.488012	0.338747	0.038		0.038	0.450012	
40	G/medihin Wineh	M	Lower	554903	1552182	0.376747	0.148043	0.038	0.269	0.307	0.069747	
41	Hailay gezahagn	M	Lower	554840	1552116	0.555043	0.304258	0.055		0.055	0.500043	
42	Mehalet Belay	F	Lower	554796	1552156	0.459258	0.258382	0.11		0.11	0.349258	
43	Tsgay Mesfin	F	Lower	554730	1552026	0.468382	0.213268	0.12		0.12	0.348382	
44	Keshi Tefay Gidey	M	Lower	554758	1551967	0.333268	0.135987	0.133		0.133	0.200268	
45	Tekle Mezgebe	F	Lower	554842	1551965	0.468987	0.38055	0.034		0.034	0.434987	
46	Hanetsa G/amlak	F	Lower	554735	1552219	0.41455	0.185496	0.154		0.154	0.26055	
47	Ke/G/meskel W/gebre	M	Lower	554682	1552217	0.539496	0.288201	0.119		0.119	0.420496	
48	Tsigea G/hanis	F	Lower	554670	1552172	0.607201	0.269113	0.25	0.188	0.438	0.169201	
49	Amit Etay	F	Lower	554647	1552121	1.268887	0.173614	0.125	0.125	0.25	1.018887	
50	G/gergis G/hiwet	M	Lower	554605	1552061	0.473614	0.125963	0.125	0.211	0.336	0.137614	
51	Degef Hailu	F	Lower	554549	1552019	0.761963	0.231138	0.125		0.125	0.636963	Samples
52	Aleganesh W/gergis	F	Lower	554551	1552077	0.356138	0.142613	0.12		0.12	0.236138	
53	Hintsa G/amlak	M	Lower	554572	1552147	0.562613	0.239188	0	0.23	0.23	0.332613	Samples
54	G/medinh G/tekle	M	Lower	554607	1552233	1.069188	0.024854		0.23	0.23	0.839188	Samples
55	Kidan G/tekle	F	Lower	554477	1552168	0.554854	0.078338	0.22		0.22	0.334854	
56	Hailay gezahagn	M	Lower	554430	1552096	0.498338	0.22887	0.05	0.12	0.17	0.328338	
57	G/silasie W/gerima	M	Lower	554348	1552140	0.39887	0.068085	0.15	0.11	0.26	0.13887	
58	G/cheal Hagos	M	Lower	554409	1552189	0.728085	0.179482		0.21	0.21	0.518085	
59	G/hanis Baraki	M	Lower	554288	1552147	0.689482	0.216406	0.15		0.15	0.539482	
						33.860661	11.08854	8.269519	3.8888	11.800419	21.43071	
						Commman	maize	Potato	Barley	Actual irriga	unirrigated	

ANNEXE 13 Current all irrigator farmers in Canal -2

S/No	Name of Farmers	Gender	Plots code or Canal-2	GPS Location X	Y	Total Command Area in ha	maize area (ha)	potato area (ha)	barley area (ha)	toata irrigated	unirrigated area	Remark
1	Keshi Behailu G/her	M	Upper	555722	1552411	0.433364	0.1225		0.125	0.233364	0.2	Samples
2	Tsega Behailu	F	Upper	555641	1552428	0.476014	0.214	0.262014		0.476014	0	Samples
3	Taddele G/hiwet	M	Upper	555620	1552358	0.641857	0.125	0.091857	0.125	0.341857	0.3	Samples
4	Tesfay G/her	M	Upper	555596	1552267	1.189187	0.325	0.04187	0.125	0.49187	0.697317	
5	Nigsti Berhu	F	Upper	555655	1552167	0.949784	0.26	-0.030216	0.12	0.349784	0.6	
6	G/cheal Hagos	M	Upper	555617	1552093	0.601316	0.25	0.026316	0.125	0.401316	0.2	
7	Mebrahtu Behailu	M	Upper	555460	1552114	0.633345	0.125	0.183345	0.125	0.433345	0.2	
8	Ametmariam Kahsay	F	Upper	555474	1552190	1.041028	0.126	0.156028	0.159	0.441028	0.6	
9	Letecheal G/ hiwet	F	Upper	555543	1552201	0.790499	0.132	0.278499		0.410499	0.38	
10	Keshi G/kidan Welu	M	Upper	555470	1552334	0.788622	0.2312	0.135422	0.122	0.488622	0.3	
11	G/her Reda	M	Upper	555418	1552243	0.877424	0.126	0.141424	0.21	0.477424	0.4	
12	Tekea Araya	M	Upper	555313	1552274	0.848164	0.2141	0.012064	0.222	0.448164	0.4	
13	Keshi Gidey G/her	M	Upper	555184	1552369	0.931279	0.126	0.183279	0.122	0.431279	0.5	
14	Silas W/gerima	F	Upper	555608	1551955	0.533364	0.2334	0.26486		0.49826	0.035104	
15	G/meskel Asefa	M	Middle	555486	1551999	1.019826	0.45	0.007317		0.457317	0.562509	
16	Tsiga G/hanis	F	Middle	555474	1551906	0.857317	0.37	0.050289		0.420289	0.437028	
17	Mehlet Belay	F	Middle	555433	1551810	0.900289	0.26	0.092693	0.125	0.477693	0.422596	
18	Brhan Tesfay	F	Middle	555376	1551763	0.477693	0.25	0.200896		0.450896	0.026797	
19	Brhane Hailu	M	Middle	555262	1551752	0.650896	0.31	0.12142		0.43142	0.219476	
20	Lemlem G/silasie	F	Middle	555186	1551737	1.213142	0.32	0.095087	0.022	0.437087	0.776055	
21	Tsarkan Hishe	F	Middle	555297	1551871	1.337087	0.35	0.06537	0.112	0.52737	0.809717	
22	G/her Atsibha	M	Middle	555148	1551897	0.82737	0.145	0.165579	0.2115	0.522079	0.305291	
23	Brhan Gidey	F	Middle	555247	1551861	1.522079	0.32	0.068855	0.023	0.411855	1.110224	
24	Mezgebe G/medihin	M	Middle	555163	1551990	0.711855	0.1246	0.251824	0.121	0.497424	0.214431	
25	Tewelde G/medihin	M	Middle	555171	1552051	1.097424	0.222	0.313059		0.535059	0.562365	
26	G/meskel Asefa	M	Middle	555058	1552028	0.735059	0.124	0.23537		0.35937	0.375689	
27	Tekle Kahsay	F	Middle	555026	1552124	1.15937	0.122	0.28737	0.011	0.42037	0.739	
28	Hagos Kidanu	M	Middle	554965	1552104	1.02037	0.212	0.311906		0.523906	0.496464	
29	G/meskel Tekle	M	Middle	554976	1552019	0.623906	0.125	0.286958	0.112	0.523958	0.099948	Samples
30	Zemeda G/hanis	F	Middle	554979	1551961	0.563958	0.225	0.091463	0.122	0.438463	0.125495	Samples
31	Haftay G/medihin	M	Middle	554968	1551894	0.438463	0.152	0.263492		0.415492	0.022971	Samples
32	Ha/mariamG/meskel	M	Middle	555055	1552028	0.415492	0.25	0.275263		0.525263	-0.109771	
33	Ha/Kasay Girum	M	Middle	555187	1551880	0.525263	0.32	0.29349		0.61349	-0.088227	
34	H/mariam Tekle	M	Middle	555150	1551983	0.638004	0.32	0.112454		0.432454	0.20555	
35	Ha/G/gergisG/medihin	M	Middle	555047	1552030	0.538004	0.211	0.070332	0.211	0.492332	0.045672	
36	G/hiwet G/her	M	Lower	554889	1551871	0.65349	0.32	0.08027		0.40027	0.25322	
37	Letebrhan Girmay	F	Lower	554944	1551816	0.632454	0.24	0.223596		0.463596	0.168858	
38	Alem W/gerima	F	Lower	554860	1551772	0.592332	0.25	0.332791		0.582791	0.009541	
39	G/mariam Mbrahtu	M	Lower	554871	1551702	0.67027	0.123	0.478629		0.601629	0.068641	
40	G/silasie W/gerima	M	Lower	554837	1551655	0.563596	0.24	0.177127		0.417127	0.146469	
41	G/cheal Hagos	M	Lower	554720	1551638	0.582791	0.32	0.162862		0.482862	0.099929	
42	G/hanis Baraki	M	Lower	554746	1551711	0.671629	0.22	0.186613		0.406613	0.265016	
43	Yemane W/gerima	M	Lower	554673	1551719	0.717127	0.22	0.236777		0.456777	0.26035	
44	Alganesh W/gerigis	F	Lower	554726	1551798	0.882862	0.23	0.2353		0.4653	0.417562	
45	G/medihin G/tekle	M	Lower	554714	1551888	0.606613	0.3	0.068706	0.112	0.480706	0.125907	
46	Hanetsa G/amlak	F	Lower	554650	1551883	0.656777	0.22	0.151852		0.371852	0.284925	
47	G/medihin Hadera	M	Lower	554595	1551821	0.734653	0.122	0.06801	0.211	0.40101	0.333643	
48	Hiwet G/yesus	F	Lower	554566	1551786	0.480706	0.23	0.12		0.3623	0.118406	Samples
49	Letebrhan G/her	F	Lower	555225	1551731	0.571852	0.221	0.11		0.4311	0.140752	Samples
50	Gebre Kahsay	M	Lower	554604	1551714	0.60101	0.122	0.123		0.245	0.35601	Samples
						37.626276	11.1708	8.162782	2.9735	22.405346	15.22093	
						Commman area	maize	Potato	Barley	Actual irrigat	unirrigated	

ANNEXE 14 Current all irrigator farmers in Canal -3

S/No	Name of Farmers	Gender	Plots code or canal 3 Canal-3	GPS Location X	Y	Total Command Area in ha	maize area (ha)	potato area (ha)	barley area (ha)	toata irrigated	unirrigated area	Remark
1	Hanis Reda	M	Upper	556025	1551503	0.594796	0.124	0.259796	0.111	0.494796	0.1	Samples
2	G/silasie Entahabu	M	Upper	555955	1551579	0.47471	0.126	0.34871		0.47471	0	Samples
3	G/her Reda	M	Upper	555935	1551657	0.599014	0.125	0.374014		0.499014	0.1	Samples
4	Keshi Hadush G/silasie	M	Upper	555930	1551652	0.526124	0.229	0.172124	0.125	0.526124	0	
5	Zegeye Beyene	M	Upper	555851	1551677	0.814293	0.35	0.084293		0.434293	0.38	
6	Teklay G/hiwet	M	Upper	555759	1551730	0.830417	0.42	0.010417		0.430417	0.4	
7	Mengstu Lemlem	M	Upper	555930	1551487	0.482014	0.213	0.087814	0.1212	0.422014	0.06	
8	Ha/Hailay Gebru	M	Upper	555930	1551445	0.479991	0.15	0.169991		0.319991	0.16	
9	Reda Nega	M	Upper	555896	1551372	0.56876	0.25	0.29876		0.54876	0.02	
10	W/silasie Debeb	M	Upper	555832	1551342	0.870846	0.12	0.228846	0.122	0.470846	0.4	
11	Futsum G/silasie	M	Upper	555804	1551274	0.663891	0.35	0.113891		0.463891	0.2	
12	Amit Kahsay	F	Upper	555826	1551218	0.85366	0.122	0.21966	0.112	0.45366	0.4	
13	Zereaydawit Futsum	M	Upper	555745	1551165	1.042821	0.35	0.02221	0.056	0.42821	0.614611	
14	Ha/Gebru Berhe	M	Upper	555781	1551473	0.786049	0.34	0.024049	0.122	0.486049	0.3	
15	K/mariam G/tsadik	M	Upper	555703	1551456	0.809476	0.143	0.156476	0.21	0.509476	0.3	
16	Brhan Zeary	F	Upper	555650	1551459	0.548854	0.28	0.168854		0.448854	0.1	
17	Brhan W/gerima	F	Upper	555566	1551540	0.730071	0.4	0.030071		0.430071	0.3	
18	G/kidan Gerase	M	Upper	555546	1551652	0.980036	0.24	0.118036	0.122	0.480036	0.5	
19	Tsega G/gergis	F	Middel	555418	1551655	0.657201	0.28	0.177201		0.457201	0.2	
20	Brehan G/silasie	M	Middel	555452	1551582	0.706393	0.45	0.056393		0.506393	0.2	
21	Atsibeha G/silasie	M	Middel	555478	1551476	0.477098	0.22	0.257098		0.477098	0	
22	Ametebrhan Lemlem	F	Middel	555578	1551442	0.815922	0.42	0.095922		0.515922	0.3	
23	Atakilti H/silasie	M	Middel	555550	1551347	0.570042	0.28	0.190042		0.470042	0.1	
24	Tsega G/silasie	F	Middel	555468	1551343	0.629579	0.4	0.229579		0.629579	0	Samples
25	G/silasie Hagos	M	Middel	555405	1551384	0.648349	0.35	0.298349		0.648349	0	Samples
26	G/kidan G/silasie	M	Middel	555360	1551390	0.744284	0.42	0.024284		0.444284	0.3	Samples
27	Tesfau G/silasie	M	Middel	555644	1551222	0.900571	0.25	0.127571	0.123	0.500571	0.4	
28	Kinfe Abreha	M	Middel	5555575	1551250	0.756872	0.41	0.046872		0.456872	0.3	
29	Brhan W/gerima	F	Middel	555573	1551153	0.76051	0.33	0.082051	0.014	0.426051	0.334459	
30	Araya G/silasie	M	Middel	555444	1551222	0.605141	0.32	0.285141		0.605141	0	
31	Mezgebe G/medihin	M	Middel	555368	1551196	0.945948	0.45	0.015948		0.465948	0.48	
32	Tsega Tesfay	F	Middel	555418	1551110	0.922371	0.25	0.047371	0.125	0.422371	0.5	
33	Hirit Abreha	F	Middel	555450	1551052	0.847433	0.42	0.027433		0.447433	0.4	
34	Letemariam Abadi	F	Lower	555344	1551389	0.64743	0.32	0.12743		0.44743	0.2	
35	Ha/G/her Abay	M	Lower	555304	1551437	0.521485	0.25	0.171485		0.421485	0.1	
36	Keshi Tesfay Debeb	M	Lower	555257	1551468	0.666332	0.32	0.146332		0.466332	0.2	
37	Gidena G/hiwet	F	Lower	555206	1551511	0.665584	0.25	0.092584	0.123	0.465584	0.2	
38	Tsegay G/hiwet	M	Lower	555204	1551452	0.43105	0.123	0.200105		0.323105	0.107945	
39	Mahder G/hiwet	F	Lower	555296	1551285	0.606019	0.45		0.22	0.606019	0	
40	Gidey Embaye	M	Lower	555296	1551252	0.565249	0.25	0.315249		0.565249	0	
41	Lemlem Aregawi	F	Lower	5552226	1551265	0.401577	0.22	0.181577		0.401577	0	
42	Tewelde G/medihin	M	Lower	555218	1551332	0.673054	0.189	0.284054		0.473054	0.2	
43	Beudula Desta	F	Lower	555163	1551334	0.819968	0.141	0.278968		0.419968	0.4	
44	Meharit Berihu	F	Lower	555145	1551439	0.476856	0.26	0.216856		0.476856	0	
45	G/gergis G/silasie	M	Lower	555080	1551439	0.839884	0.212	0.227884		0.439884	0.4	
46	Hailay Gidey	M	Lower	555117	1551313	0.398796	0.256	0.020796	0.122	0.398796	0	
47	Kinfe Abreha	M	Lower	555137	1551208	0.892086	0.126	0.251086	0.115	0.492086	0.4	
48	Keshi Aregawi Reda	M	Lower	555218	1551126	1.071572	0.22	0.026572	0.125	0.371572	0.7	Samples
49	G/haweria G/cheal	M	Lower	554985	1551255	1.001808	0.128	0.012808	0.111	0.251808	0.75	Samples
50	Mebrahtey G/meskel	M	Lower	554964	1551366	0.877812	0.152	0.325812		0.477812	0.4	Samples
51	G/libanos Gebru	M	Lower	554934	1551470	0.640081	0.132	0.108081	0.2	0.440081	0.2	
52	H/mariam G/tsadik	M	Lower	554997	1551539	0.894271	0.145	0.139271	0.21	0.494271	0.4	
						36.734451	13.726	7.976217	2.5892	24.227436	12.50702	
						Comman ar	maize	Potato	Barley	Actual irrigat	unirrigated	

ANNEXE 15 Current all irrigator farmers in Canal -4

	Name of Farmers	Gender	Plots code or canal 4	GPS Location		Total Command Area in ha	maize area (ha)	potato area (ha)	barley area (ha)	toata irrigated	unirrigated area	Remark
S/No			Canal-4	X	Y							
1	Nigsti Abreha	F	Upper	556087	1551300	0.879312	0.2232	0.13	0.121	0.4742	0.405112	Samples
2	Tsega G'gergis	F	Upper	555998	1551274	1.141058	0.1512	0.128	0.123	0.4022	0.738858	Samples
3	G'hiwet Tafere	M	Upper	555938	1551173	1.160049	0.12434	0.18	0.112	0.41634	0.743709	Samples
4	Abreha Desta	F	Upper	556050	1551162	1.003923	0.242	0.125	0.113	0.48	0.523923	
5	Hintsa Hanis	M	Upper	555834	1551154	0.737112	0.21222	0.145		0.35722	0.379892	
6	Tesfay Abreha	F	Upper	555889	1551050	0.735329	0.12612	0.117		0.24312	0.492209	
7	Brhane Behailu	M	Upper	555725	1551095	1.092702	0.322	0.23	0.121	0.673	0.419702	
8	Mebrhit Mueze	M	Upper	555729	1551027	0.826076	0.236	0.125		0.361	0.465076	
9	Letebrehan Tesfay	F	Upper	555804	1550968	0.564319	0.28	0.218		0.498	0.066319	
10	Zereay Hagos	F	Upper	555640	1551117	1.092766	0.36	0.218		0.578	0.514766	
11	Keshi Hailay Hanis	M	Upper	555587	1550957	1.406996	0.3482	0.243	0.212	0.8032	0.603796	
12	Kiros G,silasie	M	Upper	555666	1550931	0.762657	0.1236	0.133		0.2566	0.506057	
13	Abrehet Abay	M	Upper	555669	1550830	1.340056	0.22425	0.125	0.18	0.52925	0.810806	
14	Ha/Bihon Tesfue	F	Upper	555640	1550677	0.898875	0.24	0.135		0.375	0.523875	
15	Akeza Kahsay	M	Upper	555569	1550722	0.790263	0.2214	0.21511		0.43651	0.353753	
16	Abadit Tesfay	F	Upper	555513	1550770	1.4938	0.2145	0.25	0.25	0.7145	0.7793	
17	Aregawi Lema	F	Upper	555472	1550841	0.898886	0.235	0.214		0.449	0.449886	
18	Ha/ G/cheal Hagos	M	Upper	555382	1550785	1.22418	0.2142	0.2333	0.121	0.5685	0.65568	
19	Ha/Gebrhet Abay	M	Upper	555394	1550617	1.661908	0.224	0.1321	0.25	0.6061	1.055808	
20	Tsehay Gebrhet	F	Upper	555494	1550606	0.90085	0.229	0.24		0.469	0.43185	
21	Keshi Tesfay Aydebeb	M	Middle	554849	1551016	0.893527	0.225	0.213		0.438	0.455527	
22	W/silasie Aydebeb	M	Middle	554969	1550983	0.693456	0.32	0.115		0.435	0.258456	
23	Amete Kahsay	F	Middle	555002	1550871	1.177954	0.215	0.1233	0.125	0.4633	0.714654	
24	Fitsum G/silaie	M	Middle	554931	1550804	0.947961	0.1232	0.233		0.3562	0.591761	
25	Roman Gerase	F	Middle	555006	1550729	1.012802	0.1244	0.125	0.13	0.3794	0.633402	
26	Tesfau G/silasie	M	Middle	554920	1550666	1.025057	0.24	0.126	0.15	0.516	0.509057	
27	Silas Asireshay	F	Middle	555006	1550565	1.317924	0.252	0.123	0.225	0.6	0.717924	
28	Letemariam Abadi	F	Middle	555010	1550465	0.799887	0.225	0.214		0.439	0.360887	
29	G/her Atsibeha	M	Middle	554939	1550491	0.912641	0.222	0.213	0.125	0.56	0.352641	
30	Kiros Welay	F	Middle	555177	1550681	0.762284	0.42	0.123		0.543	0.219284	Samples
31	G/her Kelele	M	Middle	555077	1550621	1.139908	0.52	0.223	0.152	0.895	0.244908	Samples
32	Ke/G/ hanis G/cheal	M	Middle	555107	1550543	1.309219	0.45	0.23	0.225	0.905	0.404219	Samples
33	Welay G/her	M	middel	554805	1550453	0.626517	0.42	0.2		0.62	0.006517	
34	Liemet Desta	F	Middle	554723	1550461	0.700639	0.4	0.213		0.613	0.087639	
35	Tewelde Kasa	M	Middle	554682	1550520	0.593066	0.33	0.26		0.59	0.003066	
36	G/silasie G/her	M	Middle	554652	1550468	0.58029	0.28	0.17	0.121	0.571	0.00929	
37	Hailay G/her	M	Middle	554760	1550319	0.759576	0.123	0.1231		0.2461	0.513476	
38	Tesfay Brhane	M	Middle	554700	1550263	0.988771	0.52	0.2113	0.052	0.7833	0.205471	
39	Tsegay G/tsadik	M	Middle	554678	1550334	0.771553	0.24	0.1133		0.3533	0.418253	
40	Aregawi Hagos	M	Middle	554622	1550330	0.774006	0.126	0.2131		0.3391	0.434906	
41	K/mariam Atsibeha	M	Lower	554826	1550859	1.116297	0.1232	0.153	0.121	0.3972	0.719097	
42	Tesfay G/meskel	M	Lower	554771	1550868	0.925613	0.225	0.213	0.081	0.519	0.406613	
43	Zeray Tesfay	M	Lower	554729	1550784	0.785737	0.124	0.1223		0.2463	0.539437	
44	G/medihn G/mariam	M	Lower	554733	1550705	0.478101	0.25	0.21		0.46	0.018101	
45	Kibrom Tewelde	M	Lower	554677	1550696	0.400968	0.24	0.15		0.39	0.010968	
46	Ametebrhan Gebru	F	Lower	554747	1550607	1.307608	0.345	0.45	0.221	1.016	0.291608	
47	Mem/ Welday Niguse	M	Lower	554840	1550551	1.132935	0.212	0.135	0.125	0.472	0.660935	
48	G/her Niguse	M	Lower	554687	1550523	0.527356	0.26	0.26		0.52	0.007356	
49	Abreha Berhe	M	Lower	554840	1550386	0.955219	0.1255	0.26	0.042	0.4275	0.527719	
50	Desta Zegeye	M	Lower	554799	1550456	1.128995	0.25	0.125	0.122	0.497	0.631995	
51	G/her G/ cherkos	M	Lower	554738	1550449	0.611345	0.135	0.126		0.261	0.350345	
52	Ha/G/her Gebre	M	Lower	554625	1550337	0.661902	0.215	0.122		0.337	0.324902	
53	Ke/ H/silasie Tesfay	M	Lower	554619	1550433	0.411189	0.25	0.116		0.366	0.045189	
54	Hailecheal G/her	M	Lower	554768	1550325	0.759576	0.128	0.1216		0.2496	0.509976	Samples
55	Hailu G/cheal	M	Lower	554703	1550267	0.665495	0.29	0.125		0.415	0.250495	Samples
56	Kidan Teklay	F	Lower	554675	1550342	0.771553	0.22	0.23	0.052	0.502	0.269553	Samples
						51.038044	13.71953	10.02051	3.672	27.41204	23.626004	
						Comman ar	maize	Potato	Barley	Actual irrigat	unirrigated	

ANNEXE 16 Current all irrigator farmers in Canal -5

S/No	Name of Farmers	Gender	Plots code or Canal-5	GPS Location X	Y	Total Command Area in ha	maize area (ha)	potato area (ha)	barley area (ha)	toata irrigated	unirrigated area	Remark
1	G/haweria Abera	M	Upper	556146	1551339	0.557041	0.257041			0.257041	0.3	Samples
2	Zeray G/silasie	M	Upper	556087	1551279	0.50289	0.20289			0.20289	0.3	Samples
3	Alemat Berhe	F	Upper	556174	1551307	0.57072	0.24872		0.122	0.37072	0.2	Samples
4	Tsega Lemlem	F	Upper	556038	1551245	0.46765	0.25765	0.11		0.36765	0.1	
5	Medihin Lemlem	F	Upper	556122	1551252	0.472934	0.192934	0.18		0.372934	0.1	
6	Mehari G/medihin	M	Upper	556056	1551185	0.588226	0.208226	0.18		0.388226	0.2	
7	Ha/W/ mariam Abera	M	Upper	556007	1551119	0.471748	0.271748			0.271748	0.2	
8	Abadi Abera	M	Upper	555968	1551147	0.481223	0.191223	0.19		0.381223	0.1	
9	Kibrom W/gerima	M	Upper	555958	1551150	0.516119	0.156119	0.16		0.316119	0.2	
10	G/haweria Abera	M	Upper	555916	1551112	0.592175	0.252175	0.24		0.492175	0.1	
11	Nigsti Abreha	F	Upper	555954	1551073	0.484334	0.204334	0.18		0.384334	0.1	
12	Hailay Tesfay	M	Upper	555993	1551038	0.546624	0.246624	0.2		0.446624	0.1	
13	G/silasie Entahabu	M	Upper	556125	1551189	0.656157	0.276157	0.28		0.556157	0.1	
14	Brhan G/silasie	F	Upper	556209	1551189	0.737609	0.267609	0.27		0.537609	0.2	
15	Atsibeha G/silasie	M	Upper	556234	1551143	0.704514	0.264514	0.24		0.504514	0.2	
16	Abeba G/tsadik	F	Upper	556283	1551089	0.65169	0.28169	0.27		0.55169	0.1	
17	Silas Tesfay	F	Upper	556129	1551073	0.564328	0.204328	0.16		0.364328	0.2	
18	Zimam Hagos	F	Upper	556108	1551010	0.808368	0.188368	0.22		0.408368	0.4	
19	Brhan Hanis	F	Upper	556251	1551007	0.581607	0.281607	0.1		0.381607	0.2	
20	Hintsa Hanis	M	Upper	556244	1550954	0.486431	0.286431			0.286431	0.2	
21	Nigsti Abreha	F	Upper	556412	1551049	0.5603528	0.253528	0.25		0.503528	0.0568248	
22	Tesfay Abreha	M	Upper	556342	1551003	0.616366	0.246366	0.27		0.516366	0.1	
23	Akeza Kahsay	F	Upper	556380	1550979	0.523862	0.093862	0.23		0.323862	0.2	
24	Nigsti Girmay	F	Upper	556328	1550923	0.670751	0.250751	0.12		0.370751	0.3	
25	Brhan Tesfay	F	middel	556502	1550793	0.677611	0.277611	0.18	0.22	0.677611	0	
26	Hadish G/medihin	M	middel	556438	1550779	0.722158	0.182158	0.24		0.422158	0.3	
27	Medhin W/silasie	F	middel	556432	1550840	0.823011	0.253011	0.32	0.25	0.823011	0	
28	Haftom Mengstu	M	middel	556333	1550852	0.546982	0.066982	0.28		0.346982	0.2	
29	Tsega Girmay	F	middel	556237	1550779	0.573347	0.183347	0.19		0.373347	0.2	Samples
30	G/gergis G/anemia	M	middel	556173	1550811	0.910821	0.550821	0.26		0.810821	0.1	Samples
31	Keshi Teklay Tesfau	M	middel	556214	1550890	0.578066	0.288066	0.29		0.578066	0	Samples
32	Keshi Fitsum Kahsay	M	middel	556307	1550761	0.671036	0.106036	0.24	0.125	0.471036	0.2	
33	Hirt Belay	F	middel	556215	1550887	0.501487	0.291487	0.21		0.501487	0	
34	G/gergis Siyum	M	middel	556129	1550942	0.828113	0.207113	0.1	0.221	0.528113	0.3	
35	Haftom Abrhan	M	middel	556074	1550942	0.590329	0.348329	0.13	0.112	0.590329	0	
36	Hanis G/silasie	M	middel	556057	1550855	0.690001	0.110001	0.28		0.390001	0.3	
37	Tsega Lemlem	F	middel	556182	1550718	0.965267	0.235267	0.12	0.11	0.465267	0.5	
38	Tsigab G/meskel	M	middel	556118	1550671	0.629794	0.419794	0.21		0.629794	0	
39	Hanisa Abay	F	middel	556048	1550726	0.601023	0.381023	0.22		0.601023	0	
40	Alganesh Bsrat	F	middel	556071	1550630	1.089522	0.029522	0.25	0.21	0.489522	0.6	
41	Abadit Girmay	F	middel	556086	1550534	0.757317	0.237317	0.32		0.557317	0.2	
42	Teklay Tesfau	M	middel	555894	1550741	1.205458	0.183458	0.11	0.012	0.305458	0.9	
43	Kidan Ameha	F	middel	555888	1550840	0.689211	0.209211	0.28		0.489211	0.2	
44	Ha/ Gidey Aregawi	M	middel	555873	1550919	1.090719	0.155719	0.19	0.045	0.390719	0.7	
45	Yemane G/rafael	M	middel	555824	1550930	0.900786	0.080786	0.42		0.500786	0.4	
46	Danait G/hanis	F	middel	555911	1550989	0.638004	0.22989	0.25	0.125	0.60489	0.033114	
47	Ha/Tsigab G/meskel	M	Lowe	555329	1551400	0.70489	0.227999	0.185	0.105	0.517999	0.186891	
48	Atakilti Tekle	M	Lowe	555315	1551444	0.717999	0.078939	0.24	0.13	0.448939	0.26906	
49	Abreha Tesfau	M	Lowe	555266	1551486	0.948939	0.058004	0.38		0.438004	0.510935	
50	Tsarkan Tesfau	F	Lowe	555201	1551523	0.638004	0.1143956	0.31		0.4243956	0.2136084	
51	G/medihin Kelele	M	Lowe	555201	1551458	1.243956	0.042692	0.28	0.125	0.447692	0.796264	
52	Ha /K/mariamG/tsadik	M	Lowe	555142	1551451	0.947692	0.17301	0.29		0.46301	0.484682	
53	Ha/ Fiseha G/hiwet	M	Lowe	555066	1551454	0.86301	0.091393	0.48		0.571393	0.291617	
54	Ametecheal Hailay	F	Lowe	555317	1551295	0.671393	0.200796	0.28		0.480796	0.190597	
55	Tesfay G/hanis	M	Lowe	555284	1551251	0.880796	0.296401	0.245		0.541401	0.339395	
56	Keshi Aregawi G/hiwet	M	Lower	555231	1551330	0.941401	0.125322	0.353		0.478322	0.463079	
57	Medihin Welday	F	Lower	555215	1551267	0.878322	0.218763	0.38		0.598763	0.279559	Samples
58	Me/ mh/G/michaelGebru	M	Lower	555126	1551218	0.898763	0.115263	0.3		0.415263	0.4835	Samples
59	Hadish G/medhin	M	Lower	555000	1551253	1.115263		0.248	0.122	0.412232	0.703031	Samples
60	Keshi G/medihin Meresa	M	Lower	555228	1551130	1.141232		0.5	0.123	0.603349	0.537883	
61	Tesfay Abreha	M	Lower	555152	1551346	0.875032	0.375926	0.25	0.125	0.750926	0.124106	
62	Merg/W/gerima G/tatios	M	Lower	555105	1551321	0.750926	0.156192	0.32		0.476192	0.274734	
63	Nigsti Tsadik	F	Lower	555075	1551444	0.555278	0.205032	0.27		0.475032	0.080246	
64	Abrehet G/hanis	F	Lower	555007	1551533	0.603349	0.205278	0.35		0.555278	0.048071	
65	Ha/ Gidey Berhe	M	Lower	554914	1551489	0.876192	0.176	0.18		0.356	0.520192	
						86 46.746	**13.473**	**14.781**	**2.282**	**30.559**	**16.187**	
						Commman area	maize	Potato	Barley	Actual irrigated	unirrigated	

ANNEXE 18. The 45 Sample selected farmers measured plots

			Scheme Level GPS Data's Base mapping				
		Name of Farmers	Gender	Plots code	GPS Location		Area (m2) ha
				Canal1	X	Y	
9-Farmers	Canal 1	Keshi Tsegay Kahsay	M	HF1C1	555545	1552614	1884.7
	Canal 1	Tsehanesh Zeweldu	F	HF2C1	555562	1552544	1112.56
	Canal 1	G/silasie W/gerima	M	HF3C1	555454	1552618	1107
	Canal 1	Girmay Zewelu	M	MF1C1	554833	1552361	1234.7
	Canal 1	Hadis Seged	M	MF2C1	554770	1552340	1162.56
	Canal 1	G/her Asgedom	M	MF3C1	554784	1552296	1207.2
	Canal 1	Degef Hailu	F	LF1C1	554549	1552019	1254.7
	Canal 1	Hantsa G/amlak	M	LF2C1	554572	1552147	1232.56
	Canal 1	G/medinh G/tekle	F	LF3C1	554607	1552233	1200.21
9-Farmers	Canal 2	Keshi Behailu G/her	M	HF1C2	555722	1552411	1852
	Canal 2	Tsega Behailu	F	HF2C2	555641	1552428	1112.56
	Canal 2	Taddele G/hiwet	M	HF3C2	555620	1552358	1107.21
	Canal 2	G/meskel Tekle	M	MF1C2	554976	1552019	1234.7
	Canal 2	Zemeda G/hanis	F	MF2C2	554979	1551961	1462.56
	Canal 2	Haftay G/medihin	M	MF3C2	554968	1551894	1307.21
	Canal 2	Hiwet G/yesus	F	LF1C2	554566	1551786	1254.7
	Canal 2	Letebrhan G/her	F	LF2C2	555225	1551731	1250.56
	Canal 2	Gebre Kahsay	M	LF3C2	554604	1551714	1217.21
9-Farmers	Canal 3	Hanis Reda	M	HF1C3	556025	1551503	1236.7
	Canal 3	G/silasie Entahabu	M	HF2C3	555955	1551579	1240.56
	Canal 3	G/her Reda	M	HF3C3	555935	1551657	1217.21
	Canal 3	Tsega G/silasie	F	MF1C3	555468	1551343	1235
	Canal 3	G/silasie Hagos	M	MF2C3	555405	1551384	1420
	Canal 3	G/kidan G/silasie	M	MF3C3	555360	1551390	1307.2
	Canal 3	Keshi Aregawi Reda	M	LF1C3	555218	1551126	1223
	Canal 3	G/haweria G/cheal	M	LF2C3	554985	1551255	1164.3
	Canal 3	Mebrahtey G/meskel	M	LF3C3	554964	1551366	1123
9-Farmers	Canal 4	Nigsti Abreha	F	HF1C4	556087	1551300	1421
	Canal 4	Tsega G'gergis	F	HF2C4	555998	1551274	1321
	Canal 4	G'hiwet Tafere	M	HF3C4	555938	1551173	1463
	Canal 4	Kiros Welay	F	MF1C4	555177	1550681	1121
	Canal 4	G/her Kelele	M	MF2C4	555077	1550621	1263
	Canal 4	Ke/G/ hanis G/cheal	M	MF3C4	555107	1550543	1165
	Canal 4	Hailecheal G/her	M	LF1C4	554768	1550325	1203
	Canal 4	Hailu G/cheal	M	LF2C4	554703	1550267	1326
	Canal 4	Kidan Teklay	F	LF3C4	554675	1550342	1150
9-Farmers	Canal 5	G/haweria Abera	M	HF1C5	556146	1551339	1421
	Canal 5	Zeray G/silasie	M	HF2C5	556087	1551279	1321
	Canal 5	Alemat Berhe	F	HF3C5	556174	1551307	1463
	Canal 5	Tsega Girmay	F	MF1C5	556237	1550779	1121
	Canal 5	G/gergis G/anemia	M	MF2C5	556173	1550811	1263
	Canal 5	Keshi Teklay Tesfau	M	MF3C5	556214	1550890	1165
	Canal 5	Medihin Welday	F	LF1C5	555215	1551267	1203
	Canal 5	Me/ mh/G/michaelGebru	M	LF2C5	555126	1551218	1326
	Canal 5	Hadish G/medhin	M	LF3C5	555000	1551253	1150

ANNEXE 19 Average Minimum Temperature of the study area

Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	12.6	13.4	14.9	17.9	12.8	12.5	12.3	11.2	10.0	9.3
2004	11.6	13.1	14.6	13.4	12.2	12.0	12.5	10.0	9.6	9.3
2005	12.2	12.8	14.1	14.4	12.7	12.5	12.6	11.3	10.0	8.7
2006	12.1	12.8	14.1	13.7	12.9	12.7	12.4	11.4	10.0	9.9
2007	12.1	13.3	12.6	13.9	12.4	12.4	12.3	10.7	9.1	10.8
2008	11.5	13.0	13.8	13.5	12.7	12.9	13.3	11.5	9.7	9.1
2009	13.0	13.5	14.9	15.5	13.0	13.5	13.4	12.4	10.4	10.7
2010	12.2	14.0	14.7	14.1	13.8	12.6	10.8	10.1	8.5	7.8
2011	9.6	11.3	11.7	13.6	13.0	11.2	11.9	10.4	9.4	7.4
2012	9.6	11.3	13.0	12.4	10.8	8.2	7.2	7.3	6.6	7.4
2013	10.6	9.4	10.3	14.7	8.3	8.2	8.0	6.5	6.1	3.3
2014	7.2	8.6	8.6	8.6	7.2	7.0	6.3	6.5	7.8	6.8
2015	11.9	12.6	14.1	14.3	13.2	13.0	12.9	12.0	10.6	10.1
2016	12.0	12.0	12.0	11.0	11.0	11.5	10.0	7.5	5.5	5.5
2017	11.4	11.1	13.3	13.8	12.8	13.1	11.9	11.3	8.9	6.3
Sum	182.0	195.0	211.1	218.7	192.4	186.0	180.5	161.5	142.7	132.1
Average	**11.38**	**12.19**	**13.19**	**13.67**	**12.03**	**11.63**	**11.28**	**10.09**	**8.92**	**8.26**

ANNEXE 20 Average Maximum Temperature of the study area e

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	25.2	25.6	25.6	26.3	25.0	21.3	21.6	24.5	22.8	23.0	22.4
2004	24.4	24.8	24.2	26.5	24.8	21.9	22.1	24.2	22.4	23.1	23.2
2005	24.4	25.7	24.5	25.4	26.0	21.4	22.3	24.2	23.0	22.6	22.7
2006	30.2	25.6	24.8	24.4	25.8	21.7	20.9	23.4	23.2	22.9	22.7
2007	25.1	25.9	24.7	26.2	24.6	21.3	22.0	23.6	22.8	22.3	25.3
2008	24.3	25.8	24.3	25.5	25.0	21.6	22.5	24.2	22.8	22.2	22.7
2009	24.6	26.1	26.0	25.9	27.2	21.3	22.4	24.7	23.4	23.4	22.8
2010	25.2	24.1	25.2	25.6	26.8	22.1	21.3	23.4	22.7	22.4	21.9
2011	24.6	23.7	26.3	24.9	25.3	22.2	20.3	22.4	22.6	22.5	22.8

2012	23.8	25.7	24.7	25.4	24.5	21.2	21.8	22.6	23.9	23.4	22.8
2013	25.9	26.5	27.0	27.1	27.9	22.9	22.1	25.2	24.0	23.8	23.0
2014	25.6	25.9	24.8	25.2	26.1	22.9	22.5	23.6	24.0	22.7	22.9
2015	26.0	25.4	26.1	25.5	25.7	23.9	22.9	24.8	24.4	23.3	22.7
2016	27.5	30.0	28.5	28.5	29.0	25.5	25.0	26.0	25.5	25.0	24.5
2017	23.9	25.7	26.0	24.9	27.3	23.7	22.3	24.5	24.1	23.7	23.1
Sum	744.6	412.2	408.6	415.0	417.7	359.8	354.5	385.7	375.2	369.4	368.7
Average	46.5	25.8	25.5	25.9	26.1	22.5	22.2	24.1	23.4	23.1	23.0

ANNEXE 21 Average monthly Rain fall of the study area (2002-2017)

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	Annual R.F
2003	1.5	46.9	5.2	59.5	0.0	30.9	167.7	139.1	13.2	7.9	0.0	0.0	472
2004	6.0	9.4	23.1	105.4	7.1	20.8	206.6	201.2	0.0	12.4	11.1	0.0	603
2005	0.0	2.8	61.4	74.8	11.6	23.3	166.4	164.8	4.8	0.0	0.0	0.0	510
2006	0.0	0.0	10.6	30.6	61.7	5.2	207.4	283.8	11.2	5.6	6.8	19.1	642
2007	0.0	1.6	5.3	42.0	4.3	143	203.6	133.2	31.0	0.0	0.0	0.0	564
2008	0.0	0.0	0.0	17.7	23.5	23.7	313.6	90.7	29.1	17.5	47.5	0.0	563
2009	0.0	0.0	19.9	8.8	26.7	2.3	106.4	117.1	1.5	11.9	10.7	1.4	307
2010	0.0	0.0	46.6	82.2	97.7	7.6	222.6	121.4	52.6	5.1	10.6	5.2	652
2011	1.4	0.0	26.2	3.8	12.3	59.9	214.8	175.4	82.2	2.1	37.0	0.0	615
2012	0.0	0.0	67.2	20.5	19.5	109.5	188.3	99.2	11.0	5.4	28.4	0.0	549
2013	0.0	0.0	44.8	44.5	1.4	141.4	125.3	98.7	0.0	18.0	0.0	0.0	474
2014	0.0	1.0	38.5	19.6	58.3	10.9	139.6	131.3	21.8	14.9	36.1	7.3	479
2015	0.0	1.0	28.8	0.0	45.0	61.9	112.9	215.5	5.1	0.0	21.1	29.1	520
2016	0.0	6.5	31.6	88.4	58.9	27.5	301.1	71.3	27.5	6.3	0.0	0.0	619
2017	0.0	73.0	1.2	22.3	73.4	1.6	127.0	207.3	30.0	0.6	3.6	0.0	540
Sum	11.5	142.2	500.2	626.7	518.9	701.1	2870.4	2417.5	331.3	107.7	212.9	74.3	8515
Average	**0.7**	**8.9**	**31.3**	**39.2**	**32.4**	**43.8**	**179.4**	**151.1**	**20.7**	**6.7**	**13.3**	**4.6**	**532**

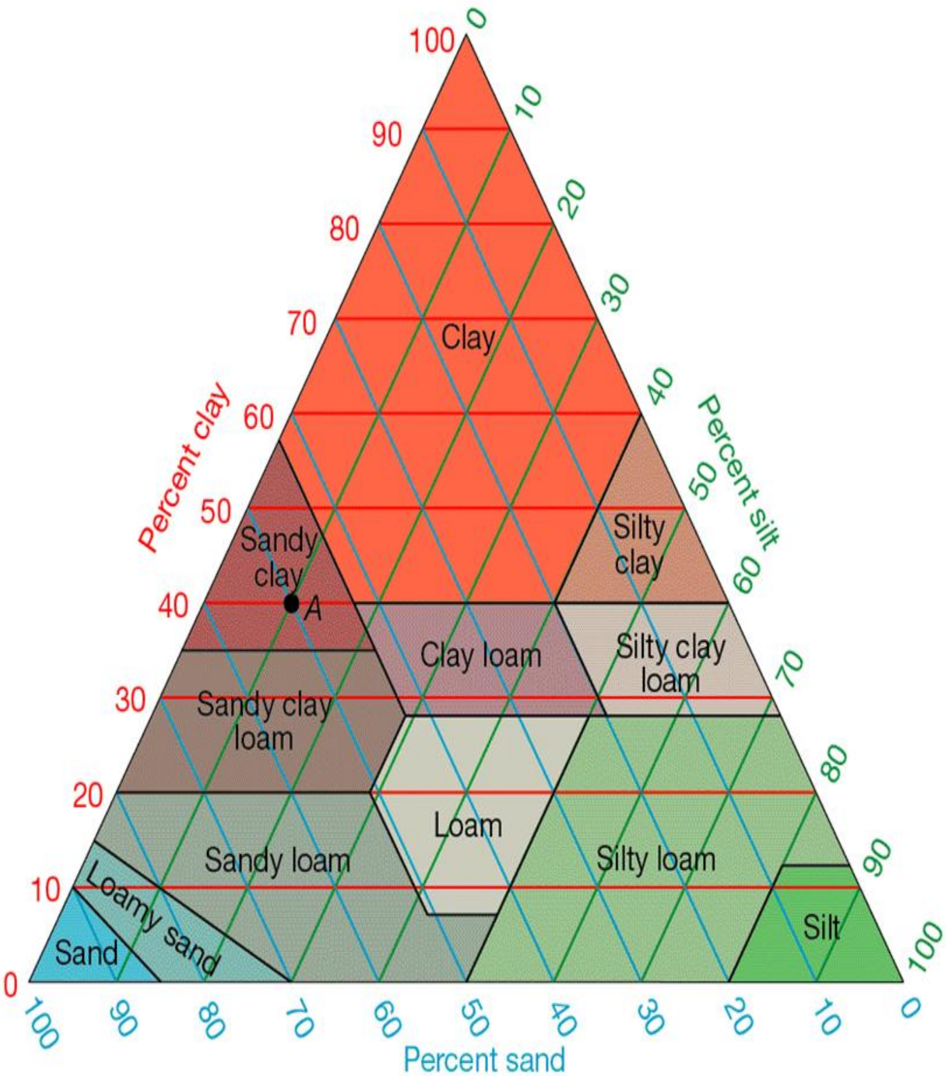
ANNEXE:22 .Soil Texture Triangle Worksheet

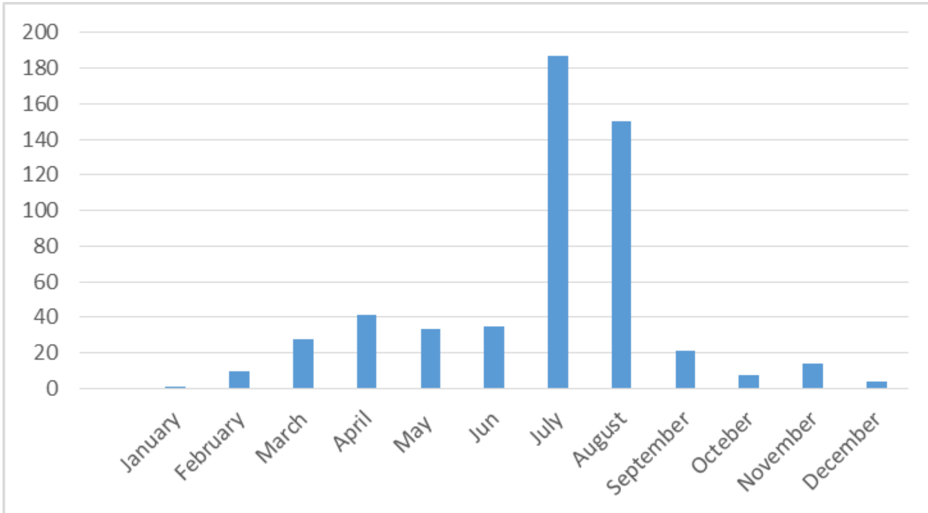
Name _________________________________ Date _______________ Period _________

Directions: Using your soil texture triangle, identify the soil texture in the table.

S/code LF1	**% Sand**	**%Silt**	**%Clay**	
HF-1/100	59	9	32	Sandy clay loam
HF-1/ 60	69	5	26	Sandy clay loam
HF-1/ 30	77	1	22	Sandy clay loam
HF-2/ 100	55	5	40	Sandy clay
HF-2/ 60	55	5	40	Sandy clay
HF-2/ 30	65	3	32	Sandy clay loam
HF-3/ 100	49	7	44	Sandy clay
HF-3/ 60	55	7	38	Sandy clay
HF-3/ 30	57	7	36	Sandy clay
MF-1/ 100	57	9	34	Sandy clay loam
MF-1/ 60	51	9	40	Sandy clay
MF-1/ 30	57	7	36	Sandy clay
MF-2/ 100	53	11	36	Sandy clay
MF-2/ 60	57	9	34	Sandy clay loam
MF-2/ 30	67	3	30	Sandy clay loam
MF-3/ 100	53	11	36	Sandy clay
MF-3/ 60	63	5	32	Sandy clay loam
MF-3/ 30	59	11	30	Sandy clay loam
LF-1/100	67	9	24	Sandy clay loam
LF-1/ 60	53	11	36	Sandy clay
LF-1/ 30	65	7	28	Sandy clay loam
LF-2/ 100	53	11	36	Sandy clay
LF-2/ 60	57	13	30	Sandy clay loam
LF-2/ 30	67	9	24	Sandy clay loam
LF-3/ 100	57	9	34	Sandy clay loam
LF-3/ 60	63	9	28	Sandy clay loam
LF-3/ 30	69	7	24	Sandy clay loam

ANNEXE: 23. SOIL TEXTURE TRIANGLES





Annex: 24 Average monthly Rain fall of the study area (2003-2017)

		V1	V2	V3	Month	Dam H. Recovered	Was Rained		un irrigated days
Apr	at point 17.4177+0.022 = 17.4	2559555.8	2538013.8	21542.061	Apr	2.2cm	15mm	17/4/18	2-days
Apr	at point 16.776+0.025 = 16.8	2134494.2	2112878.6	21615.618	Apr	2.5cm	25mm	21/4/18	3-days
				43157.68		4.7cm	40mm		
	By Inter polation		Y2 =	(x2-x1) (y3-y1)		+ y1			
				x3-x1					
				y3		x3			
			????	y2		x2			
				y1		x1			

Annex: 24 Seasonal Dam recovered by Rain fall during the irrigation 2018