COMPARATIVE EVALUATION OF ELA AND LINTALA SMALL SCALE IRRIGATION SCHEMES, WOLAITA ZONE, SOUTHERN ETHIOPIA

MASTERS OF SCIENCE IN WATER RESOURCE ENGINEERING AND MANAGEMENT

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HAWASSA UNIVERSITY,
HAWASSA, ETHIOPIA

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Declaration of the Author

I, Israel Kassa Kuma declare that this thesis represents my own work and all sources of materials used for this thesis have been duly acknowledged. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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As members of the Board of Examiners of the final Master's degree open defense, we certify that we have read and evaluated the thesis prepared by Israel Kassa Kuma under the title "comparative evaluation of Ela and Lintala small scale irrigation schemes, Wolaita Zone, Southern Ethiopia" and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master's of science in Water Resource Engineering and Management.

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Acronyms

AP Available phosphorous

BCM Billion Cubic Meters

Ce Conveyance Efficiency

CEC Cations Exchange Capacity

Cfs Cubic feet per second

CIR Crops Irrigation Requirement

CU Christiansen Uniformity

CWR Crops Water Requirement

DU Distribution Uniformity

Ea Application Efficiency

EC Electric conductivity

ETC Evapotranspiration

ETo Reference Evapotranspiration

FAO Food and Agricultural Organization

FC Field Capacity

ha Hectare

HH House Hold

IF Irrigation Frequency

IFAD International Fund for Agricultural Development

IIMI International Irrigation Management Institution

IWMI Irrigation Water Management Institute

IWS Stored Irrigation Water Supplied

IWU Irrigation Water Used

IWUA Water Users Association

Kc Crop Coefficient

NGOs Non-Governmental Organizations

OC Organic carbon

PWP Permanent Wilting Point

RAW Readily Available Water

Rd Root Depth

RIS Relative Irrigation Supply

RWS Relative Water Supply

SCS Soil Conservation Service

SGVP Standardized Gross Value of Production

SIW Stored Irrigation Water

SNNPR South Nation's Nationality and Peoples Region

SSI Small-Scale Irrigation

TAW Total Available Water

TIWS Total Irrigation Water Supplied

TIWU Total Irrigation Water Used

TN Total Nitrogen

USDA United State Development Agency

WDC Water Delivery Capacity

WUA Water Use Association

WUE water Use Efficiency

ρb Bulk Density

ρw Density of Water

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COMPARATIVE EVALUATION OF ELA AND LINTALA SMALL SCALE IRRIGATION SCHEMES, WOLAITA ZONE, SOUTHERN ETHIOPIA

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ABSTRACT

Irrigation schemes are usually constructed to deliver service on the assumed efficiency. Due to the schemes' age and management practice, service rendering status of schemes may be below assumed performance level. Non- operational parts of the irrigation schemes were commonly seen in the study schemes. Therefore these study schemes were evaluated with the help of internal and external performance indicators. Internal performance indicators were conveyance efficiency, application efficiency, irrigation adequacy and uniformity. External performance indicators were water delivery performance and water productivity. Water delivery parameters used were Relative Irrigation Supply, Relative Water Supply, and Water Delivery Capacity. The water productivity of the schemes was also compared with respect to the irrigation water used. Conveyance efficiencies of Ela and Lintala schemes were 86% and 81%, and also Irrigation application of these schemes were 55% and 42%. So that, system efficiencies of Ela and Lintala small scale irrigation schemes were 47% and 34%. So that in Ela irrigation scheme water management in the field was better than Lintala scheme. Also Storage efficiencies in Ela and Lintala plots were 86% and 81%. So, in irrigation time, selected plots acquired the required irrigation depth fairly. And calculated Irrigation uniformity in these plots were 88% and 77%. In Ela irrigation scheme, Relative water supply and Relative irrigation supply was in the interval 0.95-1.96 and 0.94-2.4. In these intervals the lower values 0.95 and 0.94 were obtained in the month February. This revealed the scheme water delivery performance couldn't answer ETc of the crops in driest month. But its water delivery capacity of main canal was 3.8. So Ela scheme canal capacity was not constraining factor for croping intensity. The Relative water supply and Relative irrigation supply of Lintala was in the intervals 2.53-3.73 and 2.8-4.5. And also its main canal capacity was 2.2. So that this scheme water delivery performance was enough to answer the ETc of the crops. In existing water management, average irrigation water productivity of maize in Ela and Lintala plots was 0.89 and 0.52 kg per m^3 of irrigation water reaching the farm.

Key words: irrigation, performance of irrigation schemes, internal and external indicators

1. INTRODUCTION

1.1. Background

Ethiopia has more than 122 BCM of surface runoff from 3 River basins MOWR/Ministry of Water Resource, (1999) and current estimation of groundwater potential is 36 BCM (Abiti, 2013). This surface and ground water resource that contributes grand effort for different developmental activities in the country. One of the developmental activities that use water is agriculture. The major means by which agricultural products increases to meet the growing population demands is irrigation (Awulachew et al, 2005).

There are two broad classes of irrigation water distribution systems. Which are pressurized and gravity flow distribution. The pressurized systems include sprinkler, trickle, and the array of similar systems in which water is conveyed to and distributed over the farmland through pressurized pipe networks. Gravity flow systems convey and distribute water at the field level by a free surface overland flow regime. This Gravity flow system is also subdivided according to configuration and operational characteristics. Surface irrigation has evolved into an extensive array of configurations which can be broadly classified as: Basin irrigation, Border irrigation, Furrow irrigation and uncontrolled flooding.

Agricultural production can be improved through irrigation development, particularly small-scale irrigation that benefits small holders and good irrigation water management. In Ethiopia, even though irrigation has been long aged practice at different farm levels, inefficient and poorly-managed irrigation water is common practices (Dessalegn, 1999). Due to inefficient and poor irrigation water management, the scheme is underperforming. The trend of low performance of small-scale irrigation schemes related with poor irrigation scheme management, flawed project design and lack of adequate community consultation during project planning, Douglas and Jaun, (1999).

Mekonen and Awulachew, (2007) stated that variety in utilization of irrigation water and land result in tremendous difference in their output. Variety in utilization of irrigation water and land is due to inconsistencies in the management systems. This inconsistency results in inefficiency, non-uniform service and inadequacy (Behailu et al, 2004).

Performances of schemes need to occasionally looked at and monitored. Some of reasons are, to improve scheme operations, to decide progress against strategic goals, to check the health of a scheme, to evaluate impacts of interventions, to better understand about determinants of performances, to diagnose constraints and compare the performance of a scheme with others or with the same scheme over time (Molden et al, 1998).

Any of the aforementioned reasons for which irrigation schemes were assessed, investigation options expected in improving services of water delivery and resource utilization (Malano et al, 2004). With the help of performance indicators, where selected irrigation schemes currently stand with respect to water used can be evaluated. In the evaluation process Molden et al, 1998 standards of comparative indicators were governed in measuring irrigation systems. Parameters like water productivity of schemes are good indicators of performance indicators. This is the major reason why Ela and Lintala irrigation schemes studied with the help of established internal and external indicators in Humbo Woreda, Wolaita Zone, SNNPR.

1.2. Statement of the Problem

There are four traditional and five modern irrigation schemes in Humbo Woreda Wolaita zone. The schemes are of different age. Non- operational irrigation structures were observed in most of irrigation schemes in the Woreda. Though scientifically substantiated, there are indices of underperforming such as poor irrigation water management. So that Systematic evaluation is inevitable to verify underperformance. To draw efficient management strategy and to deliver and render services expected, performance evaluation is necessary. This study is thus initiated to look at the performance of these schemes primarily to pin point problem spots and suggest intervention options.

1.3. Objectives of the Study

1.3.1. General objective

The main objective of the study is to evaluate the performance of Ela and Lintala SSI schemes located in SNNPR, Wolaita Zone Humbo Woreda.

1.3.2. Specific Objectives

- To explore the effectiveness of the schemes with established internal indicators viz: efficiency, uniformity and adequacy.
- To investigate their comparative performances.

1.4. Research Questions

- How is status of irrigation water management practices from River to crops root zone?

- Are the crops satisfied by irrigation water delivery performances in the schemes?

- How much is irrigation productivity in each of selected schemes?

- What are problems of irrigation schemes and institutionalization?

1.5. Scope of the study

The studied irrigation schemes were Ela and Lintala in Humbo Woreda Wolaita Zone. In the destination of River flow to the crops root zone, Farmers' water management in the schemes was the main concern of the study. Supplying the required irrigation for the crops is major action of water management. To obtain the expected efficiency of the scheme, variety of arrangements and works must be considered by the water manager.

1.6. Significance of the Study

The finding of the study may pin point the major problems of the individual irrigation schemes and then give the directions for further improvements so that the targeted farmers will be benefited from the research findings. In addition to this, the study provides base line information about these schemes. So experts and investigators who are working in the same area of interest may use the study findings.

2. LITERATURE REVIEW

2.1. Irrigation Schemes

Irrigation is the artificial supply of water to agricultural crops. It permits farming in arid regions and to offset the effect of drought in semi-arid regions. Even in areas where total seasonal rainfall is adequate in average, it may be poorly distributed throughout the year and variable from year to year. So, irrigation helps to ensure stable agricultural production (FAO, 1997).

Irrigation system has set of associates from head work to distribution system, that implements complete water application target to the crops. Concerning sort of basics involved for the system build, it can be modern system and traditional system. Modern systems have relatively permanent structure and improved water control system where as, traditional systems use local material to divert water from the River and it needs reconstruction every year after the end of the rainy season.

Both Modern and traditional systems can vary in size of command area that irrigates. FAO (1989) classified irrigation schemes based on sizes of command areas as small-scale, medium-scale and large-scale irrigation schemes. Small-scale irrigation scheme has command area less than 200ha, medium-scale irrigation scheme has command areas between 200 and 3000ha and large-scale irrigation scheme has greater than 3000 ha.

Ethiopia has an important opportunity in water-led development. But to capture its full potential, its implementation addresses critical challenges in the planning, designing, delivery and maintenance of its irrigation systems (Awulachew ,2010)

In the period of 2010 to 2015 Ethiopia was planned to increase its irrigation land from 640,000 ha to 1.8 million ha through small-scale irrigation, rain water harvesting and other medium and large-scale irrigation projects (Awulachew, 2010). This increase in irrigation land by 280% and requires tremendous resources, including financial, human capacity, infrastructure and other human and capital investments (Lempériere et al. 2014). So the country faced major technical, socio-economic, institutional and environmental challenges to achieve the national target.

The next hurdle to irrigation development is the underperformance of existing irrigation schemes. Under-performance is an issue for all scheme type small, medium, large irrigation schemes. Many irrigation projects are operating significantly under their design capacity. Lempériere et al. 2014 reported that from total 640,000 ha irrigation in Ethiopia, 410,000 ha operating below in 2010. That is 64 percent of designed schemes perform under capacity and small-scale schemes accounting for 90 percent of the gap.

2.2. Cause of low Performance of Irrigation Schemes

There are four potential kinds of performance gaps that can occur with irrigation systems (Douglas and Juan, 1999). These performance gaps with their corresponding mitigation strategies are explained.

The first is a technological performance gap. This is when the structure of an irrigation system lacks the capacity to deliver a given hydraulic performance. The solution to technology performance gaps is to change the type, design or condition of physical structure.

The second kind of performance gap is when a difference arises between how management procedures are supposed to be implemented and how they are actually implemented. This includes such problems as how people adjust gates, maintain canals and report information. This can be called a gap in implementation performance. A problem of this kind generally requires changes in procedures, supervision or training.

The third kind of performance gap is a difference between management targets and actual achievements. Examples of management targets are the size of area served by irrigation in a given season, cropping intensity, irrigation efficiency, water delivery schedules and water fee collection rates. This can be called a gap in achievement. Such problems are generally addressed either by changing the objectives (especially simplifying them) or increasing the capacity of management to achieve them. This can be done by increasing the resources or reforming organizations.

The fourth type of performance problem concerns impacts of management. This is a difference between what people think about the ultimate effects of irrigation and what actually results obtained. These are gaps in performances measures. Such as agricultural and economic profitability of irrigated agriculture and productivity per unit water used. If management procedures are being followed and targets are being achieved, but ultimate effect may not attained as intended. Then the problem is not directly done by organization management. So it is more a problem of policy than management.

Because of different limitations, such as less integration of the socio-economics, existing community water management practices, institutional, technical and policy weaknesses, several irrigation projects in Ethiopia rift valley lake basins have failed or been unsustainable (IFAD, 2005) . As the result schemes have limited contribution on livelihood of the community.

Cakmak et al, (2004) explained that large part of low performance may be due to inadequate water management at system and field level. Also Awulachew and Merrey, (2006) pointed that lack of managerial, financial and technical capacity of water users is considered to be the major cause of failure in community managed schemes. As far as irrigation management is concerned, the water needs to be gauged and properly utilized. Both excessive and inadequate water applications have negative effects (Mihret, 2013). This kind of water application declares inadequate water distribution problem in the field level and head tail problem in the scheme level. Behcet and Tarkan, (2014) indicated that leaky canal and delayed maintenance as main cause of head tail problem. In addition to delayed maintenance of leaky canal, malfunctioning of control structures and fault of diversion structures significantly contributes head tail problems.

These structures failure raises the problem of uncontrolled expansion of irrigation area in some part of the scheme where excess flow routine observed. It leads to low water use efficiency and low yields in some parts of the irrigation schemes. These are the most important reasons for not reaching the targeted performance level in irrigation systems.

But Shimelis et al, (2005) confirmed that resolving technical and agronomic problems of irrigation agriculture is impossible without understanding the social organizations (institutions, the policy environment and social relations) in which it is embedded. Also

Behcet and Tarkan, (2014) stated that giving emphasizes only for the physical structure and neglecting the social dimension also contribute for low performance.

In addition Awulachew (2010) identified the major social dimensions cited under management capabilities. These are lack of coordinated research program on agricultural water management, lack of applied research on national irrigation systems, no link between researchers and farmers and no irrigation manuals for local crops.

2.3. Performance Indicators

Irrigation is the process highly combined to social, agriculture, market and technical parameters. The performance of irrigation system is represented by its measured levels of achievement in terms of one or several parameters. These are chosen as indicators of the system's goal (Abernethy, 1989).

To compute water use performances in the scheme, a number of indicators have been proposed and tested in different parts of the world Molden et al, (1998), Kloezen and Garce's, (1998), Bos et al (2005) and Vandersypen et al (2006). The aim of each indicator is to measure level of achievement. Each result of selected parameters is elaborating the effectiveness of the scheme, whether the schemes rendering the service in designed efficiencies or not. However, measuring the effect of individual parameter on the performance of irrigation is complex; it is possible to look the effects in a gross sense Molden et al, (1998). It may be used to evaluate irrigation outputs and impacts of irrigation management practices in production, to develop interventions across different systems and systems levels, as well as to compare various irrigation technologies with one another. Generally it helps to determine problems and shows means to improve system performance Cakmak et al, (2004).

Sakthivadivel et al, (1999) stated that IWMI's comparative performance indicators are used as tools to measure irrigation systems. The result is used by different stakeholders such as system managers, farmers and policy makers.

- Policy makers and planners used; to evaluate how productively land and water resources are being used for agriculture and to make more informed strategic decisions regarding irrigation and food production.

- Irrigation managers used; to identify long-term trends in performance, to set reasonable overall objectives and to measure progress.
- Researchers used; to compare irrigation systems and identify factors that lead to better performance.
- Donor agencies, governments and NGOs used; to assess the impact of interventions in the irrigation sector and to design more effective interventions.

The true performance indicators were included both an actual value and an intended value. That enables to talk deviation between intended and actual value. If the deviation is acceptable, it further should contain information that allows the managers for decision making, (Bos, 1997) and (Bos et al, 2005).

Features of performance indicators suggested by same author are:

- ✓ Scientific base: the indicators should be based on an empirically qualified, statistically tested causal model of the irrigation process it describes.
- ✓ The indicators must be quantifiable: the data needed to quantify the indicator must be obtainable, measurable with available technology.
- ✓ Performance to a target value: this is of course obvious from the definition of performance indicators. It implies that relevance and appropriateness of the target value and tolerance can be established for the indicators.
- ✓ Provide information without bias: ideally performance indicators should not be formulated from the narrow ethical perspective. This is in reality extremely difficult as even technical measures contain value judgment.
- ✓ Ease of use and cost effectiveness: practically for routine management performance indicators should be technically feasible and used easily.

2.4. Perspectives of Performance Indicators

Small and Svendsen, 1990 categorized performance measures in irrigation systems as process measure (relating to a systems' internal operations) and output measure (relating to a systems' final output). They are referred to internal performance indicators and external performance indicators. External indicators provide little or no detail on internal processes that lead to the output.

Gorantiwar and Smout, (2005) have summarized performance measures proposed by various researches. These are under allocation type and scheduling types. Allocation types performance measures are those need to be attained primarily during the allocation of the resources at the planning and operation stages. Productivity and equity are performance measures categorized under allocation type. Scheduling type performance measure consists of irrigation scheduling, i.e. temporal and spatial distribution of irrigation water to the users. These measures are adequacy, reliability, flexibility, efficiency and sustainability.

Molden et al, (1998) stated the main output in irrigation scheme is crop production, while the inputs are water, land, and finances. These two major categories of performance measures into: economic (productivity), social (equity), environmental (sustainability) and management (reliability, adequacy, efficiency and flexibility). According to this authors a set of recognized indicators are nine in number. The first four basic performance indicators which related with land and water use are:

- Output per cropped area,
- Output per command area,
- Output per unit irrigation supply and
- Output per unit water consumed.

The next two financial related performance indicators include:

- Gross- return on investment and
- Financial self-sufficiency.

Whereas the remaining three performance indicators which related with system water delivery service are:

- Relative water supply,
- Relative irrigation supply and
- Water delivery capacity of canal

2.4.1. Types of Performance Indicators

Studies have attempted to standardize these indicators for better comparison across systems (Bos et al, 1994). Also Molden et al., (1998) listed common performance indicators in irrigation schemes' evaluation process. This generalization is from the development of performance indicators utilized by different authors through time. They stated that with so many elements of the agricultural system, it is not easy to address all areas of performance at the same time. So to evaluate irrigation schemes' performance, purpose of evaluation is primarily set. According to Yusuf, (2012) presentation, setting of some relevant criteria for performance evaluation and identifying indicators which can measure intended activities to be measured is taken primary part in irrigation system evaluation. Due to access of measurement tools, it is possible to utilize performance indicators for limited number of case studies.

Generally both internal and external performance indicators defined in terms of efficiencies, indices and other statistical expressions. Most of the external indicators expressed in indices but internal indicators are in efficiencies. Some indicators such as distribution uniformity expressed in the statistical expressions. Barrett and Associates, (1999) indicated that an efficiency is in fact a dimensionless term and it is obtained by dividing figures having the same units e.g. volume of water used (output) divided by a volume of water supplied (input). But the tone of product per mega liter of water used is an index, not efficiency. People concept towards these two different terms is indistinct manner. They use these two different terms as common term water use efficiency. This common misusage of the term water use efficiency has created great confusion. The term 'Water Use Efficiency' should be restricted to a generic label for any performance indicators that are used in study of water use in crop production. This label ‘Water Use Efficiency’ need not be defined but should be considered like a label on a toolbox. Inside the toolbox there are many specific performance indicators that should be referred as Water use Indices. Any water use index (within this toolbox) should be clearly defined with specific units when used Barrett and Associates (1999).

2.4.2. Internal indicators

Internal indicators are indicating irrigation water management conditions starting from the diversion point to crops root zone in the farm level. The quantification of irrigation water lost in each system part and in the farm level is important to tell the destination of loosed water.

A. Conveyance efficiency

Conveyance efficiency of the canal tells the degree of water loss in the canal during transmission time. It expresses the relative comparison of the water which reaches the out turns of the canal and amount of water delivered in to head of conveyance canal (Bos, 1979).

Different conditions limit conveyance efficiencies of the canal. The major condition which determines the conveyance efficiency is being lined or unlined. When the canal is lined the percolation of water in contact perimeter of the canal decreases. As the result the conveyance efficiency increases. But in unlined condition the percolation of the water in contact perimeter of the canal increases and then the conveyance losses increases. The canal lengths also contribute for high conveyance losses and tend to suffer from unreliable and untimely supply of water. Mekonen and Awulachew, (2007) exemplified farmers who were located at the end of the longest canal segment in Hare irrigation scheme with high conveyance lose. These farmers limited in their crop diversification and forced to grow relatively water stress resistant crops such as cotton and sweet potato.

B. Application efficiency

Application efficiency is the ratio of water stored in the crops root zone to the water amount actually diverted in to field FAO, (1989).

Application efficiency is a common yardstick of relative irrigation losses and this definition is valid for all situations and all irrigation methods Jurriens et al (2001). Losses from the field occur as deep percolation and tail water runoff. These all reduces the application efficiency. Water application efficiency gives a general sense of how well an irrigation system performs its primary task of getting water to the plant roots.

However it is possible to have high application performance, there exist irrigation water stresses in the crop root zone. High application performance is expressing the relation between quantity of water stored in root zone and amount of diverted water to the field. When depth of water stored in root zone nearly in the same amount with depth of diverted water to the field, at that time high application efficiency achieved. But this quantity of water may not capable to refill the storage volume of root zone. On the other hand low application efficiency can be seen when large volume of water applied. The amount of applied irrigation water exceeds the root zone storage capacity and then it is subjected to loss in the form of runoff or percolation. For example, if the root zone of the soil to be irrigated can store only 100 mm, but 400 mm is applied with absolute uniformity, the water application efficiency is only 25%.

Barrett and Associates, (1999) reported that worldwide average ranges of application efficiencies of different irrigation systems being followed are the followings.

- surface: 60 to 90%,
- sprinkler: 65 to 90%,
- drip: 75 to 90%

C. Water distribution uniformity

The uniformity of the applied water may affect irrigation efficiency. The fraction of water used efficiently is important for improved irrigation practice. The uniformity is a statistical property of the applied water distribution. This distribution depends on many factors that are related to the method of irrigation, soil topography, soil infiltration characteristics and hydraulics of the irrigation system Terri, (2003). In the surface irrigation the water distribution work mainly depends on the land leveling which should be considered in the design time. An applied water distribution is usually described in the extent of particular location depth of water (volume per unit area). Then irrigation water distribution represented the extent in which the water has penetrated to a uniform depth, throughout the field.

Distribution uniformity is the ratio of the average of low quarter of irrigation distribution in the field to the average of irrigation depths over the whole field Jurriens, et al, (2001). This term represented by the symbol (DU).

$$DU=\frac{average\ of\ lower\ quarter\ irrigation\ depths}{average\ of\ whole\ field\ irrigation\ depths}*100\% \ldots Eq(2.1)$$

Christiansen (1942) proposed a coefficient of irrigation water distribution based on the catch volumes as;

$$CU= 100(1-\frac{\sum|Xi-\bar{X}|}{\sum Xi}) \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (2.2)}$$

Where

CU is the Christiansen's uniformity coefficient in percent,

X is the depth of irrigation water in mm and

$\bar{X}$ is mean of irrigation depth in mm.

D. Adequacy

FAO, (1989) stated that, water storage efficiency is the degree of satisfaction by refilling prior volume of water used up by crops. Mishra and Ahmed, (1990) also explained that adequacy of irrigation depends on how much water is stored within the crop root zone.

Jurriens, et al, (2001) expressed adequacy of irrigation in terms of storage efficiency.
Storage efficiency is one of the important soil characteristics in irrigated agriculture. Soil textures and structures are physical feature that affects storage volume. Textural

classes are sorted as coarse, fine and medium classes. Sandy soils typically have high intake rates and low soil moisture storage capacities. This soil requires entirely different irrigation strategy than the deep clay soil. Deep clay soil has low infiltration rates and high moisture-storage capacities Walker, 1989. Sandy soil requires more frequent, smaller applications of water whereas clay soils can be irrigated less frequently and too larger water application depth. The remaining textural classes have intermediate water application strategies between these two different characterized soils.

In addition to the textural characteristics, aggregated or no aggregated affect water storage capacity of the soil. When the soil is aggregated, its pore size increased. Then ease movement of air, water through plant roots in the soil taken place. Due to this plant growth rate facilitated Thomas et al, (2013).

Available water stored in the soil refers to the capacity of a soil to retain water. It is expressed in similar manner as the amount of water remaining when downward drainage has markedly decreased after rainfall or irrigation. This level is called field capacity. Field capacity is the amount of water that a well-drained soil should hold against gravitational forces. Lower limit of moisture depletion is permanent welting point. The soil moisture varies from the field capacity to the permanent welting point (Allen et al, 1998). The total available moisture content for plants is the difference of these two points. This expression in depth is calculated by the help of the following equation.

$$TAW = \left(\frac{FC-PWP}{100}\right)d \qquad \text{Eq (2.3)}$$

Where

TAW is total available water,

d is crop root depth in mm,

FC is field capacity in volume fraction and

PWP is permanent wilting point in volume fraction.

Although water is theoretically available until permanent wilting point, crop water uptake is reduced well before wilting point is reached. Where the soil is sufficiently wet, the soil supplies water fast enough to meet the atmospheric demand of the crop. In this time water uptake equals ETc. As the soil water content decreases, water becomes more strongly bound to the soil matrix and is more difficult to extract. When the soil water content drops below a threshold value, soil water cannot quickly transported towards the roots and not responds the transpiration demand. At this moment the crop begins to experience stress. The fraction of TAW that a crop can extract from the root zone without suffering is the readily available soil water.

$$RAW = nTAW \qquad \text{Eq(2.4)}$$

Where: TAW is total available moisture (mm).

RAW is readily available soil water in the root zone [mm],

n is average fraction of total available soil water varies from 0-1,

The factor n differs from one crop to another. The factor n normally varies from 0.30 for shallow rooted plants at high rates of (ETc > 8 mm d^{-1}) to 0.70 for deep rooted plants at low rates of (ETc < 3 mm d^{-1}). According to FAO, (1998) n=0.50 is commonly used for many crops.

The same author presented the ranges of root zone depth (RZD) for common crops in the selected investigation irrigation schemes (table-1). In the given RZD intervals, the smaller values for RZD may be used for irrigation scheduling and the larger values for modeling soil water stress or for rain fed conditions. The maximum effective root depth and factors of allowable moisture depletion of crops in non stressed condition presented as follows.

Table 1, Crops effective root depth and factors of allowable moisture depletion (FAO, 1998)

Crops	Maximum effective root zone depth(m)	Allowable soil moisture depletion (n)
Cabbage	0.5-0.8	0.45
Onion	0.3-0.6	0.35
Field corn	1-1.7	0.55
Tomato	0.7-1.5	0.4
Potato	0.4-0.6	0.35
Pepper	0.5-1	0.3

The adequacy of irrigation is not strictly a simple function of the area that achieves or exceeds specified soil water content. More correctly, it is a measure of the soil water deficit over the whole field is meet FAO, (1989).

2.4.3. External indicators

This indicator contemplates on the productivity relative with the resource used. In the evaluation of the schemes' performance, if water is a limiting factor for production, output per unit water is more important. But land is limiting relative to water, output per unit land may be more important.

It is not rational to say same weight of different crops indicate the same performance level of scheme. For the viable comparison, either the type of the crop should be the same or prices of unit weight of different crops have alike market value. Either the types of crops are the same or not, revenue is more rational to express the effectiveness of the schemes productivity. It may be expressed in terms of local cost of products.

The sale cost of the product can be affected by other determinants such as location of the scheme from the market. For example the farmers at the long distance from the market obligated to compensate transportation fee in the sale cost. And also level and variations in crop yield, production cost and output price are exogenous variables. These are sources of loss and considered as business risk to smallholder irrigating farmers. Prices of vegetables can be seasonally low and high because of an atomistic market product (characterized by many sellers), volatile business environment, and perishable nature of products under developed value chains. Compared to cereal crops, irrigated agriculture of high value crops like vegetables generates more profit per unit irrigated area (Getnet et al, 2015).

Low yield is another profit factor in the irrigated agriculture Van Halsema et al, (2011). It is commonly seen in areas where poor farmers agronomic and management practices adopted.

The depletion of the qualities of the resources involved in the irrigation production decreases the quantity and quality of production in the scheme. The land and water qualities in the irrigation system should be maintained for expected production. For example the quantity of salts in the soil exceeds permissible value then growth, yield, and quality of most crops adversely affected Yeshitela et al, (2012).

Water delivery indicators RWS, RIS and WDC are better to put the irrigation system in its physical and management context. During the measure of the above water delivery indicators; crops water demands, water supplied for crops and physical capacity of irrigation structures are necessary.

The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. Gross irrigation requirement can be obtained when net irrigation requirement divided by overall efficiency (Andreas and Karen, 2002).

A. Relative water supply

Relative water supply was initially developed by Levine (1982). It is parameter to measure water available for irrigation. It indicates how much water in the form of rain and irrigation. This is ratio of total water supplied (irrigation plus rainfall) in growing season to crops water demand. It signifies whether the water supply is in short or in excess relative to demand.

B. Relative irrigation supply

Relative irrigation supply presented by Perry, (1996). This is the ratio of crops net irrigation supply to irrigation demand in the crops growing season. It indicates the fraction of irrigation actually supplied in relation with the net irrigation needs Molden, et al. (1998).This indicator is useful to assess the degree of irrigation water stress or abundance. Relative irrigation supply is the inverse of the irrigation efficiency Bos and Nugteren, (1974).

Irrigation water supply system subjected for different losses in a gross. Water used by crops is predominantly lost by transpiration and evaporation from surfaces of the soil and plants. The amount of water used by plants together with water losses through evaporation is called evapotranspiration.

Both RWS and RIS relate supply to demand. These give some indications for water abundance or scarcity, and how supply and demand are matched. For the adequate total water supply and irrigation supplies, the value greater than one. But for both RIS and RWS a value less than one indicates that farmers are practicing deficit irrigation. So care must be taken in the interpretation of results.

C. Water delivery capacity

The water delivery capacity indicates the degree in which the actual canal capacity is sufficient to convey the peak crops irrigation demand throughout the system Molden et al, (1998). It is an indication which irrigation structure is anyway constraint for cropping intensities. Values much greater than one indicates the canal capacity is not a constraint to meet crop water demands. The value close to one indicates difficulty in meeting short-term peak demands.

Crops water demand is calculated according to FAO, (1998). Since manual calculation is very complex, long stepped and tedious, CROPWAT computer model is recommended for calculation. This computer model uses monthly climatic data (temperature, relative humidity, wind speed, sunshine hours) for the calculation of Eto through Penman-Monteith method.

$$Eto = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}U2(es-ea)}{\Delta+\gamma(1+0.34u2)} \text{ ....Eq(2.5)}$$

Where;

ETo reference evapotranspiration (mm day^{-1}),

Rn net radiation at the crop surface (MJ $m^{-2}day^{-1}$),

G soil heat flux density (MJ $m^{-2}day^{-1}$),

T mean daily air temperature (°C),

U_2 wind speed at 2m height (m s^{-1}),

es saturation vapour pressure (kPa),

ea actual vapour pressure (kPa),

es – ea saturation vapour pressure deficit (kPa),

Δ slope vapour pressure curve (kPa $°C^{-1}$) ,

γ psychrometric constant (kPa $°C^{-1}$).

Next rain fall, crop data and soil characteristics are necessary in puts for crop water requirement and irrigation requirement calculations.

C. Water use efficiency

The output in irrigation work is crop production, while the major inputs are water, land, and finances (Molden et al, 1998). This output is expressed by the weight of crop yield or economic equivalence per unit of land and water used. The SGVP makes it possible to compare the performance of schemes; no matter where they are or what kind of crops are being grown (Sakthivadivel et al, 1999).

Irrigation efficiency is clearly influenced by the amount of water used in relation to the irrigation water applied to the crop. But water use efficiency (WUE) is the most widely used parameter to describe irrigation effectiveness Viets, (1962).

$$WUE=\frac{Yg}{ETC}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq(2.6)$$

Where ; WUE is water use efficiency,

Yg is the economic yield and

ETc is the crop water used.

Water use efficiency is usually expressed by the economic yield and crop dry matter. These two WUE expressions (economic yield or dry matter yield) have led to some inconsistencies in the use of WUE concept. The transpiration ratio (transpiration per unit dry matter) is more consistent value that depends primarily on crop species and the environmental evaporative demand.

2.5. Irrigation scheme management

According to Metcalf, (1991) the management activity is a major component of success for any irrigation scheme. Conveyance and delivery of irrigation water from the source to the field are facilitated by management activity Mondal and Saleh, (2003). Also water use status (equity, flexibility and reliability), physical status (the health of control and diversion structures) and organizational condition (cost recovery for maintenance and operation of the scheme) are management activities of irrigation schemes.

FAO, (1998) approximated that 40 percent or more of the water diverted is wasted at the farm level through deep percolation and surface runoff. These takes place a higher value on water resources management and therefore tend to focus attention on wasteful practices.

Mihret and Ermias, (2014) explained that without a strong WUA, it is impossible to fill farmer's practical skill gaps. These skill gaps included lack of maintenance strategy, unfair distribution of irrigation water, unreliable irrigation water supply and untimely delivery of irrigation water.

Poor water control structures and a complete absence of discharge measuring devices are often the results of poor irrigation schemes management Lempérière and Van der

Schans, (2004). In poor irrigation governance there exist deficiencies in irrigation management structures. Due to poor organizational management Lempériere et al, (2014) structured for establishing and strengthening IWUA. Farmers don't have recognized legal power and the roles, responsibilities and authorities in the management organization. It is not clearly defined and even it is totally missing from the by-laws Shimelis et al, (2005). In such conditions, unless financial support from external body, they are not willing for scheduled maintenance García et al, (2011).

2.6. SOCIO ECONOMICS

Irrigation development is identified as an important tool to stimulate economic growth and rural development. It is considered as a cornerstone of food security and poverty reduction in Ethiopia Fitsum et al, (2009).

But many countries are faced insufficiency of water resources to satisfy their current agricultural, domestic, industrial and environmental water demands Şener et al, (2007). However water is scarce, there are many ways of using it more efficiently or making each drop of water more productive Rosegrant, (2002). This is achieved by proper operation, maintenance and management of the irrigation system at their design recommendations.

The social benefit of water should be an important component of a basin water management strategy. Water governance is the set of formal and informal processes through which decisions related to water management are made. Good water governance primarily knows about what processes work best in a particular physical and socioeconomic context. Irrigation system designers should be conscious to assure equity and share of irrigation water among users that encouraged good water governance at all levels.

In some basins, excessive diversion of river water for irrigation brought environmental and ecological disasters in downstream areas. On the other hand the environmental damage such as salinity due to water logging and soil erosion are the effect of unsound managed irrigation schemes.

Water availability and having adequate water in timely is one of the major conditions encouraging farmer participation in irrigation management Shimelis et al, (2005). On the other hand water scarcity is one reason for lack of good governance IWMI, (2010).When there is no legal provision to safeguard farmers' interest and ensure their representation; the disadvantaged farmers especially the tail-end and small farmers do not have any incentive to join the organizations. Without their participation in the organization, management works cannot be complete.

3. MATERIALS AND METHODS

3.1. Descriptions of the Study Area

Humbo woreda is located in SNNPR, Walita Zone. It is one of the 12 Woredas under this zone. This Woreda is bordered by; Sidama Zone (Leku Abaya Woreda) from the east, Gamo Gofa Zone (Boreda Woreda) from the south, Wolaita zone (Sodo Zuria Woreda) from the north and Wolaita zone (Ofa Woreda) from the west.

Capital of the woreda Tebela town is at the distance of 348km from Addis Ababa via Butajira. It also found at 174km from Hawasa. The capital of the Woreda Tebela found at 18 km from Wolaita Soddo along Arba Minch road.

The woreda has a total area of 859.4km^2 and its topography values in the ranges of 1001 - 2010 (m) above sea level. From the computed results of climatic data over the period of 1996-2015, 20 ^{0}C mean annual temperature, 1349 mm mean annual rainfall and 3.97 mm/day average annual ETo were recorded in the study area. The prominent (well known) soil types in the woreda are reddish and black cotton soils. Much of this land is intensively cultivating. These areas are used to grow cereal crops, and cash crops like coffee. Mixed agricultural activities that are crop production with livestock rearing is adopted in the Woreda. Most of the agricultural activities are using rain fall in the raining season.

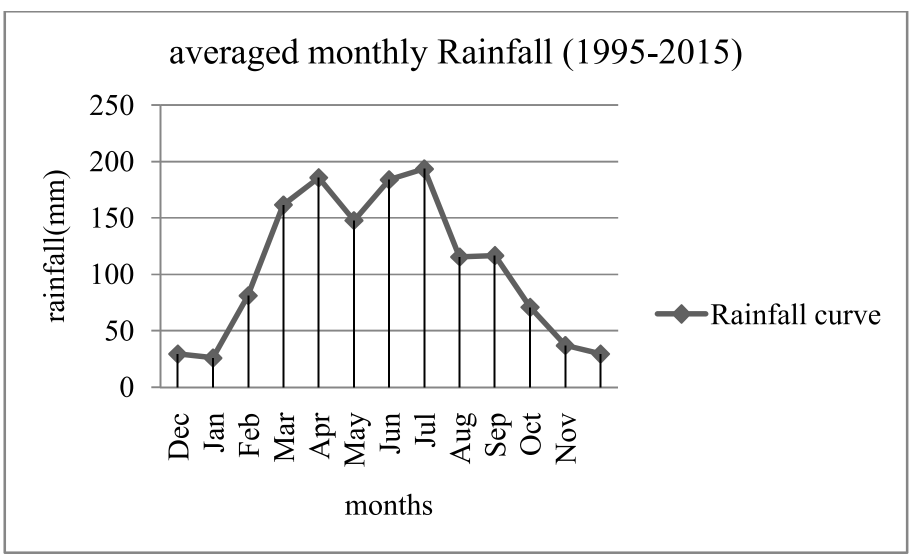

Figure-1, Rain fall distribution in the study area

In the study area, the maximum rain fall is expecting in the area from months June to September. In the period between March and May despite high rainfall variability, lighter rain fall is expected. October to February is the dry season where irrigation is practicing.

There are three main Rivers that are crossing some parts of Woreda's cultivable land. The Rivers are Bilate, Hamesa and Lintala. Two Rivers Bilate and Lintala crossed the Woreda along eastern and western parts. But Hamesa River crosses the Woreda along the middle /central part.

3.2. Irrigation schemes in the Woreda

Among three main Rivers, Bilate River is used to irrigate land in four different Kebles. The irrigation schemes exist in these Kebeles are Abaya Bisare, Abaya Guruchoo, Abaya Chokare and Abaya Bilate. These four Kebeles are exist in the same agro-ecological zone called dry midland (hot). The distance of these irrigation schemes on average 55 kms far from the capital of the Woreda Tebela in east direction.

Similarly, Hamesa River also irrigates lands in four different Kebeles. They are Ampo Ela, Bossa Wanche, Abela Faracho and Abela Lasho. Abela Faracho and Abela Lasho are located in dry midland agro-ecological zone. The remaining two Kebeles exist in the Wet midland (moderate) agro-ecological zone. The distance of these Kebeles is not greater than 14 kms from Tebela.

Lintala River is used for irrigation only in one Kebele called Sere Tawurata. Lintala irrigation scheme is in dry midland agro-ecological zone. It is about 40 km far from Humbo Tebela in west direction. In the woreda total designed irrigation area of schemes', years in which the schemes constructed and their type are in table 2.

Table-2, Irrigation schemes in the Woreda (Humbo Tebela irrigation Bureau 2015)

Irrigation schemes	Type of irrigation schemes	Schemes constructed (yrs)	Designed command area (ha)	Current Beneficiaries (HH)
Abaya Bilate	Traditional	2002	240	278
Abaya Gurucho	Traditional	1998	220	610
Abaya Chokare	Traditional	2006	160	310
Abaya Bisare	Modern	2008	200	300
Bosa Irrigation	Modern	2007	100	53
Ampo Ela	Modern	1993	80	216
Abela Faracho	Traditional	2013	80	68
Abela Lasho	Modern	1994	110	240
Lintala irrigation	Modern	2007	70	24

Totally 1260 ha of farm land is expected to irrigate from these three Rivers. Cereals, fruits and vegetables are under irrigation. Maize, Tomatoes, Cabbage, Potato, Pepper and Onion are dominant crops. Households benefiting from these irrigation schemes are accounting 7 % of the total population of the Woreda.

In addition to irrigation activities in scheme level, micro irrigation activities are practiced in the study area. There is estimation that irrigation potential will be large while micro irrigation activities are included. In this study, irrigation activity in the scheme level was point of interest.

Traditional irrigation schemes are schemes with local diversion and water control structures. It needs reconstruction every time after end of rain season. Since diversion and water control structures are not permanent in this scheme type, it is not appropriate for measurements. Therefore the study included two modern irrigation schemes for comparison. They have permanent diversion structures and improved water control systems. In the selected irrigation schemes some part of canal sections are lined. In Lintala scheme main canal is completely lined but in Ela scheme only 60% of main canal was lined. These lined main canals are rectangular shaped with masonry sided walls and concrete bedded. In both studied schemes secondary and tertiary canals are remain unlined. The soil types in the schemes where earthen canal constructed are sandy loam.

The third scheme which was constructed in Bilate River originally planned to study was non-functional and the weir was removed by flood in the study time.

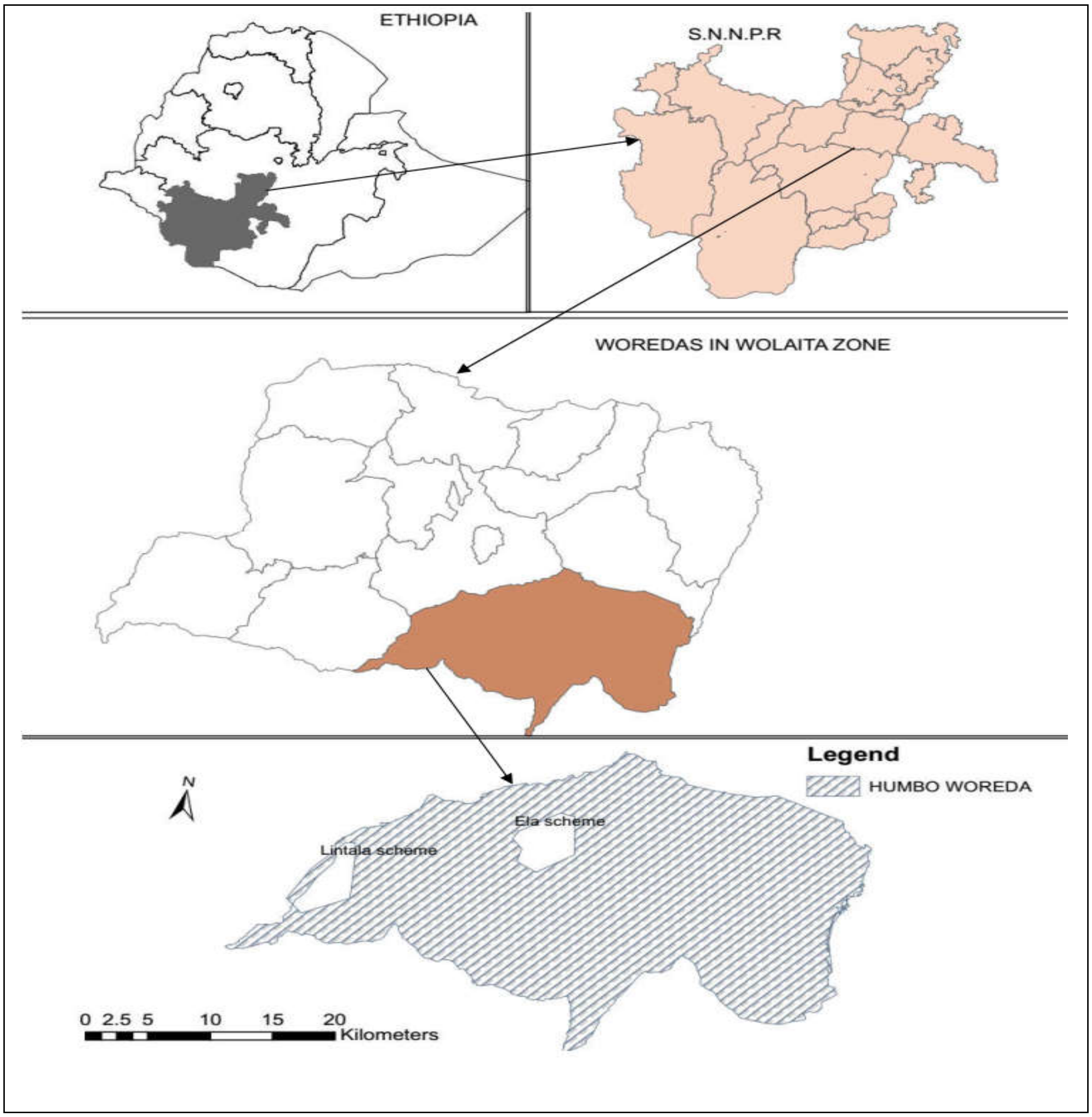

Figure-2, Location map of the study area

The geographical location of Ela and Lintala weir sites were ($6^0$45’04’’ N, $37^0$47’99’’E) and ($6^0$40’ 41’’N, $37^0$38’17’’E) respectively.

Since these irrigation schemes are modern type, they are appropriate for comparison. Lintala irrigation scheme was selected because it is the only modern irrigation scheme that uses Lintala River. Ela irrigation scheme is the oldest modern scheme in the woreda. Here the long service was one of the selection criteria. Simple layout of irrigation schemes canals are shown below.

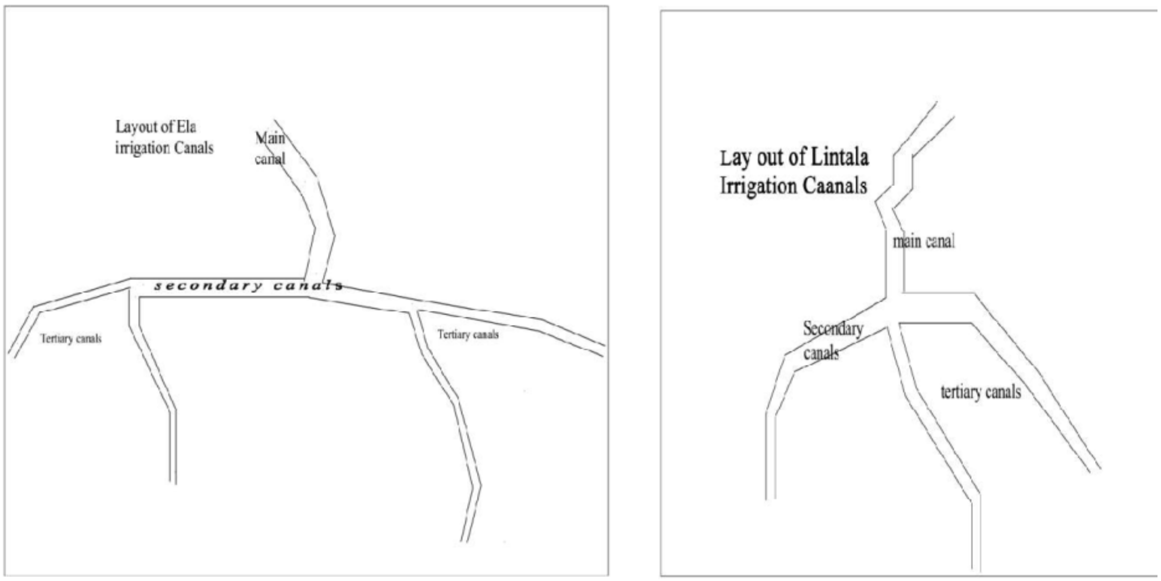

Figure-3 Canals layout of study scheme

In the selected irrigation schemes irrigation water application is border irrigation. Irrigation water is applied to individual borders from small hand dug checks from the field head ditch.

In the study Soil chemical and physical characteristics were imperative parameters looked in the irrigation schemes. Comparison of irrigation production in selected schemes is reliable if soil characteristics are similar. But the soil acidity exceeds permissible limit it may require leaching and total water supply to the plot may vary with soils acidity . Not only soil acidity, it may need treatment if mineral concentration in the soil is below or above expected ranges. The corresponding chemical and physical characteristics of soil in the irrigation schemes looked were PH, EC(ms), %OC %TN AP and CEC and Texture. Totally six samples were tested from both schemes. The first three samples from Ela and the remaining are from Lintala scheme.

Table:-3 Chemical and physical characteristics of soil in the selected schemes

Irrigation scheme	Location	Examined parameters									
								Soil type			
		PH	EC(ms)	% OC	% TN	AP (ppm) g/kg soil	CEC (meq/100g)	% of sand	% of clay	% of silt	Textural classes
Ela irrigation scheme	u/s sample site 1	6.1	0.0308	1.521	0.1311	2.62	11.92	72	7	21	Sandy loam
	Middle sample site 2	5.3	0.0285	1.638	0.1412	3.38	12.18	60	5	35	Sandy loam
	D/s sample site 3	6.4	0.0325	2.5155	0.2168	12.56	20.24	60	3	37	Sandy loam
Lintala Irrigation scheme	U/s sample site 1	6.5	0.0399	1.95	0.1681	1.26	17.72	60	7	33	Sandy loam
	Middle sample site 2	6.8	0.0406	1.365	0.1177	2.82	26.3	60	15	25	Sandy loam
	D/s sample site 3	7.1	0.0442	1.365	0.1177	1.72	34.76	62	17	21	Sandy loam

Looking the soils' profiles taken from plots of both studied schemes, no acidic behavior of all the samples and PH value was in the ranges 5.3- 7.1. So these acidic characters of all soil samples were almost similar and it could not significantly affected comparison of irrigation production. On the other hand the soil behaviors observed were not acidic, so that testing irrigation water quality was not reasonable. Because for several years these plots were under irrigation for several years and no acidic behavior was looked. Therefore logically this tells the water is not acidic and testing selected Rivers' water was not so far important.

3.3. Method of Data collection

Preliminary survey was carried out to characterize the status of the schemes under investigation. Observed parts of the schemes were Weir site, conveyance structures and distribution systems. Then after the effectiveness of the schemes were evaluated with the help of internal indicators vis efficiency, uniformity and adequacy. Effectiveness is the product of efficiency uniformity and adequacy parameters (James, 1988).

3.3.1. Internal indicators

When water is applied to a crop, fractions of the total water applied arrive at various destinations. Irrigation system evaluation points the destiny of various fractions of the total applied irrigation water. How much water enters to the crop, how much is distributed among the plants, how much of the remainder is recoverable, how much enters the ground water and surface drainage are addressed with the help of internal indicators.

a. Conveyance Efficiency

In the conveyance measure, the quantification of discharge at two selected part of canal is essential. Discharge was calculated by using area-velocity method. Both cross-sectional area and flow velocity are necessary variables in discharge calculation. So wetted canal dimensions at the selected parts were directly measured by using meter. At the binging and end of the selected canal, each 10m lengths were fixed to observe velocity of floating material. At these positions, fixed canal lengths and scored travel time of floating object (leaves) were used for velocity calculation. But actual velocity of floating material during measures was not represented the flow velocity of the water in the canal. Because the flows near the rough surface of the canal resisting and move slowly. On the other hand the flows near the surface move fast. Average flow velocity was used in the computation. It was obtained by multiplying actual velocity of floating material with float coefficient. The water depth in the canal was too shallow for that the float coefficient commonly used was 0.85.

Then the discharge at that point obtained by (eq 3.1).\

$$Q=V*A \qquad \text{Eq(3.1)}$$

Where

Q is discharge (m^3/s)

V is average flow velocity (m/s)

A is wetted cross sectional area of the canal (m^2).

Finally conveyance efficiency of the canal calculated using

$$Ce = \frac{Qf}{Qi} x100 \% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq(3.2)$$

Where

Q_f is discharge at out turn point (m^3/s)

Q_i is discharge at initial point (m^3/s)

This measure was taken in each of selected canal sections/main, secondary and tertiary canals/ in three randomly selected days. Measurement was taken once in each of selected months (December, January and February). So one day was randomly selected from the days in that month. In each of canal section conveyance measure was taken 3 times and the result is averaged. Totally in Ela and Lintala schemes 21 and 18 times conveyance measures were taken in all canals. The conveyance performance of the schemes was expressed by using weighted average of conveyance efficiencies in each of canal segments.

Canal section	Ela Canal length (km)	Lintala Canal length (km)
Main canal	1.00	0.68
Secondary canal	0.60	0.40
	0.90	0.32
Tertiary canal	0.90	0.50
	0.82	0.60
	0.68	0.70
	0.55	
All canal length	5.45	3.20

Table-4 Canal segments of Ela and Lintala irrigation schemes

All canal length in Ela and Lintala schemes were 5.45 and 3.2kms.

Comparison of conveyance performances is not reliable by using different canal conditions. Even in the same canal length, Lined and Unlined canal condition affects conveyance performance. In Ela scheme 600m was lined from main canal and the remaining part was unlined. From Lintala scheme the main canal completely lined whose length was 680m. The lined canal lengths in both schemes were more or less similar. But canal length of unlined part was not similar. From Ela and Lintala 4.85 and 2.52km canal length was unlined from total canal parts. So that conveyance efficiency of unlined canal section in Ela scheme was ideally converted in to expected conveyance efficiency, if unlined canal length of this scheme is identical with Lintala scheme's unlined canal length. The conversion expression of conveyance efficiency by considering identical canal length (2.52km) is developed and used:-

$$\eta_{(2.52km)} = 100-(100-\eta_{(4.85km)})\left[\frac{2.52km}{4.85km}\right] \text{……………………………eq(3.3)}$$

Where η is conveyance efficiency of canal

b. Application Efficiency

To measure irrigation application, sample plots which planted maize were taken from Ela and Lintala irrigation schemes. The areas of these plots were $1120m^2$ and $928m^2$. Then each plot area was divided in to 8 grids. Each of the grid samples represented the irrigation area of 140 m^2 and 116 m^2 in Ela and Lintala plots. That is 12.5% of each of selected plots.

In the irrigation application, irrigation water diverted to the selected plots and water stored in the selected crop root zone was necessary things. Hence canal dimensions near selected plots were not optimum to use floating method, 3'' Parshall Flume was selected to measure discharges entering in to the selected plots. Its' measurement was according to expression (Parshall,1950).

$$Q=Cf(H)^{nf} \text{ ………………………………………Eq(3.4)}$$

Where:

Q is discharge through the flume (cfs)

C_f is discharge coefficient

H is depth at the point of measurement (ft)

nf is discharge exponent which is depend on flume size

The volume of the water that passed through Parshall flume was computed by multiplying discharge and time elapsed. Finally the depth of irrigation water supplied to the selected plots area was determined.

To measure the water stored in the selected crop root zone, sampling depth of soil was determined first. This depth must be the root depth of the selected crop at the existing growth stage. To determine maize root depth, planted date interviewed the farmers. In Ela irrigation scheme the field measures began 32 days after selected crop/maize was planted. In Lintla irrigation scheme the field measures began 35 days after selected crop/ maize was planted. At this growth period maize exist in development stage in both selected plots. This stage is the stage from the end of the initial stage to attainment of effective full ground cover. So, 60cm depth was considered as maize root zone and sapling was taken from this depth for calculation of moisture difference before and after irrigation.

Before and after irrigation, sampling was taken from this depth. Then part of stored irrigation water in the root zone was determined by gravimetric method. In the gravimetric method the samples were dried in an oven at 105° C till constant weight of the samples achieved. It was generally for 24 hours with open steel cylindrical container. The weight of moisture was determined by deducting dried weight of soil sample from known weight of wet soil sample. It was calculated according to expression (FAO, 1989).

$$\Theta = \left(\frac{Ww - Wd}{Wd}\right) \qquad \text{Eq(3.5)}$$

Where:

Θ is soil moisture content in weight based,

W_w is wet weight of the soil in (gm) and

W_d is dry weight of the soil in (gm).

This weight based moisture content converted into volumetric moisture content by multiplying bulk density (ρ_b) and divided by specific weight of water (ρ_w). Thus soil moisture percentage in volume based was calculated using equation (FAO, 1989).

$$\Theta = \frac{\rho b}{\rho w}\left(\frac{ww - wd}{wd}\right)*100 \qquad \text{Eq(3.6)}$$

To obtain depth of stored irrigation water in the root zone, this moisture percentage on volume based was multiplied by soil sample depth. These flow observations through parshall flume and soil moisture content determination were simultaneously taken in each irrigation time. These were governed for three successive irrigation times in the selected plots. From moisture content determination in each of selected plot, 8 samples before irrigation and 8 samples after irrigation were taken in each irrigation time. Totally from each of selected plot 48 samples were used to determine moisture content of the soil before and after irrigation.

Finally using water supplied to the plot and water stored in the root zone, application efficiency was calculated with the help of:

$$Ea=\frac{Depht\ of\ water\ srored\ in\ the\ root\ zone}{Depth\ of\ water\ diverted\ to\ the\ field} * 100\ \% \text{.........................Eq(3.7)}$$

This was governed for three successive irrigation times in each of selected plots and the final result is the averaged.

c. Irrigation uniformity

For CU calculation, depths of application in the root zone were used again. Depth of application in each grid point was collected from soil samples taken from the plots before and after irrigation. Then Christiansen (1942) equation was used

$$CU= 100(1 - \frac{\sum|Xi-\bar{X}|}{\sum Xi}) \text{.................................Eq(3.9)}$$.

d. Irrigation Adequacy

Irrigation adequacy is the soils storage efficiency. So that, the soil storage capacities was determined first. In determination of soil storage capacity, soils' physical characteristics tested. These tested parameters were texture, bulk density, field capacity and permanent wilting point.

Then volume based percentage of soil storage capacity was calculated as

$$TAW= (FC-PWP) \text{...Eq(3.10)}$$

Where

TAW is available water,

FC is field capacity in volume fraction and

PWP is permanent wilting point in volume fraction.

When the soil saturates, whole pore space is filled with water and hence $\eta_{(\%)}$ is equals to θ sat. where $\eta_{(\%)}$ is porosity of the soil and θ sat is soil moisture content at saturation point. These soils saturation at 0(bar) was calculated using the equation;

$$\eta_{(\%)}=(1-\gamma_b/\gamma_d)*100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq(3.9)$$

Where $\eta_{(\%)}$ is porosity of the soil

γ_b is bulk density of the selected soil and

γ_d is particle density of the soil (2.65 gm/cm^3)

After storage capacity of the soil was determined, the maize fixed irrigation depth is decided. FAO's (1989) recommendation RAW is half of TAW is used to decide fixed maize irrigation depth when data was not available. It was obtained by multiplying the required irrigation percentage by root depth. This fixed irrigation depth in each plot was standardized to evaluate farmers' irrigation application practice.

In the selected plots, samples before and after irrigation taken were again used to determine depth of water applied. In the time of sampling, the required depth was pre calculated from soil storage capacity and available moisture. It is the ratio of applied irrigation to required irrigation.

3.3.2. External indicators

Selected external indicators in the study were water delivery indicators and water productivity. Parameters of water delivery indicators were RWS, RIS and WDC. RWS and RIS parameters show whether irrigation water demand and supply is matched. But WDC indicates whether the capacity of irrigation structure (main canal) is constraining for cropping intensities in irrigation area. The RWS and RIS parameters compared with in dry months while all the command area was irrigating.

i. RIS

To compute RIS; both irrigation water supplied and crops irrigation demand in the vegetation period was necessary in the scheme level.

Irrigation water supplied for total irrigation area was approximated from measured discharge at system head. Daily irrigation water supplied at system head was averaged from discharge measures at the morning, at noon and at late part of the day. In each month, irrigation water supplied was measured in five randomly selected days. Then result was averaged. This averaged result was considered as days' constant flow in that month.

To estimate irrigation water supplied at root zone, average of measured discharge at system head was multiplied with system efficiency. This averaged surface irrigation system efficiency is 45% (Andreas and Karen, 2002). Because of existing irrigation practice and unimproved irrigation water use in the study schemes, actually measured system efficiency was not used for this calculation.

Crops irrigation requirement, crops water requirement and effective rain fall (mm) were calculated with the help of CROPWAT software version 8.

This computer model requires input data such as ETo of study area, rain fall, crop data and soil data. Used input data in the calculation is in appendix tables.

This software first calculated ETo and effective rain fall. ETo is calculated in Penman-Monteith method and effective rain fall in USDA soil conservation service approach. In these calculations meteorological data was used. These were temperature, humidity, wind speed and sunshine hour of the day. So 20 years meteorological data was collected from nearby meteorology station. The required soil data was collected from the result of tested soil parameters in the soil laboratory. Most of the required crop data were used from FAO (1998) recommendations. By using these all information, CROPWAT was generated crop irrigation requirement, crop water requirement and effective rainfall for that specific crop. But in both study schemes variety of crops planted in different planting date was observed. Each crop type has its CWR, CIR and effective rainfall. So earlier of calculating these: planting date, crops' vegetation period and percentage of the area that covered in same crop pattern was documented by field scurvy. In the assessment the same crop which was planted within 15 days interval was grouped. Among these days interval, the middle day is considered as planting date for that pattern. Then crops pattern in each of the scheme was developed. As the result, in Ela irrigation scheme 18 crop patterns were found in the study season. Also 12 crop patterns observed in Litala irrigation scheme.

After these necessary inputs supplied to the model, it generated particular pattern crops' water required, irrigation required and effective rain fall. The scheme level crops' water required, irrigation required and effective rain fall was the weighted average of specific result.

$$ave\ irr\ requi = \frac{CIR_{maize}*Area_{maize}+CIR_{onion}*Area_{onion}+CIR_{cabbage}*+Area_{cabbage}}{total\ irrigation\ area} \text{Eq (3.8)}$$

Finally RIS was calculated using equation

$$\text{RIS}=\frac{irrigation\ watr\ supply}{irrigation\ water\ demand} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Eq (3.9}$$

ii. RWS

Total water supply and crops water demand in the scheme is required inputs in relative water supply expression. Total water supply is the sum of effective rainfall and irrigation water supplied in the scheme. Equation 3.10 is used for calculation.

$$\text{RWS}=\frac{Total\ watr\ supply}{crops\ water\ demand} \ldots\ldots\ldots\ldots\ldots\ldots\text{Eq (3.10)}$$

iii. WDC

Irrigation water carrying capacity of canal near system head and the required irrigation water flow that satisfies scheme's peak crop irrigation demand is necessary parameters. Designed canal capacity was calculated with the help of Manning' s equation 3.11. Measured canal cross-section, bed slope and appropriate n-vale during peak discharge for which the channel is designed were estimated.

$$Q = A\frac{1}{n}R^{2/3}S^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Eq(3.11)}$$

Where:

Q is design discharge (m^3/s),

A is the cross-sectional area of flow m^2,

R is hydraulic radius (m),

S is longitudinal slope of the canal and

n is Manning's coefficient

The longitudinal slope of the main canal was measured with the help of level per 50m canal length. The canal dimension at this point was measured by meter.

To estimate peak crop water demand of the scheme, peak ETc in monthly basis was calculated. Then result of the scheme peak ETc divided by averaged surface irrigation system efficiency. Finally peak crop irrigation demand in the scheme level was determined at system head and then WDC of the system was calculated using equation

$$WDC=\frac{canal\ capacity\ at\ system\ head}{peak\ consumptive\ demand}\ldots\ldots\ldots\ldots Eq(3.12)$$

IV. Water productivity

For the calculation of irrigation water productivity, irrigation water supplied with in vegetation period and selected crop (maize) dry weight was used.

Hence the irrigation water supplied for maize was measured for three successive irrigation times, total irrigation water supplied was approximated from these measured irrigation water supplied. Then dry weigh of harvested maize from these selected plots were monitored and compared. Used Expression for water use efficiency was;

$$\text{Output per crop water supplied} = \frac{Producvtion\ (kg)}{Volume\ of\ water\ diverted\ to\ farm(cum)}\ldots.Eq(3.13)$$

3.3.3. Supplementary observations in the study

The scheme status was primarily checked in field visit. In the assessment time scheme structures' functionality was observed and documented. By using the listed faults of scheme structures, farmers' management conditions attempted to address. Finally in the existing scheme management practice, the farmers' gap that contributed to water use fault was implicated. The tool used to this condition was questionnaire and interview. Finally irrigation land productivity in existing irrigation scheme management was found by using expression;

$$\text{Output per irrigated area} = \frac{producvtion}{croped\ area} \times 100 \quad \text{Eq(3.14)}$$

4. Result and discussion

4.1. Evaluation of irrigation schemes with internal indicators

The irrigation schemes' system performances were evaluated with the help of internal indicators. These results point to service rendering status of the scheme and water use conditions.

4.1.1. Conveyance efficiencies of the schemes

Conveyance efficiency of the scheme is the summation of conveyance performances of different canal segments. Weighted average of efficiencies is conveyance efficiency of the scheme.

Canal length is one of the determinants of conveyance performances. In the same condition the larger the canal length subjected to large irrigation water loss. On the other hand being lined and unlined determines the conveyance performance. In Ela irrigation scheme about 60% of the main canal length was lined and remaining 40% length was unlined. The other canal sections both secondary and tertiary canals were remained unlined. In Lintala irrigation scheme whole length of main canal was lined but the remaining sections; secondary and tertiary canals were similarly unlined. The length of specific canal sections and corresponding conveyance performances are in tables 5 and 6.

Table 5, Conveyance efficiency of the canals in Ela scheme

Scheme name	Canal section	Canal length (km)	Conveyance efficiency (%) actual canal length
Ella irrigation	Main canal	1.00	**91**
	Secondary canal	0.60	79
		0.90	75
	Tertiary canal	0.90	69
		0.82	72
		0.68	73
		0.55	75.5
	All canal length	5.45	77%

Table 6, Conveyance efficiency of the canals in Lintala scheme

Scheme name	Canal section	Canal length (km)	Conveyance efficiency (%) actual canal length
Lintala irrigation	Main canal	0.68	**93**
	Secondary canal	0.40	79
		0.32	78
	Tertiary canal	0.50	79
		0.60	77
		0.70	78
Total	All canal length	3.20	81%

In Ela and Lintala irrigation schemes the conveyance efficiencies of the canals per actual lengths were presented. Conveyance efficiency of Ela and Lintala irrigation schemes were 77% and 81% per actual canal length.

Conveyance efficiency of Lined main canal length (600m) in Ela was 96%. And conveyance efficiency of Lined main canal with length (680m) in Lintala was 93%. The line canal lengths of both schemes were more or less similar. Using these lined canal lengths, conveyance performance of Ela scheme is better than Lintala scheme.

Total unlined canal length of Ela and Lintala irrigation schemes were 4.85km and 2.52km respectively. In both irrigation schemes conveyance losses due to unlined parts of the canals were determined. In Ela scheme weighted average of conveyance efficiency of unlined canal was 74%. And in Lintala scheme weighted average of conveyance efficiency of unlined canal was 78%. But comparing conveyance performances of the schemes by using actual unlined canal length is not reliable. So that actual unlined canal length of Ela scheme is ideally converted to considered unlined canal length in Lintala. Then conveyance efficiency of Ela scheme with considered unlined canal length (2.52km) is increased to 86%. As the result within unit unlined canal length, Ela irrigation scheme conveyance performance is better than Lintala irrigation scheme. Ela scheme irrigation water management in both lined and unlined parts of the canals were better compared with Lintala scheme.

According to FAO 1997, conveyance efficiency of lined and adequately maintained canal may reach 95%. But conveyance performances of both study schemes were smaller. During investigation time many factors that contributed to conveyance losses were observed in both irrigation schemes. Some of these were larger the canal length, unlined part of canal section, weeding canal bed and breaks and leaking parts even in lined canal section.

4.1.2. Application efficiency of the schemes

If the water application of the soils has to be proper, the following results can be derived from the soils moisture retention curves. Ela soil is at PWP (15bar) where there is 66.66mm of water in the soil. Hence suction is 15bar at this point; simply water cannot be taken by plants. At FC (0.33bar), depth of moisture in this soil is 127.92mm. According to FAO's (1989) recommendation RAW is half of TAW, the crop irrigate again when moisture depletion reaches to midpoint between FC and PWP. If the maize has to be proper, it was irrigating again when moisture depletion reaches allowable moisture depletion level. This means in Ela soil selected crop irrigate again while soil moisture content is at 97.29mm. So unit application depth in Ela soil must be 30.63mm in the selected crop (maize) root zone.

And also Lintala soil is at PWP (15bar) where there is 65.22mm of water in the soil. At FC (0.33bar), depth of moisture in this soil is 121.02mm. When next irrigation is taken place at allowable moisture depletion, the crop irrigate again when moisture depletion reaches to midpoint between FC and PWP/93.12mm remains/ and the unit application depth in this soil must be 27.9mm. These results were standardized to look irrigation practices of farmers and the farmers' irrigation application.

Diverted irrigation water per unit area in the first, the second and the third irrigation time in Ela plot were 56.79, 55.49 and 54.4(mm). Also diverted irrigation water per unit area in the first, the second and the third irrigation time in Lintala plot were 48.99, 53.15 and 54.33(mm).Then available moisture contents of soils before and after irrigation was listed in tables 7 and 8. Then irrigation depth in each irrigation time was obtained by deducting moisture content before irrigation to moisture content after irrigation.

Table 7, Moisture content (mm) measured in Ela plot

Grid point	In the first irrigation time			In the second irrigation time			In the third irrigation time		
	After Irr	Before irr	Moisture difference	After irr	Before irr	Moisture difference	After irr	Before irr	Moisture difference
1	128.00	89.20	*38.80*	128.32	88.72	*39.60*	127.98	93.68	*34.30*
2	129.2	94.40	*34.80*	128.12	89.82	*38.30*	129.20	97.17	*32.03*
3	127.98	93.88	*34.10*	130.20	91.90	*38.30*	126.88	97.08	*29.80*
4	127.94	95.74	*32.20*	128.20	90.80	*37.40*	124.87	95.07	*29.80*
5	128.92	97.72	*31.20*	129.12	93.32	*35.80*	121.90	95.70	*26.20*
6	115.69	86.29	*29.40*	129.52	98.12	*31.40*	120.56	95.36	*25.20*
7	117.99	91.29	*26.70*	111.45	82.15	*29.30*	114.87	90.57	*24.30*
8	114.90	90.29	*24.70*	110.87	86.57	*24.30*	112.54	88.54	*24.00*

Table 8, Moisture content (mm) measured in Lintala plot

Grid points	In the first irrigation time			In the second irrigation time			In the third irrigation time		
	After irr	Before irr	Moisture difference	After irr	Before irr	Moisture difference	After irr	Before irr	Moisture difference
1	126.70	92.50	*34.20*	126.40	94.60	*31.80*	124.62	91.12	*33.50*
2	119.73	92.23	*27.50*	118.20	92.10	*26.10*	125.12	92.12	*33.00*
3	118.8	92.28	*26.52*	120.12	94.72	*25.40*	120.22	94.12	*26.10*
4	119.22	92.72	*26.50*	119.63	94.78	*24.85*	119.47	94.12	*25.35*
5	118.62	92.22	*26.40*	116.23	95.33	*20.90*	115.91	93.61	*22.30*
6	109.40	93.00	*16.40*	112.94	94.44	*18.50*	113.42	93.72	*19.70*
7	110.40	95.20	*15.20*	111.12	93.22	*17.90*	111.23	93.43	*17.80*
8	105.40	91.20	*14.20*	108.02	94.82	*13.20*	108.90	92	*16.90*

In Ela plot, the averages of stored irrigation depths in first, second and third irrigation events were 31.06, 33.55 and 28.03 (mm). Also in Lintala plot the averages of stored irrigation depths in first, second and third irrigation events were 22.65, 21.65 and 23.15 (mm).

Then application efficiency in the Ela plot within first, second and third irrigation phases were (55, 60 and 51) %. So application efficiency of Ela scheme was 55%. Also application efficiencies in Lintala plot within first, second and third irrigation phases were (46, 40 and 42) %. Then average irrigation application efficiencies in Lintala was 42%. So that application efficiency in Ela plot is better than Lintala.

The values of application efficiency measured in two study schemes are still in the ranges expected from such surface irrigation methods, i.e. 40 to 60 percent (FAO, 1995).

Application efficiency in Ela plot is getting larger than application efficiency in Lintala. The reason for low water application efficiency in Lintala small scale irrigation is associated to lack of technical capacity of farmers, absence of extension workers and the required trainings, absence of knowledge of irrigation time and scheduling by farmers.

4.1.3. System efficiency of the schemes

In case study, overall efficiency of the system was calculated from the above conveyance and application efficiencies. As the result irrigation schemes' system efficiency in Ela and Lintala were 42% and 34% in the study time. As the result system efficiency of Ela was better than Lintala. For surface irrigation system, averaged overall system efficiency is 45 % (Andreas and Karen, 2002). System efficiencies of the study schemes were smaller than the expected average system efficiency. This shows presence of large irrigation water losses in the selected study schemes. However irrigation water is available at the system head, system efficiency may be smaller due to farmers' irrigation water conveyance and application practice. In the study schemes gap of farmers' in irrigation water conveyance and application practice was observed. This farmers' gap may be improved through training. So that Water delivery computation is used the average of surface irrigation system efficiency instead of calculated system efficiency.

4.1.4. Irrigation uniformity

Table -9, irrigation uniformity in irrigation events

Plots	Abbreviation	In first irrigation time	In second irrigation time	In third irrigation time	Average Of irrigation uniformity.
Ela	CU	88.92	86.95	88.37	88.08
Lintala	CU	74.00	78.93	78.81	77.25

In each of the schemes the results of CU presented in the above table. CU in Ela scheme was 88 % and it was 77% in Lintala scheme. So in Ela plot irrigation distribution is better than Lintala.

4.1.5. Irrigation adequacy

Before discussing parameters of irrigation adequacy, soil characteristics that help to determine soils storage capacity were determined and the result is observed in table 10.

Table 10, Physical characteristics of the selected soil samples

Irrigation schemes	Texture	Bulk density gm/cm^3	FC (%) by volume	PWP (%) by volume
Ela	Sandy loam	1.24	21.32	11.11
Lintala	Sandy loam	1.20	20.17	10.87

Ela soil saturates when the volume base moisture content is 53.2% and also Lintala soil saturates when soil moisture content reaches 54.7%. The characteristics of the soils in the study schemes are more of less the same. From the above soils characteristics in the above table; saturation points and moisture retention capacity of the soils was illustrated in the following figure.

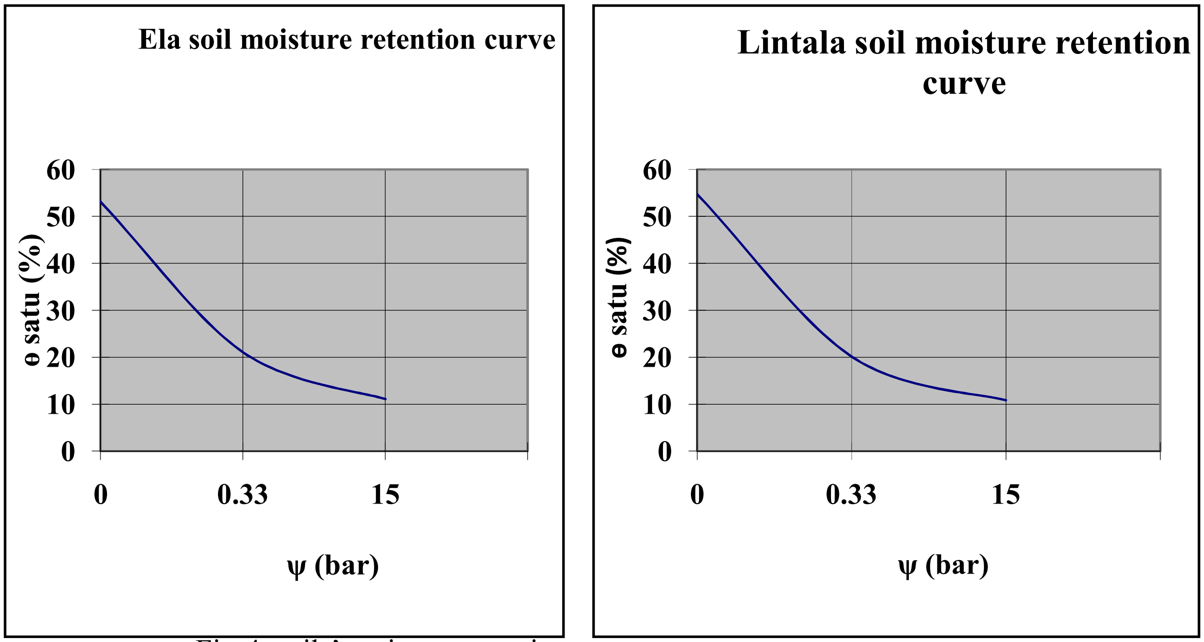

Fig-4, soils' moisture retention curve

Most of time adequacy of irrigation is expressed in terms of storage efficiency. This result tells the storage volume of the soil that obtained the required irrigation depth. According to FAO'S (1989), moisture restoration and moisture depletion must oscillate between FC to midway between FC and PWP. FC is 127.92mm and point between FC and PWP 97.29mm in Ela plot. Also moisture restoration and moisture depletion must oscillate between 121.02mm to 93.12mm in Lintala plot. In the selected plots, the maize root can absorb moisture easily when moisture amount of the soil is within these intervals. So RAW of the maize in Ela and Lintala plots were 30.63mm and 27.90mm. By putting this under consideration, the farmers' irrigation practice in each irrigation time was observed in Table below.

Table 11, The required irrigation depths, applied irrigation depths and storage efficiencies of the soils.

Plot name	Irrigation event	Required irrigation depth(mm)	Applied irrigation depth(mm)	Storage efficiency (%)	Average storage efficiency (%)
Ela plot	1	35.56	31.18	88	86%
	2	37.74	33.55	89	
	3	33.77	28.03	83	
Lintala plot	1	28.35	22.65	80	81%
	2	26.76	21.65	81	
	3	27.99	23.36	83	

Irrigation adequacy in terms of the storage efficiency was looked above. Irrigation adequacy in Ela and Lintala plots were 86% and 81% respectively. Relatively, adequacy of irrigation in Ela plot is better than Lintala. Molden and Gates (1990) recommended irrigation adequacy. The adequacy in range of (90%-100%) is good, (80%-90%) is fairly adequate and below 80% is not satisfactory irrigation. Comparing the irrigation adequacy of study schemes with this standard, both the schemes' irrigation adequacy fallen above 80%. This shows the irrigation adequacy of both study schemes were fair. But depth of application in Lintala plot was lighter compared with Ela.

In addition to this irrigation adequacy was seen with respect ETc and farmers' irrigation intervals. In the study time the maize crop was in the development stage in both of selected plots. The kc value and ETo of the study area was 0.8, and 4.76mm per day. Therefore ETC of the maize in the study area was 3.8mm per day. By using these data the application performance was evaluated with respect to maize ETc and farmer's irrigation interval. As discussed above average irrigation depth in Ela and Lintala plots were 30.88 mm and 22.48mm. So that the maize irrigation interval in Ela plot must be 8 days and it must be 6 days in Lintala plot. But actual irrigation interval that farmers were exercising in Ela plot was 13 days and it was 8 days in Lintala plot. Due to the existing irrigation practice, the maize in Ela plot was irrigating after 5 more days from expected irrigation day. But in Lintala the maize was irrigating again after 2 more days from expected irrigation day. So Ela maize was exercising more water stress until the next irrigation time. And moisture depletion before irrigation was fallen below the assumed depletion point in Ela plot. However Ela scheme was better in the refilling the soil storage volume in unit application, its irrigation interval is not taken place at assumed depletion point of the soil. It was not appropriate and the maize was in stress until the next irrigation. So that Litala irrigation interval was better to satisfy crop irrigation requirement than Ela. On the other hand, in Lintala plot farmer's application practice per irrigation time was not good in refilling the intended storage volume of the soil.

4.2. Evaluation of irrigation schemes with external indicators

The external indicators used are irrigation water delivery performances and water productivity. The water delivery performances looked with parameters RIS, RWS and WDC. The water productivity explained in terms of product (kg) and irrigation water diverted to the plot (m^3) in the base period.

4.2.1. Water delivery conditions of the schemes

In relative irrigation supply, irrigation water supplied and crops irrigation demand was listed first. Within study season irrigation water supplied in scheme level was collected in tables 12 and 15. Also ETc, CIR and effective rain fall in appendix (E-Z_8) are summarized and their weighted average in each month presented in tables 14 and 17.

a. RIS and RWS of Ela scheme

In Ela scheme both RIS and RWS was looked in the months in which 100% of the irrigation area was irrigating. These months were December, January and February. In the remaining months, farmers were not using irrigation water to irrigate only crops but also they used water for land preparation. So that irrigation water delivery performance with respect to crops irrigation requirement and ETc is not reliable in the remaining months.

Table-12, Monthly measured irrigation water supplied in Ela

Scheme	Months	Daily averaged discharge at system head(l/s)	System efficiency %	averaged daily irrigation supplied at farm level (l/s)	Daily irrigation water supplied (m^3) per 24 hr	Monthly Irrigation water supplied (mm)
Ela	Oct	128.34	45	57.75	4989.95	143.23
	Nov	135.99	45	61.20	5287.32	146.87
	Dec	129.70	45	58.36	5042.69	144.74
	Jan	119.44	45	53.75	4643.88	133.30
	Feb	129.74	45	58.38	5044.18	130.78
	Mar	113.62	45	51.13	4417.55	126.80
	Apr	124.45	45	56.00	4838.76	134.41

Table 13, CIR, effective rain fall and ETc in Ela with system efficiency 45%

Months	ETC(mm)	RAIN(mm)	IRR requi (mm)	% of irrigation area
Oct	5.95	6.82	0.23	18
Nov	36.92	27.03	9.76	82
Dece	90.55	32.41	60.31	100
Jan	144.74	28.10	115.91	100
Feb	163.34	23.71	139.75	100
March	83.30	37.95	50.21	89
April	11.97	11.18	1.57	13
May	0.80	1.17	0.00	5

Table 14, RIS and RWS in Ela scheme

Irrigation scheme	Months	RIS	RWS
Ela	Oct	622	25
	nov	15	4.7
	Dece	2.40	1.96
	Jan	1.15	1.12
	Feb	0.94	0.95
	March	2.52	1.98
	Apri	85	12.16

Both RWS and RIS relate how irrigation water supply and irrigation demand are matched. RWS and RIS value of 1 or higher indicates adequate water delivery for crops and its value less than 1 indicates inadequate water supply for crops (Beyribey, 1997; Degirmenci et al., 2003; Kuscu et al., 2008). In Ela the average RWS and RIS was found to be 0.94 and 0.95 in the month February. This is because of less rainfall in February and also River water was exploited by different users' and rate of consumption was large. So that value of RWS is almost equals to RIS. RWS and RIS values were lower than 1. This indicates that crops are not getting enough water in Ela.

b. RIS and RWS of Lintala scheme

RIS and RWS of Lintala were also looked in the months in which 100% of the irrigation area was irrigating. These months were November, December, January and February.

Table-15, Monthly measured irrigation water supplied in Lintala

Scheme	Months	Daily averaged discharge at system head(l/s)	System efficiency %	average daily irrigation supplied (l/s)	Daily irrigation water supplied (m^3) per 10 hr	Monthly Irrigation water supplied (mm)
Lintala	Oct	29.60	45	13.32	479.5	123.87
	Nov	40.82	45	18.37	661.36	165.34
	Dec	69.89	45	31.45	1132.26	292.5
	Jan	93.56	45	42.10	1515.48	391.5
	Feb	104.29	45	46.93	1689.34	394.18
	Mar	52.64	45	23.69	852.7	220.28

Table 16, CIR, effective rain fall and ETc in Lintala with system efficiency 45%

Months	ETC (mm)	RAIN(mm)	IRR requi (mm)	% of irrigation area
Oct	2.70	3.04	0.20	11
Nov	55.13	40.15	16.21	100
Dece	99.85	34.90	65.00	100
Jan	158.66	28.10	130.50	100
Feb	165.37	24.66	140.3	100
March	33.84	14.83	29.40	93

Table 17, RIS and RWS in Lintala scheme

Irrigation scheme	Months	RIS	RWS
Lintala	Oct	619	47
	Nov	10.2	3.73
	Dec	4.50	3.28
	Jan	3.00	2.64
	Feb	2.80	2.53
	Mar	7.4	7

The RIS and RWS of Lintala scheme were greater than one. In this scheme irrigation water delivery performance satisfied CWR and CIR in all time. So water delivery performance of Lintala is better than Ela irrigation scheme.

For comparisons of RIS and RWS of the schemes, the following figure is presented.

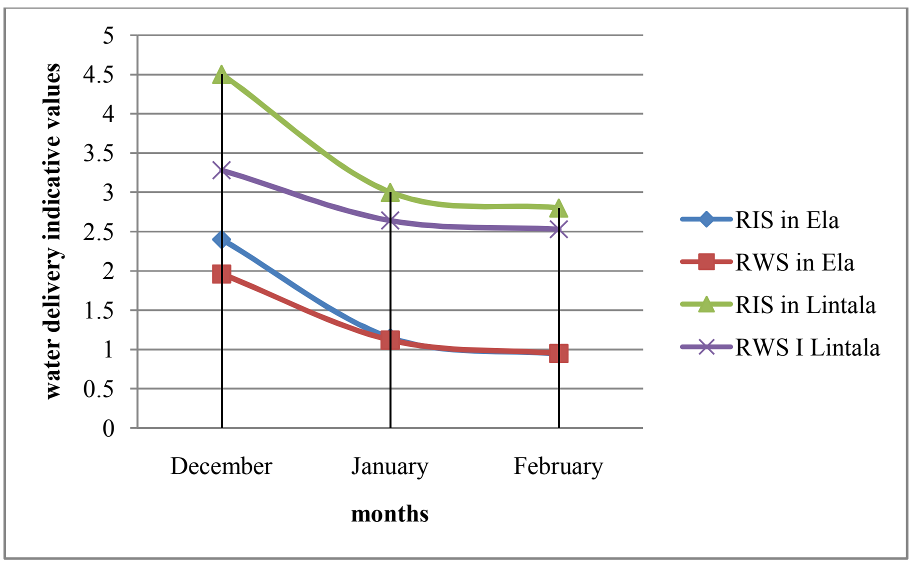

Fig-5, RWS and RIS graphs

In the study area farmers are using rain fall to produce crops in non dry time and they use irrigation in dry time, September to November was transition period from non dry time to dry time. In this time most of non dry time products were harvesting. As the result most of the plots in the schemes were unplanted and in preparation phase for the dry time plantation. On the other hand large amount of irrigation water was available. Due to this, the calculated water delivery values are much larger in these transition months. But for comparison of water delivery values of dry months were valid in which 100% of irrigation area was under irrigation.

c. Water delivery capacity

Water delivery capacity relates the crops peak irrigation water consumption to the designed canal capacity at system head. This is an indication in which irrigation structure constrains cropping intensities. The shape of canal in two schemes was rectangular. Longitudinal Slope and canal dimensions are in appendix Table C.

According to the computed results, irrigation scheme's canal capacity at heads of Ela and Lintala are 521 l/s and 207 l/s. These expressions for unit irrigation area are (4.8 and 2.95) l/s/hectare. However the designed command area of Lintala is not irrigating, the designed canal capacity is expected to irrigate designed command area that is 70ha.

In these irrigation schemes the crops peak irrigation water consumption was listed in tables 13 and 16. In both schemes peak irrigation consumption was observed in the month February. Peak monthly irrigation requirement in Ela was 139.75mm while it was 140.3mm in Lintala. In daily bases, ETC was 4.9mm/ day in Ela and 5mm /day in Lintala. These are equivalent with unit area irrigation discharge 0.56 l/s/ha and 0.57l/s/ha. These were net peak irrigation requirements in the root zone. By using these at farm level, corresponding discharges at system head was considered. The corresponding discharges at system head are 1.26l/s/ ha and 1.28l/s/ha in Ela and Lintala scheme where 45% average system efficiency was used.

Table 18, irrigation water delivery capacity of the schemes

A	B	C	D	E	F=E/D
Schemes	Peak CIR in unit farm area (l/s)/day	System efficiency %	Discharge at system head required to satisfy Peak CIR	Canal capacity at head per unit ha	WDC
Ela	0.56	45%	1.26 l/s/ha	4.8 l/s	3.8
Lintala	0.57	45%	1.28 l/s/ha	2.9 l/s	2.2

Using the computed values of canal capacities and peak CIR, the WDC at scheme level was 3.8 and 2.2 in Ela and Lintala schemes. These realized the canal capacity was not constraint to satisfy peak crops irrigation requirement in both schemes.

4.2.2. Irrigation productivity

Irrigation water productivity is the amount of output per unit water volume involved in the production, or the value added to water in a given circumstance (Molden et al. 1998). Dry weight of maize was considered for comparison of irrigation water productivity.

With the concern of Irrigation water supplied which was measured in the selected plot; total water volume involved in the maize production was estimated. The estimated irrigation water involved in the production was in Table below.

Table 19, Water productivity in the schemes

Irri/scheme	Average IWS (mm)	IF	TIWS (mm)	Product per irrigation supplied kg/m^3
Ela	55.56	8	444.48	0.89
Lintala	52.15	15	782.25	0.52

In Ela irrigation scheme weight of maize per unit volume of irrigation water diverted to the farm was 0.89 kg/m^3 and it was 0.52 kg/m^3 in Lintala irrigation scheme. So the production per irrigation water supplied, in Ela irrigation schemes was better than Lintala irrigation scheme.

The productivity of irrigation scheme by using exiting cropped area was also compared. In the field survey the existing crop patterns' planting date and their planted area was documented in both of study schemes.

Table 20-planting dates and percentage of planted area for each pattern

Patterns	Schemes					
	Ela			Lintala		
	Crops patterns	Planting date day/month	% of planted area	Crops patterns	Planting date day/month	% of planted area
1	Cabbage	18/11	2	Cabbage	11/11	5
2	Cabbage	02/12	7	Cabbage	26/11	5
3	Cabbage	18/12	4	Maize	02/11	25
4	Pepper	20/10	4	Maize	18/11	30
5	Pepper	06/11	3	Pepper	02/11	5
6	Pepper	21/11	4	Pepper	17/11	5
7	Maize	12/11	23	Onion	25/10	4
8	Maize	26/11	25	Onion	10/11	4
9	Onion	06/10	2	Onion	25/11	4
10	Onion	21/10	3	Tomato	12/10	3
11	Onion	06/11	4	Tomato	27/10	4
12	Potato	21/10	5	Tomato	12/11	6
13	Potato	05/12	4			
14	Potato	20/12	3			
15	Tomato	10/10	2			
16	Tomato	26/10	2			
17	Tomato	11/11	1			
18	Tomato	26/12	2			

As shown in Table 19 there were 18 crop patterns in Ela irrigation scheme in study time. But the crop patterns in Lintlala scheme were only 12. Crop types dominantly planting in Ela scheme were Tomatoes, Pepper, Cabbage, Maize Onion and Potato. The percentages of their cropped areas were (7, 11, 13, 48, 9 and 12). And also Tomatoes, Pepper, Cabbage, Maize and Onion were dominant crops in Lintala irrigation scheme. The percentages of corresponding crops area were (13, 10, 10, 55 and 12).

Using these crops patterns in each of study irrigation schemes, irrigation productivity in the scheme level was also surveyed. As the result the average value of each crop type productivity in 5 irrigation seasons in (kg/ha), the farmers production cost and net income was listed in the tables 21 and 22.

Table-21, crop type productivity in Ela

Crop type	Averaged total Amount of product (kg)/ha	Unit price (birr)	Total sell cost(birr)/ha	Expenditure birr /ha	Net income per (ha)
Tomato	12,360	4.6	56,856	27,161	29,695
Pepper	4,118	9.5	39,121	21,243	17,878
Cabbage	16,210	3.7	59,977	24,318	35,659
Maize	3,700	4.5	16,650	6,145	10,505
Onion	9,500	5.5	52,250	23,982	28,268
Potato	12,500	2.5	31,250	10,976	20,274

In Ela irrigation scheme the profitability of the irrigation work in a hectare area is listed in above Table-21. The revenue of the farmers by planting cabbage was more efficient. But planting maize was the least profited. The remaining crops profited between the profit of maize and cabbage. Relatively Pepper Tomato and Onion were better market crops in Ela irrigation scheme.

Table-22, Crop type productivity in Lintala

Crop type	Total Amount of product (kg)/ha	Unit price (birr)	Total sell cost	Expenditure birr/ha	Net income in birr per (ha)
Tomato	9940	3.5	34790	8986	25804
Pepper	2912	7.5	21840	5353	16487
Cabbage	14300	3.4	48620	12695	35925
Maize	3300	3.8	12540	4569	7971
Onion	5800	4.5	26100	6561	19539

The revenue of the farmers by planting cabbage was also more efficient but planting maize was the least profited. The remaining crops profit was between the profits of Maize and cabbage. In Lintala irrigation scheme Tomato, pepper and onion were relatively better profited products. The profitability of the crops in both Ela and Lintala irrigation schemes explained in terms of crop types versus profit in the following graph:

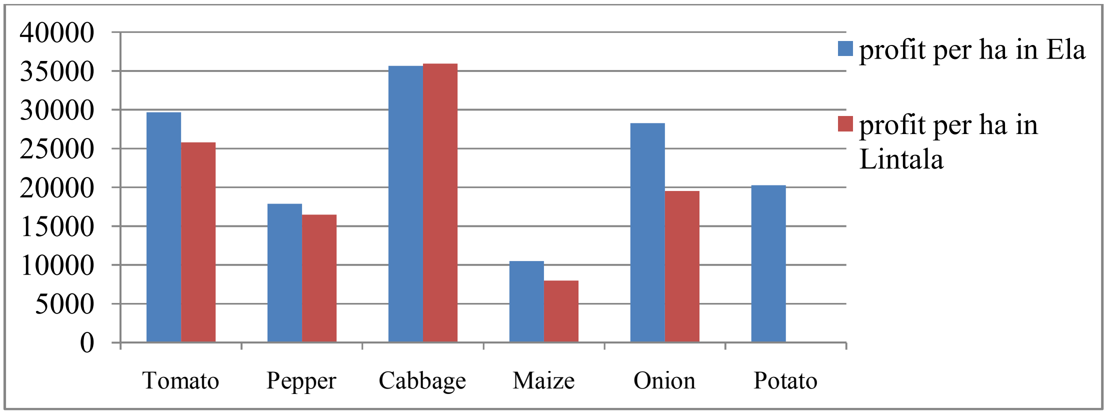

Fig-6, Profit of crops per ha

Finally the scheme productivity per ha area in Ela and Lintala were 21,354birr and 15,354birr.

So Ela was better in production per irrigation land used. From the above findings the Ela farmers' irrigation water management in canal sections and their practice in refilling water in the root zone were better compared with Lintala farmers' irrigation practice. In Ela scheme due to long year's farmers' irrigation experience, productivity of the scheme is relatively larger. In addition to better irrigation experience in Ela scheme, the scheme near the market made irrigation work to be more productive compared with Lintala. However productivity in Ela is better than Lintala some production obstruction was observed in the scheme. These were irrigation water delivery was below the required irrigation in dry season. So that irrigation water delivery required adjustment in the scheme level. On the other hand in Lintala scheme shortage of farmers' irrigation experience and lack of road access declined both productivity and profitability of irrigation works. Looking the average sell cost of each crop product, unit sell cost in Lintala scheme was below the unit sell cost in Ela irrigation scheme.

4.3. Observations results and additional imperatives in the schemes compared

Existing condition of the schemes functionality was observed and listed. Then existing management condition of the water users was checked in the study time. The observation results in each scheme discussed below.

a. Ela scheme

In Ela irrigation scheme, Weir was functional and it was delivering water to the canal accordingly. But starting from intake canal to division boxes all water control gates was uninstalled. As the result all designed water division structures were not operational. Some of intake and water division parts are in figures below.

Fig-7, Absence of water control gates in the Ela scheme

From field survey uncontrolled, unadjusted and difficulty of amounting the required discharge at head of the system was distinguished. This problem was practiced in all areas where flow control structures were not operational. In this large gap of maintenance and operation works were seen in the scheme.

Since main intake gate is not present, the intake will remain open. This provides the opportunity of river water to enter in to the canal in all time. In the time of undesired flood, water logging in the irrigation land is expected risk.

This non- functional intake and other control structures failure in Ela irrigation scheme was implicated unimproved irrigation scheme management. The farmers did not played role in maintenance of these non operational parts. They mentioned a lot of constraints to implement maintenance works. Among these; absence of water users' role and responsibilities and technical skills were the main.

According to Lempériere et al. 2014, in most community managed irrigation schemes, farmers have not recognized the irrigation organization responsibility. To manage their irrigation scheme they do not adhere to implement rules and regulations. Then irrigation community is considered to be weak and lacks sufficient authority. Due to none authorized irrigation cooperatives in Ela irrigation scheme rapid maintenance work was not done.

In addition to these observed problems of the system, other external production constraint was observed in the scheme. This was plant disease. It was observed at most of irrigation areas. Farmers were not equipped for prevention actions. So that Farmers training and capacity building is essential action to be done in this scheme. Unless and otherwise farmers cannot be productive in the irrigation activity.

Fig-8, Plant disease in Ela irrigation scheme

b. Lintala scheme

Canal head regulators are used to control the supply of water that entering to the canal. Control entry of silt to the canal and prevent the entry of undesired flood are major activities of flow controlling components (Bibhabasu, 2012). In the Lintala irrigation scheme under sluice and intake gate were not operational. Due to not operational sluice, silt was continuously accumulating in the settling basin. Then accumulated silt goes to main canal along non-functional intake. Finally silt accumulated in canal sections was influenced hydraulic performance in the intake canal as shown in figure below.

Fig-9, Non functional in take in the Lintala scheme

Lambisso, 2005 reported the assessment result on design practices and performance of small scale irrigation structures in SNNPR. His study report revealed that headwork sedimentation was observed at 11 of the 26 sample sites. This was about 42% of the selected sample sites. So this is common irrigation scheme performance constraint in the region.

On the other hand silt accumulation in the upper settling basin cease irrigation water flow in the main canal. Unless manual excavation works; no means of removing silt that comes with flood. This increased undesired work load for farmers as shown below figure.

Fig-10, Silt excavation from canals in Litala irrigation scheme

Lambisso , 2005 reported that out of 26 study sites, 13 sites main canals were highly charged with sediment. He realized in his study is that considerable number of schemes (18%) have already totally failed because of the various problems such as main canal siltation, sedimentation of the headwork, problem of seepage through foundation, main canal seepage, scouring of downstream bank, drying of rivers, damage on impervious and flexible apron, change of river course, damage of under sluices and damage on cross drainage works.

In addition to observed problems of the system, external notable production constraints in this scheme were listed. These are absence of road access and potable water. Due to these reasons, most of irrigation land owners were not accommodated in their irrigation land. These contributed for weak cooperation and inappropriate scheme management activity.

c. Schemes management condition

Scheme management is universal work that mobilizes all irrigation scheme activities. Some of the activities intended to be done by management bodies are; collection of irrigation service fee, organization and supervision of collective maintenance work, book keeping, preparation of financial and activities reports, and internal auditing of IWUAs finance (Lempériere et al. 2014).

Keeping the irrigation system operational is aim of maintenance action. The major activities included here are; inspection of the system and identification of maintenance needs, establishing the calendar for maintenance works, budget maintenance works, implement and monitor maintenance works.

Ensuring the fair share of irrigation water for IWUA members is out came of operation works. The major activities included here are; establishing crop calendar and crop pattern, implement and enforce water distribution rules, adjust water distribution according to crop pattern and arbitrate conflicts about water between farmers.

The intended activity of general assembly is actively participating in the meeting and that build up democratic decisions.

The administrative members of Ela irrigation scheme 23 in number. Among these 7 were major chiefs. In Lintala scheme only 3 management committees were exist. From these management bodies, 1 is chief of management, 1 is secretary and 1 is financial coordinator. As the result Ela scheme has more administrative members than Lintala.

Also the administrative structures of Ela irrigation scheme comprise more work positions.

In Ela irrigation scheme the actual activities completed by management bodies were enforce IWUA by-laws and operational rules, collection of yearly irrigation service fee which is in flat rate 50 birr/user and apply sanction for none or late payment of irrigation service fee. But in Lintala irrigation scheme; unless operation and canal clearing works, almost all management activities listed in the questionnaire were ignored.

But from the intended works to be done by irrigation management bodies, some were not completely done by scheme administration members. These are preparation of physical and financial reports, lack of communication procedures from both upper and lower management level/woreda and IWUAs/ and lack internal auditing was unusual activity and still not adopted in both schemes. These shows lack of transparency and democratic administration system. If reports and communications not present in the management system, it is difficult to ensure collected fee is investing on the irrigation works.

It is realized that the success of irrigation projects depend on the participation of the beneficiaries in all phases (conception, planning, construction and operation) of the project (Douglas, 1999). But in the study schemes general assembly was not considering their roles and responsibilities. So that weak WUAs were observed in these schemes.

5. Conclusion

The status of irrigation water management in both of selected schemes was explored with the help of internal indicators. Internal indicators; conveyance and application efficiencies, adequacy and uniformity of irrigation were found in the study. Conveyance efficiency of Ela and Lintala irrigation schemes per actual canal lengths were 77% and 81%. But considering conveyance canals' conveyance performance in both lined and unlined condition Ela farmers irrigation water management was relatively better compared with Lintala scheme farmers management during water transports (from river to the field).

But considerable amount of irrigation water was losing from both irrigation schemes during irrigation water conveyance. In both schemes more irrigation water loss was found in unlined canal sections. In addition to this, accumulation of silt within the canal and non functionality of division and diversion structures contributed irrigation water losses.

Field application efficiency mainly depend on irrigation method and farmers discipline. According to FAO 1997, surface irrigation system field application efficiency in good farmers' discipline can attained to 60% in average. Application efficiency of the study schemes were 55% and 42% in Ela and Lintala irrigation schemes. However this unit application result is better it may not telling the farmers water application is answering crops irrigation requirement. Ela irrigation scheme was better in irrigation application than Lintala. Despite application efficiency, storage efficiency is better to tell irrigation farmers' applied irrigation water is answering crops water requirement.

Due to conveyance and application losses only 42% and 34% of diverted irrigation water reached to the crop root zone in Ela and Lintala scheme. These results are below the average surface irrigation system efficiency. Lintala has larger rate of irrigation water loses in system.

CU was 88% in Ela and it was 77% in Lintala irrigation schemes. Thus irrigation uniformity of Ela irrigation scheme was better than Lintala and this implicated good experience of Ela irrigation farmers water management in the field. Adequacy of irrigation in Ela and Lintala irrigation schemes were 86% and 81%. In both study schemes, however storage efficiency values were satisfactory; it may not be satisfactory when farmers' irrigation interval is larger than necessary irrigation interval. In existing farmers' irrigation interval, Crops water requirement cannot answer in Ela scheme. In this plot the maize was keep on under stress before next irrigation time. So that some modifications of irrigation scheduling is necessary but Lintala scheme irrigation interval was relatively better than Ela scheme irrigation interval.

RWS and RIS in Lintala irrigation scheme were greater than one through the irrigation time. RIS varies from 2.8-4.5 where as RWS varies from 2.53-3.73. This expresses irrigation water delivery performance of the scheme could answer crop water demand in the scheme. RIS and RWS of Ela scheme varies from 0.94-2.4 and 0.95-1.96. Similarly, RIS and RWS of Ela scheme were also greater than one in December and January. But RIS and RWS in February was less than one. So that in this scheme water delivery performance couldn't answered crop water demand in February.

WDC of Ela and Lintala are 3.8 and 2.2. In both of study schemes, canal capacity was enough to carry required irrigation water which satisfies peak crops irrigation demand.

The production per unit irrigation supplied in Ela and Lintala were (0.89 and 0.52) kg/m^3. Ela irrigation scheme is relatively good in irrigation water productivity. Long years irrigation practice of the farmers and good irrigation water management in during water conveyance and application phases lead for this better irrigation production and also this scheme was more profitable in irrigation activity compared with Lintala.

Rather than specific crop profitability, each crop product per unit area was assessed in both irrigation schemes. Cabbage Tomato and onion were market effective crops in the study areas and high profited as well. But maize was the least profited. In Ela and Lintala schemes 48% and 55% of irrigation area was planted maize in the study time. However vegetables and fruits were more profiting crops in the schemes, farmers were dominantly planting least profited crop maize. In Ela, Farmers considered the maize as more disease resistance crop and in Lintala scheme, farmers considering it as easily producing crop. In addition to the mentioned low irrigation water use efficiency, farmers' consideration in the selection of effective crop plantation was contributed for low profitability in both irrigation schemes.

During field observation lot of non operational parts of the scheme structures were seen in both irrigation schemes. In case of these non operational parts, a lot of irrigation water was losing in the time of operation. This gap played great role in declining irrigation water use performance. On the other hand these non operational parts hindered hydraulics in the scheme. As the result irrigation activity was tedious especially in Lintala irrigation scheme. Unless immediate solution is given, the scheme is not secured from complete failure.

The scheme management issues in both study sites found that there was no any satisfactory management activity completed in both schemes. Presence of fractured irrigation structures starting from head work to the division box was observed. Non-functionalities of flow control gates and division boxes were observed mistake of the systems and still kept without maintenances in both schemes.

Ela irrigation scheme management structure was structurally better than Lintala irrigation scheme. But they were similar in failure of management activities that must be performed technically and financially. Most of members of IWUAs were not considering the role of their involvement in decision making and budgeting. This indicated the IWUAs were not equipped and not skilled in scheme administration.

In each of studied irrigation schemes there were external problems that hinder the rate of irrigation productions. In Ela irrigation scheme plant disease was out of control that discouraged the irrigation agriculture. In Lintala, problem of infrastructure was taken large part in the reduction of product. The lack of road access forced the farmers' product to be cheap. The lack of potable water in the area made irrigation land owners not to settle. This problem indirectly injured the organization of irrigation water users. Then weak scheme management system was adopted here. So farmers must be equipped through training.

6. Recommendation

Results of internal and external performance indicators pointed out performance level of the study schemes. From the research finding the following points are recommended.

- Earthen canal sections contributed for large irrigation water losses and lining unlined canal section is recommended.
- System efficiency, adequacy and irrigation uniformity in Lintala was performed below the Ela. Lighter irrigation practice was adopted by farmers. So that irrigation practice of farmers in Lintala scheme should be supported by training and experience sharing is important.
- Structural failures were common in both study schemes and system maintenance is essential.
- Strengthening water users association in the schemes use is very vital for better management of the schemes.
- Despite high canal capacity in Ela, RIS and RWS are below one in driest period. Its irrigating area is larger than the designed command area. So adjustment of water distribution schedule with crops pattern may reduce water losses.
- Further scientific investigation on the area of agronomical problems is very important in Ela irrigation scheme.

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APPENDIXES

1. **Appendix Tables**

Table A, Supplied irrigation water measures with the help of 3" parshal flume

Irrigation scheme	Plots	Irrigation phase	Parshal flume reading (cm)	Elapsed time (sec)	Discharge in (l/s)	Irrigation volume(m^3)	Irrigation area(m^2)	Irrigation depth in (mm)
Ela irrigation	Plot1	1	14	7564.00	**8.41**	63.61	1120.00	56.80
		2	13	8297.00	**7.49**	62.14	1120.00	55.49
		3	13	8132.00	**7.49**	60.91	1120.00	54.38
Lintala irrigation	Plot2	1	15	4862.00	**9.35**	45.46	928.00	48.99
		2	14	5865.00	**8.41**	49.32	928.00	53.15
		3	16	4876.00	**10.34**	50.42	928.00	54.33

Table B, Used soil data in CWR calculation

Schemes	Ela	Lintala
Soil type	Sandy loam	Sandy loam
FC-PWP	102mm/m	93mm/m
Maximum root depth (cm)	100	100
Initial soil moisture depletion	50%	50%
Initial available soil moisture	51mm/m	46.5

Table C, calculated canal capacity

Canal dimensions	Ela	Lintala
Width	1	0.6
Height	0.7	0.6
Slop per 50m	0.00101	0.001
Cross- sectional area(m^2)	0.7	0.36
Wetted Perimeter (m)	2.4	1.8
Hydraulic radius(m)	0.291667	0.2
n value for lined canals	0.015	0.015
Discharge (m^3/s)	0.652267	0.259556
20% free board	0.130453	0.051911
Designed canal capacity (l/s)	521.814	207.645

Table D, Used crops data in CWR calculation

Crop type	Crop features	Vegetation period			
		initial	Development	Mid-season	Late season
Cabbage	Kc	0.7	1.5		0.95
	stages	30	30	35	25
	Rooting depth	0.2		0.4	
	Critical depletion fraction	0.4		0.5	0.5
	Yield response factor	0.4	1.1	0.8	0.4
Pepper	Kc	0.6	1.05		0.9
	stages	30	40	30	25
	Rooting depth	0.2		0.7	
	Critical depletion fraction	0.5		0.5	0.5
	Yield response factor	0.45	0.9	0.7	0.2
Onion	kc	0.7	1		1
	stages	30	35	40	20
	Rooting depth	0.2		0.4	
	Critical depletion fraction	0.4		0.5	0.5
	Yield response factor	0.4	1.1	0.8	0.4
Tomato	kc	0.6	1.15		0.75
	stages	30	35	40	30
	Rooting depth	0.3		0.5	
	Critical depletion fraction	0.5		0.5	0.5
	Yield response factor	0.4	1.1	0.8	0.4
Potato	kc	0.6	1.15		0.75
	stages	30	35	40	30
	Rooting depth	0.3		0.5	
	Critical depletion fraction	0.5		0.5	0.5
	Yield response factor	0.4	1.1	0.8	0.4
Maize	kc	0.7	1.2		0.6
	stages	35	35	35	15
	Rooting depth	0.3		1	
	Critical depletion fraction	0.4		0.5	0.6
	Yield response factor	0.4	1.5	0.5	0.2

Table E, cabbage water requirement in Ela pattern 1 with planting date18/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.7	2.84	8.5	6.2	8.5
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Deve	0.71	2.85	28.5	10.6	17.9
Dec	3	Deve	0.81	3.44	37.9	10.2	27.7
Jan	1	Deve	0.93	4.2	42	10	31.9
Jan	2	Mid	1.04	4.93	49.3	9.2	40.1
Jan	3	Mid	1.05	5.27	58	8.9	49.1
Feb	1	Mid	1.05	5.6	56	7.1	48.9
Feb	2	Mid	1.05	5.89	58.9	6	52.9
Feb	3	Late	1.04	5.59	44.8	11.9	32.9
Mar	1	Late	1	5.18	51.8	18.4	33.4
Mar	2	Late	0.97	4.85	33.9	16.4	10.5
					526	146.8	378.5

Table F, cabbage water requirement in Ela pattern 2 with planting date 02/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.7	2.83	25.4	12.6	11.4
Dec	2	Init	0.7	2.82	28.2	10.6	17.6
Dec	3	Init	0.7	2.99	32.9	10.2	22.7
Jan	1	Deve	0.77	3.46	34.6	10	24.6
Jan	2	Deve	0.89	4.21	42.1	9.2	32.9
Jan	3	Mid	1.01	5.05	55.6	8.9	46.7
Feb	1	Mid	1.06	5.63	56.3	7.1	49.1
Feb	2	Mid	1.06	5.92	59.2	6	53.2
Feb	3	Mid	1.06	5.72	45.8	11.9	33.9
Mar	1	Late	1.05	5.46	54.6	18.4	36.2
Mar	2	Late	1.02	5.11	51.1	23.5	27.7
Mar	3	Late	0.97	4.64	51	28.9	22.1
					536.8	157.4	378

Table G, cabbage water requirement in Ela pattern 3 with planting date 18/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.7	2.82	8.5	3.2	8.5
Dec	3	Init	0.7	2.99	32.9	10.2	22.7
Jan	1	Init	0.7	3.16	31.6	10	21.6
Jan	2	Deve	0.71	3.39	33.9	9.2	24.7
Jan	3	Deve	0.82	4.09	45	8.9	36.1
Feb	1	Deve	0.94	5.01	50.1	7.1	42.9
Feb	2	Mid	1.04	5.83	58.3	6	52.3
Feb	3	Mid	1.05	5.7	45.6	11.9	33.7
Mar	1	Mid	1.05	5.46	54.6	18.4	36.2
Mar	2	Mid	1.05	5.29	52.9	23.5	29.5
Mar	3	Late	1.03	4.94	54.4	28.9	25.4
Apr	1	Late	0.99	4.47	44.7	35.7	9
Apr	2	Late	0.95	4.07	24.4	25	3.6
					536.9	198	346.2

Table H, pepper water requirement in Ela pattern 4 with planting date 20/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.6	2.39	2.4	3.3	2.4
Oct	3	Init	0.6	2.4	26.4	29.1	0
Nov	1	Init	0.6	2.42	24.2	24.4	0
Nov	2	Deve	0.6	2.45	24.5	20.8	3.7
Nov	3	Deve	0.68	2.76	27.6	17.7	9.9
Dec	1	Deve	0.79	3.2	32	14.1	17.9
Dec	2	Deve	0.9	3.63	36.3	10.6	25.7
Dec	3	Mid	1.01	4.32	47.5	10.2	37.3
Jan	1	Mid	1.04	4.69	46.9	10	36.9
Jan	2	Mid	1.04	4.95	49.5	9.2	40.3
Jan	3	Late	1.03	5.18	57	8.9	48
Feb	1	Late	0.99	5.26	52.6	7.1	45.5
Feb	2	Late	0.94	5.24	52.4	6	46.4
Feb	3	Late	0.91	4.91	4.9	1.5	4.9
					484.2	173	318.9

Table I, pepper water requirement in Ela pattern 5 with planting date 06/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.6	2.42	12.1	12.2	0
Nov	2	Init	0.6	2.44	24.4	20.8	3.6
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Deve	0.62	2.49	24.9	14.1	10.8
Dec	2	Deve	0.72	2.89	28.9	10.6	18.3
Dec	3	Deve	0.84	3.57	39.3	10.2	29.1
Jan	1	Deve	0.95	4.31	43.1	10	33.1
Jan	2	Mid	1.04	4.97	49.7	9.2	40.5
Jan	3	Mid	1.05	5.26	57.8	8.9	48.9
Feb	1	Mid	1.05	5.59	55.9	7.1	48.7
Feb	2	Late	1.03	5.79	57.9	6	51.9
Feb	3	Late	0.98	5.32	42.6	11.9	30.7
Mar	1	Late	0.93	4.83	48.3	18.4	29.9
					509.1	157.1	352.1

Table J, pepper water requirement in Ela pattern 6 with planting date 21/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Init	0.6	2.42	24.2	14.1	10.2
Dec	2	Init	0.6	2.41	24.1	10.6	13.5
Dec	3	Deve	0.67	2.86	31.4	10.2	21.2
Jan	1	Deve	0.79	3.57	35.7	10	25.6
Jan	2	Deve	0.9	4.31	43.1	9.2	33.8
Jan	3	Mid	1.02	5.12	56.3	8.9	47.4
Feb	1	Mid	1.06	5.64	56.4	7.1	49.2
Feb	2	Mid	1.06	5.93	59.3	6	53.3
Feb	3	Mid	1.06	5.73	45.8	11.9	34
Mar	1	Late	1.02	5.31	53.1	18.4	34.7
Mar	2	Late	0.96	4.83	48.3	23.5	24.8
Mar	3	Late	0.91	4.36	21.8	13.2	7.3
					523.8	160.7	361.7

Table K, maize water requirement in Ela pattern 7 with planting date 12/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.7	2.84	25.6	18.7	4.8
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Deve	0.71	2.88	28.8	10.6	18.2
Dec	3	Deve	0.84	3.61	39.7	10.2	29.5
Jan	1	Deve	1	4.5	45	10	35
Jan	2	Deve	1.14	5.44	54.4	9.2	45.1
Jan	3	Mid	1.21	6.04	66.5	8.9	57.6
Feb	1	Mid	1.21	6.42	64.2	7.1	57.1
Feb	2	Mid	1.21	6.76	67.6	6	61.6
Feb	3	Late	1.16	6.25	50	11.9	38.2
Mar	1	Late	0.82	4.27	42.7	18.4	24.3
Mar	2	Late	0.6	3.03	3	2.3	3
					544	145.2	399.1

Table L, maize water requirement in Ela pattern 8 with planting date 26/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.7	2.83	14.2	8.9	5.3
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Init	0.7	2.82	28.2	10.6	17.6
Dec	3	Deve	0.7	2.99	32.9	10.2	22.7
Jan	1	Deve	0.79	3.59	35.9	10	25.9
Jan	2	Deve	0.94	4.48	44.8	9.2	35.6
Jan	3	Deve	1.09	5.48	60.2	8.9	51.3
Feb	1	Mid	1.21	6.42	64.2	7.1	57
Feb	2	Mid	1.21	6.78	67.8	6	61.8
Feb	3	Mid	1.21	6.55	52.4	11.9	40.5
Mar	1	Mid	1.21	6.27	62.7	18.4	44.3
Mar	2	Late	0.99	4.96	49.6	23.5	26.1
Mar	3	Late	0.68	3.25	16.3	13.2	1.8
					557.3	151.9	404.1

Table M, onion water requirement in Ela pattern 9 with planting date 6/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	1	Init	0.7	2.66	13.3	16.3	0
Oct	2	Init	0.7	2.78	27.8	33.1	0
Oct	3	Init	0.7	2.8	30.8	29.1	1.8
Nov	1	Deve	0.72	2.89	28.9	24.4	4.5
Nov	2	Deve	0.79	3.22	32.2	20.8	11.4
Nov	3	Deve	0.87	3.53	35.3	17.7	17.6
Dec	1	Mid	0.95	3.84	38.4	14.1	24.4
Dec	2	Mid	0.98	3.95	39.5	10.6	28.9
Dec	3	Mid	0.98	4.19	46	10.2	35.9
Jan	1	Mid	0.98	4.43	44.3	10	34.2
Jan	2	Late	0.98	4.68	46.8	9.2	37.6
Jan	3	Late	1	5	55	8.9	46.1
Feb	1	Late	1	5.31	37.2	5	30.1
					475.5	209.4	272.3

Table N, onion water requirement in Ela pattern 10 with planting date 21/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.7	2.8	30.8	29.1	1.8
Nov	1	Init	0.7	2.82	28.2	24.4	3.8
Nov	2	Deve	0.7	2.84	28.4	20.8	7.6
Nov	3	Deve	0.75	3.05	30.5	17.7	12.8
Dec	1	Deve	0.84	3.38	33.8	14.1	19.7
Dec	2	Deve	0.92	3.7	37	10.6	26.4
Dec	3	Mid	0.99	4.21	46.3	10.2	36.1
Jan	1	Mid	0.99	4.47	44.7	10	34.7
Jan	2	Mid	0.99	4.71	47.1	9.2	37.9
Jan	3	Mid	0.99	4.96	54.5	8.9	45.6
Feb	1	Late	1.01	5.35	53.5	7.1	46.3
Feb	2	Late	1.01	5.65	56.5	6	50.5
Feb	3	Late	1.01	5.46	10.9	3	10.9
					502.3	171.1	334.2

Table O, onion water requirement in Ela pattern 11 with planting date 06/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.7	2.82	14.1	12.2	1.9
Nov	2	Init	0.7	2.84	28.4	20.8	7.6
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Deve	0.71	2.88	28.8	14.1	14.7
Dec	2	Deve	0.79	3.18	31.8	10.6	21.2
Dec	3	Deve	0.88	3.76	41.3	10.2	31.2
Jan	1	Mid	0.97	4.38	43.8	10	33.8
Jan	2	Mid	1	4.76	47.6	9.2	38.4
Jan	3	Mid	1	5.01	55.1	8.9	46.2
Feb	1	Mid	1	5.32	53.2	7.1	46.1
Feb	2	Late	1	5.6	56	6	50
Feb	3	Late	1	5.43	43.4	11.9	31.6
Mar	1	Late	1	5.21	52.1	18.4	33.7
					524	157.1	366.9

Table P, Potato water requirement in Ela pattern 12 with planting date 21/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.5	2	22	29.1	0
Nov	1	Init	0.5	2.02	20.2	24.4	0
Nov	2	Deve	0.5	2.04	20.4	20.8	0
Nov	3	Deve	0.62	2.5	25	17.7	7.3
Dec	1	Deve	0.8	3.23	32.3	14.1	18.3
Dec	2	Deve	0.98	3.96	39.6	10.6	29
Dec	3	Mid	1.13	4.82	53	10.2	42.9
Jan	1	Mid	1.14	5.14	51.4	10	41.4
Jan	2	Mid	1.14	5.42	54.2	9.2	45
Jan	3	Mid	1.14	5.7	62.7	8.9	53.8
Feb	1	Late	1.09	5.82	58.2	7.1	51
Feb	2	Late	0.97	5.42	54.2	6	48.2
Feb	3	Late	0.85	4.62	36.9	11.9	25.1
Mar	1	Late	0.78	4.03	16.1	7.4	6.9
					546.4	187.4	368.9

Table Q, Potato water requirement in Ela pattern 13 with planting date 05/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.5	2.02	12.1	8.4	5.1
Dec	2	Init	0.5	2.01	20.1	10.6	9.5
Dec	3	Init	0.5	2.13	23.5	10.2	13.3
Jan	1	Deve	0.55	2.49	24.9	10	14.9
Jan	2	Deve	0.73	3.49	34.9	9.2	25.7
Jan	3	Deve	0.93	4.66	51.2	8.9	42.3
Feb	1	Mid	1.12	5.93	59.3	7.1	52.2
Feb	2	Mid	1.16	6.46	64.6	6	58.6
Feb	3	Mid	1.16	6.24	50	11.9	38.1
Mar	1	Mid	1.16	5.99	59.9	18.4	41.5
Mar	2	Late	1.15	5.8	58	23.5	34.5
Mar	3	Late	1.06	5.06	55.6	28.9	26.7
Apr	1	Late	0.91	4.14	41.4	35.7	5.7
Apr	2	Late	0.79	3.38	27	33.4	0
					582.6	222.2	368.1

Table R, Potato water requirement in Ela pattern 14 with planting date 20/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.5	2.01	2	1.1	2
Dec	3	Init	0.5	2.13	23.5	10.2	13.3
Jan	1	Init	0.5	2.26	22.6	10	12.6
Jan	2	Deve	0.51	2.41	24.1	9.2	14.8
Jan	3	Deve	0.65	3.25	35.7	8.9	26.8
Feb	1	Deve	0.84	4.49	44.9	7.1	37.7
Feb	2	Deve	1.03	5.76	57.6	6	51.6
Feb	3	Mid	1.15	6.2	49.6	11.9	37.8
Mar	1	Mid	1.15	5.96	59.6	18.4	41.2
Mar	2	Mid	1.15	5.78	57.8	23.5	34.3
Mar	3	Mid	1.15	5.49	60.4	28.9	31.5
Apr	1	Late	1.11	5.03	50.3	35.7	14.7
Apr	2	Late	0.98	4.18	41.8	41.7	0.1
Apr	3	Late	0.84	3.4	34	42.3	0
May	1	Late	0.75	2.87	8.6	13	0
					572.5	267.9	318.3

Table S, Tomato water requirement in Ela pattern 15 with planting date 10/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	1	Init	0.6	2.28	2.3	3.3	2.3
Oct	2	Init	0.6	2.39	23.9	33.1	0
Oct	3	Init	0.6	2.4	26.4	29.1	0
Nov	1	Deve	0.6	2.44	24.4	24.4	0
Nov	2	Deve	0.71	2.9	29	20.8	8.2
Nov	3	Deve	0.87	3.5	35	17.7	17.3
Dec	1	Deve	1.02	4.11	41.1	14.1	27
Dec	2	Mid	1.13	4.54	45.4	10.6	34.8
Dec	3	Mid	1.13	4.83	53.1	10.2	43
Jan	1	Mid	1.13	5.11	51.1	10	41.1
Jan	2	Mid	1.13	5.39	53.9	9.2	44.6
Jan	3	Late	1.08	5.41	59.5	8.9	50.6
Feb	1	Late	0.95	5.05	50.5	7.1	43.4
Feb	2	Late	0.82	4.61	46.1	6	40.1
Feb	3	Late	0.76	4.08	4.1	1.5	4.1
					545.7	206	356.3

Table T, Tomato water requirement in Ela pattern 16 with planting date 26/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.6	2.4	14.4	15.9	0
Nov	1	Init	0.6	2.42	24.2	24.4	0
Nov	2	Init	0.6	2.44	24.4	20.8	3.6
Nov	3	Deve	0.63	2.56	25.6	17.7	7.9
Dec	1	Deve	0.78	3.14	31.4	14.1	17.4
Dec	2	Deve	0.93	3.76	37.6	10.6	27
Dec	3	Mid	1.09	4.67	51.4	10.2	41.2
Jan	1	Mid	1.14	5.17	51.7	10	41.7
Jan	2	Mid	1.14	5.45	54.5	9.2	45.3
Jan	3	Mid	1.14	5.73	63	8.9	54.1
Feb	1	Late	1.14	6.05	60.5	7.1	53.3
Feb	2	Late	1.03	5.79	57.9	6	51.9
Feb	3	Late	0.92	4.97	39.7	11.9	27.9
Mar	1	Late	0.81	4.19	37.7	16.6	19.3
					574	183.4	390.5

Table U, Tomato water requirement in Ela pattern 17 with planting date 11/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.6	2.44	24.4	20.8	3.6
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Init	0.6	2.42	24.2	14.1	10.2
Dec	2	Deve	0.69	2.76	27.6	10.6	17
Dec	3	Deve	0.85	3.64	40.1	10.2	29.9
Jan	1	Deve	1.02	4.6	46	10	36
Jan	2	Mid	1.14	5.44	54.4	9.2	45.2
Jan	3	Mid	1.15	5.77	63.5	8.9	54.6
Feb	1	Mid	1.15	6.13	61.3	7.1	54.2
Feb	2	Mid	1.15	6.45	64.5	6	58.5
Feb	3	Late	1.13	6.1	48.8	11.9	36.9
Mar	1	Late	1.01	5.25	52.5	18.4	34.1
Mar	2	Late	0.88	4.41	44.1	23.5	20.7
Mar	3	Late	0.78	3.72	18.6	13.2	4.1
					594.2	181.5	411.4

Table V, Tomato water requirement in Ela pattern 18 with planting date 26/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.6	2.56	15.4	5.6	10.3
Jan	1	Init	0.6	2.71	27.1	10	17.1
Jan	2	Init	0.6	2.86	28.6	9.2	19.3
Jan	3	Deve	0.64	3.2	35.2	8.9	26.3
Feb	1	Deve	0.79	4.23	42.3	7.1	35.1
Feb	2	Deve	0.95	5.32	53.2	6	47.2
Feb	3	Deve	1.09	5.9	47.2	11.9	35.3
Mar	1	Mid	1.15	5.94	59.4	18.4	41
Mar	2	Mid	1.15	5.76	57.6	23.5	34.1
Mar	3	Mid	1.15	5.48	60.2	28.9	31.3
Apr	1	Late	1.14	5.19	51.9	35.7	16.2
Apr	2	Late	1.06	4.52	45.2	41.7	3.5
Apr	3	Late	0.92	3.73	37.3	42.3	0
May	1	Late	0.78	3.02	27.2	38.9	0
					587.7	288.1	316.7

Table W, Cabbage water requirement in Lintala pattern 1 with planting date 11/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.7	2.84	28.4	20.8	7.6
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Deve	0.76	3.07	30.7	10.6	20.1
Dec	3	Deve	0.89	3.78	41.6	10.2	31.4
Jan	1	Mid	1.01	4.55	45.5	10	35.5
Jan	2	Mid	1.05	4.99	49.9	9.2	40.7
Jan	3	Mid	1.05	5.25	57.8	8.9	48.9
Feb	1	Mid	1.05	5.58	55.8	7.1	48.7
Feb	2	Late	1.04	5.81	58.1	6	52.1
Feb	3	Late	1.01	5.44	43.5	11.9	31.7
Mar	1	Late	0.97	5.04	50.4	18.4	32
					518.5	144.9	373.5

Table X, Cabbage water requirement in Lintala pattern 2 with planting date 26/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.7	2.83	14.2	8.9	5.3
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Init	0.7	2.82	28.2	10.6	17.6
Dec	3	Deve	0.72	3.09	33.9	10.2	23.8
Jan	1	Deve	0.84	3.78	37.8	10	27.8
Jan	2	Deve	0.96	4.55	45.5	9.2	36.3
Jan	3	Mid	1.05	5.26	57.8	8.9	48.9
Feb	1	Mid	1.06	5.62	56.2	7.1	49.1
Feb	2	Mid	1.06	5.92	59.2	6	53.2
Feb	3	Mid	1.06	5.71	45.7	11.9	33.9
Mar	1	Late	1.03	5.36	53.6	18.4	35.2
Mar	2	Late	0.99	4.98	49.8	23.5	26.3
Mar	3	Late	0.96	4.58	22.9	13.2	8.4
					533	151.9	379.8

Table Y, Maize water requirement in Lintala pattern 3 with planting date 2/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.7	2.82	25.4	22	1
Nov	2	Init	0.7	2.84	28.4	20.8	7.6
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Deve	0.71	2.88	28.8	14.1	14.8
Dec	2	Deve	0.84	3.36	33.6	10.6	23
Dec	3	Deve	0.99	4.21	46.3	10.2	36.1
Jan	1	Deve	1.14	5.13	51.3	10	41.3
Jan	2	Mid	1.2	5.71	57.1	9.2	47.9
Jan	3	Mid	1.2	6.01	66.1	8.9	57.1
Feb	1	Mid	1.2	6.38	63.8	7.1	56.7
Feb	2	Late	1.12	6.26	62.6	6	56.5
Feb	3	Late	0.79	4.27	34.2	11.9	22.3
Mar	1	Late	0.61	3.18	3.2	1.8	3.2
					529	150.3	378.1

Table Z, Maize water requirement in Lintala pattern 4 with planting date 18/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.7	2.84	8.5	6.2	8.5
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Init	0.7	2.82	28.2	10.6	17.6
Dec	3	Deve	0.76	3.24	35.7	10.2	25.5
Jan	1	Deve	0.91	4.12	41.2	10	31.1
Jan	2	Deve	1.06	5.03	50.3	9.2	41.1
Jan	3	Mid	1.19	5.96	65.6	8.9	56.7
Feb	1	Mid	1.21	6.44	64.4	7.1	57.3
Feb	2	Mid	1.21	6.78	67.8	6	61.8
Feb	3	Mid	1.21	6.55	52.4	11.9	40.5
Mar	1	Late	1.06	5.51	55.1	18.4	36.7
Mar	2	Late	0.72	3.63	25.4	16.4	1.9
					551.1	146.8	403.5

Table Z1, Pepper water requirement in Lintala pattern 5 with planting date 02/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.6	2.42	21.8	22	0
Nov	2	Init	0.6	2.44	24.4	20.8	3.6
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Deve	0.65	2.63	26.3	14.1	12.2
Dec	2	Deve	0.76	3.07	30.7	10.6	20.1
Dec	3	Deve	0.88	3.76	41.3	10.2	31.1
Jan	1	Deve	1	4.5	45	10	35
Jan	2	Mid	1.05	4.99	49.9	9.2	40.7
Jan	3	Mid	1.05	5.25	57.7	8.9	48.8
Feb	1	Late	1.05	5.57	55.7	7.1	48.6
Feb	2	Late	1.01	5.66	56.6	6	50.6
Feb	3	Late	0.96	5.2	41.6	11.9	29.7
Mar	1	Late	0.92	4.78	28.7	11	19.5
					503.8	159.5	346.4

Table Z2, Pepper water requirement in Lintala pattern 6 with planting date 17/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.6	2.44	9.7	8.3	0
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Init	0.6	2.42	24.2	14.1	10.2
Dec	2	Deve	0.61	2.46	24.6	10.6	14
Dec	3	Deve	0.71	3.05	33.6	10.2	23.4
Jan	1	Deve	0.83	3.77	37.7	10	27.7
Jan	2	Deve	0.95	4.52	45.2	9.2	35.9
Jan	3	Mid	1.05	5.24	57.7	8.9	48.7
Feb	1	Mid	1.06	5.62	56.2	7.1	49.1
Feb	2	Mid	1.06	5.92	59.2	6	53.2
Feb	3	Late	1.05	5.67	45.4	11.9	33.5
Mar	1	Late	1	5.17	51.7	18.4	33.3
Mar	2	Late	0.94	4.7	47	23.5	23.6
Mar	3	Late	0.9	4.31	4.3	2.6	4.3
					520.7	158.5	363.4

Table Z3, Onion water requirement in Lintala pattern 7 with planting date 25/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.7	2.8	19.6	18.5	5.1
Nov	1	Init	0.7	2.82	28.2	24.4	3.8
Nov	2	Init	0.7	2.84	28.4	20.8	7.6
Nov	3	Deve	0.72	2.93	29.3	17.7	11.5
Dec	1	Deve	0.81	3.25	32.5	14.1	18.4
Dec	2	Deve	0.89	3.58	35.8	10.6	25.2
Dec	3	Mid	0.97	4.15	45.7	10.2	35.5
Jan	1	Mid	0.99	4.49	44.9	10	34.9
Jan	2	Mid	0.99	4.73	47.3	9.2	38.1
Jan	3	Mid	0.99	4.98	54.7	8.9	45.8
Feb	1	Late	1	5.32	53.2	7.1	46.1
Feb	2	Late	1.01	5.65	56.5	6	50.5
Feb	3	Late	1.01	5.46	32.7	8.9	26.8
					508.8	166.5	349.3

Table Z4, Onion water requirement in Lintala pattern 8 with planting date 10/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.7	2.82	2.8	2.4	2.8
Nov	2	Init	0.7	2.84	28.4	20.8	7.6
Nov	3	Init	0.7	2.83	28.3	17.7	10.6
Dec	1	Deve	0.7	2.83	28.3	14.1	14.2
Dec	2	Deve	0.76	3.04	30.4	10.6	19.8
Dec	3	Deve	0.85	3.62	39.8	10.2	29.6
Jan	1	Deve	0.94	4.23	42.3	10	32.3
Jan	2	Mid	1	4.76	47.6	9.2	38.4
Jan	3	Mid	1	5.02	55.2	8.9	46.3
Feb	1	Mid	1	5.33	53.3	7.1	46.2
Feb	2	Mid	1	5.61	56.1	6	50.1
Feb	3	Late	1	5.42	43.4	11.9	31.5
Mar	1	Late	1	5.19	51.9	18.4	33.5
Mar	2	Late	1	5.04	20.2	9.4	8.4
					528	156.7	371.3

Table Z5, Onion water requirement in Lintala pattern 9 with planting date 25/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.7	2.83	17	10.6	8.1
Dec	1	Init	0.7	2.83	28.3	14.1	14.2
Dec	2	Init	0.7	2.82	28.2	10.6	17.6
Dec	3	Deve	0.72	3.08	33.9	10.2	23.7
Jan	1	Deve	0.81	3.65	36.5	10	26.5
Jan	2	Deve	0.9	4.27	42.7	9.2	33.5
Jan	3	Mid	0.98	4.92	54.2	8.9	45.3
Feb	1	Mid	1.01	5.35	53.5	7.1	46.4
Feb	2	Mid	1.01	5.63	56.3	6	50.3
Feb	3	Mid	1.01	5.44	43.5	11.9	31.7
Mar	1	Late	1.01	5.21	52.1	18.4	33.7
Mar	2	Late	1	5.04	50.4	23.5	27
Mar	3	Late	1	4.78	43	23.7	14.1
					539.7	164.2	372

Table Z6, Tomato water requirement in Lintala pattern 10with planting date 12/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.6	2.39	21.5	29.8	0
Oct	3	Init	0.6	2.4	26.4	29.1	0
Nov	1	Init	0.6	2.42	24.2	24.4	0
Nov	2	Deve	0.68	2.78	27.8	20.8	7
Nov	3	Deve	0.84	3.38	33.8	17.7	16.1
Dec	1	Deve	0.99	3.99	39.9	14.1	25.8
Dec	2	Mid	1.12	4.5	45	10.6	34.4
Dec	3	Mid	1.13	4.84	53.2	10.2	43
Jan	1	Mid	1.13	5.11	51.1	10	41.1
Jan	2	Mid	1.13	5.39	53.9	9.2	44.7
Jan	3	Late	1.1	5.51	60.6	8.9	51.7
Feb	1	Late	0.98	5.19	51.9	7.1	44.8
	2	Late	0.85	4.76	47.6	6	41.6
	3	Late	0.77	4.16	12.5	4.4	6.5
					549.4	202.4	356.7

Table Z7, Tomato water requirement in Lintala pattern 11 with planting date 27/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.6	2.4	12	13.2	0
Nov	1	Init	0.6	2.42	24.2	24.4	0
Nov	2	Init	0.6	2.44	24.4	20.8	3.6
Nov	3	Deve	0.62	2.52	25.2	17.7	7.5
Dec	1	Deve	0.76	3.08	30.8	14.1	16.8
Dec	2	Deve	0.92	3.7	37	10.6	26.4
Dec	3	Mid	1.08	4.62	50.8	10.2	40.6
Jan	1	Mid	1.15	5.17	51.7	10	41.7
Jan	2	Mid	1.15	5.45	54.5	9.2	45.3
Jan	3	Mid	1.15	5.73	63.1	8.9	54.2
Feb	1	Late	1.14	6.07	60.7	7.1	53.6
Feb	2	Late	1.05	5.87	58.7	6	52.7
Feb	3	Late	0.93	5.04	40.3	11.9	28.4
Mar	1	Late	0.82	4.22	42.2	18.4	23.8
					575.7	182.6	394.6

Table Z8, Tomato water requirement in Lintala pattern 12 with planting date 12/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.6	2.44	21.9	18.7	1.1
Nov	3	Init	0.6	2.43	24.3	17.7	6.5
Dec	1	Init	0.6	2.42	24.2	14.1	10.2
Dec	2	Deve	0.67	2.7	27	10.6	16.4
Dec	3	Deve	0.84	3.57	39.3	10.2	29.1
Jan	1	Deve	1	4.53	45.3	10	35.3
Jan	2	Mid	1.14	5.41	54.1	9.2	44.9
Jan	3	Mid	1.15	5.77	63.5	8.9	54.6
Feb	1	Mid	1.15	6.13	61.3	7.1	54.2
Feb	2	Mid	1.15	6.45	64.5	6	58.5
Feb	3	Late	1.14	6.14	49.1	11.9	37.3
Mar	1	Late	1.03	5.32	53.2	18.4	34.8
Mar	2	Late	0.89	4.48	44.8	23.5	21.4
Mar	3	Late	0.78	3.75	22.5	15.8	8
					595.2	182.1	412.3

Table Z9, Climate data and ETo of study area.

Country : ETHIOPIA Altitude : 1685m	Latitude: 6^o 45' N Longitude: 37^o 47'E		Station : Wolaita Sodo				
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	Hours	MJ/m²/day	mm/day
January	15.1	27.4	49	1.9	8.8	21.1	4.76
February	15.1	28.7	43	2.3	8.6	21.9	5.5
March	14.7	28.4	51	1.8	7.8	21.5	5.03
April	14	26.6	65	1.4	7.1	20.4	4.28
May	14.3	24.8	74	1.3	6	18.1	3.64
June	14.3	23.2	77	1.4	4.5	15.5	3.13
July	14.3	22.1	79	1.1	3.5	14.1	2.8
August	14.7	22.5	79	1.1	4.3	15.8	3.05
September	14.3	24	73	1.1	5.3	17.5	3.44
October	14.3	25.1	66	1.4	7.3	20	3.98
November	15.4	26.2	55	1.2	8	20.1	4.06
December	15.7	26.4	50	1.3	7.6	18.9	4.02
Average	14.7	25.4	63	1.4	6.6	18.7	3.97

Table Z10, Storage efficiency in Ela plot.

Scheme	Irrigation time	FC(mm)	Moisture (after irrigation)mm	Moisture content before irrigation(mm)	Storage depth or required depth(mm)	*Applied irrigation depth*	*Average Storage efficiency (%)*
Ela	First irrigation time	127.92	128	89.20	38.72	*38.72*	100
		127.92	129.20	94.40	33.52	*33.52*	100
		127.92	127.98	93.88	34.04	*34.04*	100
		127.92	127.94	95.74	32.18	*32.18*	100
		127.92	128.92	97.72	30.20	*30.20*	100
		127.92	115.69	86.29	41.63	*29.40*	71
		127.92	117.99	91.29	36.63	*26.70*	73
		127.92	114.90	90.29	37.63	*24.70*	66
		Average			35.56	31.18	88
	Second irrigation time	127.92	128.32	88.72	39.20	39.20	100
		127.92	128.12	89.82	38.10	38.10	100
		127.92	130.20	91.90	36.02	36.02	100
		127.92	128.20	90.80	37.12	37.12	100
		127.92	129.12	93.32	34.60	34.60	100
		127.92	129.52	98.12	29.80	29.80	100
		127.92	111.45	82.15	45.77	29.30	64
		127.92	110.87	86.57	41.35	24.30	59
		Average			37.74	33.55	89
	Third irrigation time	127.92	127.98	93.68	34.24	34.24	100
		127.92	129.2	97.17	30.75	30.75	100
		127.92	126.88	97.08	30.84	29.80	97
		127.92	124.87	95.07	32.85	29.80	91
		127.92	121.9	95.7	32.22	26.20	81
		127.92	120.56	95.36	32.56	25.20	77
		127.92	114.87	90.57	37.35	24.30	65
		127.92	112.54	88.54	39.38	24.00	61
		Average			33.77	28.03	83

Table Z11, Storage efficiency in Lintala plot.

Scheme	Irrigation time	FC(mm)	Moisture (after irrigation)mm	Moisture content before irrigation(mm)	Storage depth or required depth(mm)	*Applied irrigation depth*	*Average Storage efficiency (%)*
Lintala	First irrigation time	121.02	126.70	92.50	28.52	28.52	100
		121.02	119.73	92.23	28.79	*27.50*	96
		121.02	118.80	92.28	28.74	*26.52*	92
		121.02	119.22	92.72	28.30	*26.50*	94
		121.02	118.62	92.22	28.80	*26.40*	92
		121.02	109.40	93.00	28.02	*16.40*	59
		121.02	110.40	95.20	25.82	*15.20*	59
		121.02	105.40	91.20	29.82	*14.20*	48
		Average			28.35	22.65	80
	Second irrigation time	121.02	126.40	94.60	26.42	26.42	100
		121.02	118.20	92.10	28.92	*26.10*	90
		121.02	120.12	94.72	26.30	*25.40*	97
		121.02	119.63	94.78	26.24	*24.85*	95
		121.02	116.23	95.33	25.69	*20.90*	81
		121.02	112.94	94.44	26.58	*18.50*	70
		121.02	111.12	93.22	27.8	*17.90*	64
		121.02	108.02	94.82	26.20	*13.20*	50
		Average			26.76	21.65	81
	Third irrigation time	121.02	124.62	91.12	29.9	29.90	100
		121.02	125.12	92.12	28.9	28.90	100
		121.02	120.22	94.12	26.9	26.10	97
		121.02	119.47	94.12	26.9	25.35	94
		121.02	115.91	93.61	27.41	22.30	81
		121.02	113.42	93.72	27.3	19.70	72
		121.02	111.23	93.43	27.59	17.80	65
		121.02	108.90	92.00	29.02	16.90	58
		Average			27.99	23.36	83

Table Z12, Existing conditions of irrigation schemes collected through observation

Observation Check list		**Scheme name**	
Scheme name		**Ela irrigation**	**Lintala iriigation**
Water source		Hamesa river	Lintala river
Diversion head work		Vertical drop Weir	Vertical drop Weir
Water control structures/ gates		Absent	Non functional
Energy used in flow system		Gravity	Gravity
Water delivery/ conveyance structure		Open rectangular canal	Open rectangular canal
Lined conditions of canal	Main canal	60% lined 40% unlined	Lined
	Secondary canal	Unlined	Unlined
	Tertiary canal	Unlined	Unlined
Health of conveyance structure		With some fractures	Functional
Division structures		Not operational	Not operational
Discharge measuring structures		Absent	Absent
Silt control		Under sluice	Under sluice
Status of Under sluice		Not functional	Not functional
Ways of silt excluding		Manually excavated	Manually excavated
Actual irrigation area		108ha	12 ha
Designed command area		80ha	70 ha
Type of vegetables grown		Onion Potato Cabbage Pepper	Onion Cabbage Pepper
Type of fruits grown		Tomato	Tomato
Health of the planted crop		Most crops Un healthy	In good health
House hold beneficiaries		216	24
Presence of administrative committee		Yes	Yes
Structure of WUA committee		7 major chiefs	1 main chef
		3 monitors	1 secretary
		3 sellers	1 financial coordinator
		3 purchasers	
		7 water distributers	
Main activities completed by committee of water		Plane and implement canal	Plane and implement

use associations	clearance	canal clearance
	Operation and water distribution	Operation and water distribution
	Meeting and reporting rarely	-
	Collect yearly irrigation service fee 50 birr per house hold	-
Presence of major problems couldn't resolved by the capacity of scheme management	Agronomic problem/ crops disease	-Lack of road access -Lack of drinking water -No of irrigation land owners not accommodated

Table Z13, Questions and respondent number in irrigation schemes

General task of IWUAs/title	Specific task intended to be done by IWUAs	Ela irrigation scheme			Lintala irrigation scheme		
		Total No of respondent	No of response (yes)	% of response(yes)	Total No of responders	No of response(yes)	% of response (yes)
Communication, Role and responsibility of general assembly	Setting the annual budget for the IWUA including the level of fees and charges payable by members	23	6	26.09	15	1	6.66
	Approve annual/seasonal action plan and corresponding budget	23	0	0.00	15	0	0
	Electing the executive officers and members of the committee in the IWUAs	23	12	52.17	15	12	80
	Set and modify internal regulations	23	23	100.0	15	4	26.6
	Approve change of the IWUA service area	23	10	43.48	15	0	
Operation and maintenance works	Prepare an annual/seasonal plan for water distribution	23	23	100	15	15	100
	Prepare annual/seasonal / action plan for maintenance of irrigation structures	23	0	0.00	15	0	0
	Identify and mitigate the risk of damage to irrigation structures and equipment	23	0	0.00	15	0	0
	Training members in irrigation techniques	23	0	0.00	15	0	0
The main management tools of IWUAs	operational rules is enforced IWUA by-laws	23	21	91.30	15	0	0
	Collection of irrigation service fee	23	23	100	15	0	0
	apply sanction for non or late payment	23	23	100	15	0	0
	Prepare annual/seasonal financial reports	23	5	21.7	15	0	0
	Implementation of internal auditing	23	0	0.00	15	0	0
	Implement communication procedures within IWUAs	23	6	26.09	15	3	20

Table Z14 soil test result interpretation guid/manual Wolaita Sodo soil test laboratory (2015)

Parameters	Level		Qualitative description	General interpretation
Ph	>8.5		Very high	Alkali soils, Ca and Mg may be non available. May have high Na content; toxicity of boron possible. Low micronutrient availability
	7-8.5		High	Low availability of P and micronutrients (except Mo)
	5.5-7		Medium	Prepared ranges for most crops
	<5.5		Very low	Acidic soil, Al toxicity, excess Fe, Cu, Mn and Zn, low availability of Ca,Mg and Mo. Phosphorus fixation associated with Al and Fe oxides. Nitrification is retarded.
Ece in mS/cm and correspondin g salt content	<2	<0.15	Non saline	Negligible effect on crop production
	2-4	0.15	Slightly saline	Negligible effect except for crops with very low tolerance.
	4-8	0.15-0.35	Moderately saline	Crop yields with low tolerance to salinity will be reduced.
	8-15	0.35-0.65	Strongly saline	Only tolerance crops will grow
	>15	>0.65	Very strongly saline	Only high tolerant crops can grow satisfactorily
Oc	>20		Very high	Interpretation of values of soil organic carbon short comings due to difficulty of proper directives
	10-20		High	
	4-10		Medium	
	2-4		Low	
	<2		Very low	
TN	>1		Very high	Also total nitrogen values are difficult to interpret because the type of nitrogen present and their pertinence to plant nutrients are not always known. Generally low PH reduces availability of nitrogen due to the reduction of microbial activity and hence available N is very low irrespective of the amount of total nitrogen present.
	0.5-1		High	
	0.2-0.5		medium	
	0.1-0.2		Low	
	<0.1		Very low	
Cec	>40		High to very high	Normally good amount of agricultural soils need only small amount of lime and k fertilizers.
	25-40		High to medium	Normally satisfactory for agriculture if fertilizer are used.
	5-25		Low	Marginal for irrigation.

<table>
<tr><td></td><td><5</td><td colspan="2">Very low</td><td colspan="2">Very low in mineral reserves, normally not conductive for irrigation. Except for rice.</td></tr>
<tr><td rowspan="4">AP</td><td>deficient</td><td>doubtful</td><td>adeq uate</td><td rowspan="2">Low</td><td rowspan="2">For crops need p such as cereals, maize, soja</td></tr>
<tr><td>4</td><td>5-7</td><td>8</td></tr>
<tr><td>7</td><td>8-13</td><td>14</td><td>Medium</td><td>For crops need p such as cotton, sweet corn, tomato</td></tr>
<tr><td>11</td><td>12-20</td><td>21</td><td>High</td><td>Irish potato, oignons, celery</td></tr>
<tr><td>Textural classes</td><td colspan="5"></td></tr>
</table>

Analysis of agricultural Soils

In order to ensure sustained production and increased yields per unit area, more judicious soil management practices are needed. In order to attain this, it is necessary to follow scientific approaches. Such approach calls for thorough understanding of the soil environment and the factors that influences agricultural yields. A proper understanding of soil property both chemical and physical is necessary to optimize management process. Proper evaluation of soil fertility status and improved soil management practices for reclamation and appropriate fertilizer recommendation for attaining optimum economic yields are highly supported by reliable soil and plant analytical data. So that in the study the most important soil characteristics in the agricultural production was examined. Such characteristics included; PH, EC, CEC, AP, OC, TN and texture determination.

Almost all PH results of examined soils in both Ela and Lintala irrigation lands was in the expected range of PH values and it was not factor of agricultural production.

The next soil characteristics tested was electric conductivity. From the results of this test in both irrigation schemes soil no salinity effect and it has negligible effect on crop production.

The interpretation of the values of organic carbon and total available nitrogen independently become difficult due to loss of proper directives. So most of the time it has been described in C:N ratio. Normally agricultural soils have a C: N ratio 10:1. In the soil with C: N ratio greater than 25:1, N deficit may occur and may require N fertilizer application. In corporation of plant residues that ate not easily decomposed can greatly affect the C: N ratio. Straw residues tend to increase the C:N ratio. While legume residues with high N contents tend to reduce the C/N ratio. In Ela and Lintal irrigation soil C: N values also in the range of C: N in normal agricultural soils have.

Also the CEC is also important implication of the soil productivity. There is correlation usually exist between clay % and CEC under a similar mineralogical condition. With increase clay % there is also increase in CEC and the reverse is also true (yerima, 1989). In the examined samples the u/s soils of ELAand Lintal irrigation land was satisfactory for agriculture if fertilizer is used.

Soil texture is the last parameter examined in the study. Texture is the relative distribution of the various sizes separates in the soil. The texture of the soil has a great bearing on its ability to retain water, nutrients; degree of infiltration etc… this property can thus be used to determine the frequency of irrigation and or type of fertilizer application. Soil dominated by sand and silt are non plastic, have low water retention capacity, rapid infiltration, a low specific surface and low CEC. Such soils however generally have a good drainage and aeration. Sandy soils have poor structure, high particle and specific densities and lack of coherence. Soils dominated by clay and fine silt have a high water, gas and nutrient retention capacities. They have lower water infiltration rates than sand soil. In the study schemes similar sandy loam soil type and physical characteristics

2. Appendix figures

Figure 1, Weeded canals in Ela and Lintala

Figure 2, Flows measurements

Figure 3, Soil sampling by using core sampler