Evaluation of local water management practices in small-scale irrigation systems: Case study of Gatto and Arguba, Ethiopia

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Presented in International Conference on Advancements and Futuristic Trends in Mechanical and Materials Engineering held at Indian Institute of Technology Ropar (IITR), Rupnagar, during December 5-7, 2019.

KEYWORDS

Water Management, Performance Indicators, Small-scale Irrigation, Irrigation Sustainability

ABSTRACT

Many irrigation schemes are characterized by a low level of overall performance. The technical and economic performance of irrigation schemes has generally been far below potential. The objective of this study was to assess and evaluate local water management practices for selected small scale irrigation schemes to improve irrigation water management and irrigation performance. Comparative performance indicators were used to evaluate the performance of the schemes. The result of sustainability for Gatto was 0.7867 and that of arguba was 0.881. The output per unit irrigated cropped area was 18633 birr/ha for Gatto and 16828 birr/ha for Arguba irrigation schemes respectively. The output per unit irrigation water supply was 2.3 birr/m3 and 2.32 birr/m3 for Gatto and Arguba irrigation schemes. Finally for both irrigation schemes a great effort was needed to maximize the return from each drop of water and improve the irrigation efficiency. Applying reasonable irrigation water fee, furrow layouts and irrigation scheduling would improve the performance of the schemes.

1. Introduction

1.1 Background

With steady increase of the global population, the contribution of irrigation towards boosting agricultural production is enormous. Particularly, in some emerging and least developed countries irrigation development and use is a backbone to the extent that it is responsible for the nation's "welfare and feeding the vast majority of their population. According to International Fund for Agricultural Development (IFAD, 2014) and (Hess, 2010) only 20% of the world's total croplands are irrigated. However, these lands contribute to some 40% of the global agricultural harvest. The figure indicates that irrigated agriculture on average is roughly more than two and half times as productive as rain fed agriculture. Agriculture depending on rainfall has failed to produce enough food, and with increasing rainfall variability, productivity of rain fed agriculture is expected to diminish. To meet increasing demand for food by 2050 the global agricultural production would need to increase by 60% of the production in 2005 (FAO, 2012). As such without significant investments in irrigation, agricultural production is unlikely to cope with ever increasing demand for food. It was identified that globally 60% of the diverted fresh water for agriculture does not contribute directly to food production. This amount of water is discharged because of poor water control, inefficient irrigation systems with leaky conveyance and distribution, poor on-farm water management practices, etc. (WAF, 2009). It depicts that only about 40% of global fresh water abstracted for irrigation is being effectively used for consumptive use in agriculture. Part of the amount of the discharged water of these systems is lost to saline groundwater or to poor quality drainage water. However, in some cases, discharged irrigation water can be recovered in the downstream reaches.

Agriculture consuming about 80% of fresh water abstraction in several least developed courtiers is considered the most inefficient water user

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sector. With increasing number of countries facing water shortages, agriculture is expected to face a serious water stress in several regions. Thus, water scarcity remains to be a major challenge to feeding the global population. According to [30] by 2025, 1,800 million people are expected to be living in countries or regions with„ absolute‟ water scarcity and two thirds of the global population could be under„ stress‟ conditions. FAO (2005) Also forecasts that without changes in efficiency of water use, by 2050 the world will need as much as 60% more water of the abstraction in 2005 for agriculture, which remains a challenge to the sector.

Ethiopia is situated in the "Horn of Africa" and lies between 3°30´ and 14°50´ North latitudes and 32°42´ and 48°12´ East longitudes. It is the second most populous country in sub-Saharan Africa (SSA) (and third on the continent) population approaching 80 million and 85% dependent on agriculture and live in rural areas. Agriculture employs 80% of the labor force and accounts 50% of the GDP. It has a surface area of about 1.127 Million km_2, of which 1,119,683 km2 land and 7,444 km_2 water area. The country has a land boundary length of 5311km. Ethiopia in the horn of Africa has special features because of its topography, geology and climate, (Awulachew, 2001). It has 12 river basins with an annual runoff volume of 122 billion m_3 of water with an estimated 40 billion m_3 of ground water potential. This amounts to about 1743 m_3 of water per person per year: a relatively large volume. But due to economic water scarcity which is described through lack of water storage capacity and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year with frequent crop failures due to dry spells and droughts. Moreover, there is significant erosion, reducing the productivity of farmland.

In Ethiopia agriculture is heavily reliant on rainfall and productivity and production are strongly influenced by climatic and hydrological variability that are reflected as dry spells, droughts and floods. Droughts and floods are endemic, with significant events every 3 to 5 years, with increasing frequency compared to two or three decades ago. Droughts destroy watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales (whether small, medium or large) and options (diversion, storage, gravity, pumped, etc.). The principal component of project development (finance) is a constraint to incur huge investment for irrigation; small scale irrigation can be an alternative solution to enhance food production. This is of course without undermining the strategic importance of developing medium to large scale irrigation schemes to feed the expanding population in the foreseeable future. Development of small scale irrigation through river diversion, constructing micro dams, water harvesting structures, etc. may be considered as pragmatic approach in the contemporary Ethiopia for ensuring food self-sufficiency.

Improving the performance of irrigation schemes through various interventions is considered a key issue for addressing the need for increased productivity of irrigated lands under pressure on water resources. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance. The technical and economic performance of public irrigation schemes in these countries has generally been far below potential, and that of large-scale irrigation schemes in some cases is particularly very low (Darghouth, 2005). These schemes have been characterized by high unreliability of water supplies. However, large-scale irrigation schemes are generally shared by groups of water users and are often complex; hence require appropriate institutional setups and technical and operational plans for adequate performance. Areas of poor irrigation performance include mismatch of supplies and demands, insufficient maintenance, inadequate manual operation of structures, operational leakages and field losses, poor irrigation service, waterlogging and salinization. A large part of the low irrigation performance is, however, attributed to inadequate water management at scheme, system and field levels (Cakmak et al., 2004). As a result, in several irrigation schemes, irrigation water has been used at a very low efficiency, hydraulic performance has been low and irrigation service to farmers has been stumpy. The main causes for ill performance were related to inadequate institutional setups and non-flexibility of the hardware of the schemes.

In view of the fact that water shortage will be a major constraint to agricultural production and that there is a need for increase in the productivity of irrigation schemes, the overall performance of schemes would have to be improved. Water needs to be used more efficiently and water diversions per unit of irrigated land need to be reduced. With expected slow down in expansion of irrigated land, greater focus seems to be put on improvement of existing irrigation schemes and their effective long-term operation and maintenance. Plusquellec (2009) Stresses that, given diminishing fresh water resources and declining irrigation expansion, improving the productivity of existing irrigation schemes by addressing their deficiencies in management and poor performance in a holistic manner can no longer be ignored. Moreover, there is aneed for intuitional transformation has already been implemented in many irrigation schemes around the world. Appropriate mechanisms for saving irrigation water need to be implemented in schemes based on convenience.

This research deals with two community managed small-scale irrigation schemes in Ethiopia. These irrigation schemes are named Gatto and Arguba small-scale schemes which are found in Derashe Woreda Segen zone of SNNPR. The key stake holders of these schemes are smallholder farmers. The schemes are community managed, because farmers are responsible for management of irrigation water and maintenance of their infrastructure through their water users association (WUA).

1.2 Problem statement

Small-scale subsistent irrigation is by far dominant in Ethiopia due to its small investment cost, ease of construction, simplicity of operation & maintenance have been a strategic target of the country for achieving sustainable food security and self-sufficiency. So many of such schemes have been designed and constructed in the previous years in different parts of the country. These schemes play a vital role in improving the livelihoods of the small holder farmers. However, existing Small-scale community managed irrigation schemes, particularly in Sub-Saharan Africa, lack sound institutional and operational setups that could achieve increased productivity, reliable irrigation service, and long-term sustainability and it face various problems related to operation and maintenance, water management and sustainability. These problems have greatly reduced their benefits and challenged their overall sustainability.

The major problem related with irrigation development is also their negative impact on the environment and human health. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource water if they are mismanaged. In recognition of both the benefit and hazards assessment and evaluation of irrigation schemes performance has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that may be both effective and feasible in improving system performance.

Besides the poor performance of irrigation projects in the country, evaluation of irrigation projects is not common: lack of knowledge and tools used to assess the performance of projects adds to the problem. But now, different indicators have been developed are used to assess hydrological, agronomic and financial performance of irrigation system. Which are helpful to determine the conditions of the system and proper functioning of its elements? And it was attempted to apply this set of comparative indicators to the two community managed small scale irrigation schemes of Gatto and Arguba irrigation. CBIWM focuses on the collective management of irrigation water to improve human well-being and poverty reduction.

In Ethiopia it is not well structured to manage small-scale effectively and efficiently. The solution to this problem is developing sound institutional and operational water management setups, which would better enhance irrigation service, water productivity and sustainability in the community managed schemes. The two community managed small scale irrigation are found in SNNPR state in Derasheworeda. Farmer follows traditional farming practice. However, due to low water management practice, low agricultural input utilization and low skilled manpower seem to have hampered the development of the two irrigation schemes. Thus use of irrigation scheme, introducing improved farming technologies and inputs, improving skilled manpower package of the woreda and increasing the capacity of the local community is very important to attain food security and transform the life of the poor.

1.3 Objectives

1.3.1 General objective

The general objective of this study is to assess and evaluate local water management practices of two selected small scale irrigation schemes with the view to improve irrigation water management and irrigation performance.

1.3.2 Specific objectives are

- To evaluate selected water management performance indicators in the two small-scale irrigation schemes
- To compare performance of the two schemes and identify performance gaps
- Propose performance improvement options

1.4 Research questions

To achieve these objective the following questions will be addressed

- What are the levels of the performances of both schemes in terms of selected indicator?
- Which scheme is relatively performing better and what are the performances gaps?
- What are the intervention options to improve the performances of the schemes?

1.5 Scope of the study

This study made a comparative evaluation of water management practices in the community managed small scale irrigation schemes. Selected relevant comparative performance indicators were applied for comparison. The study proposes good and operational water management arrangements that would ensure better irrigation management and sustainability in these schemes. These water management interventions could also be extended to other similar community managed schemes in Ethiopia. The research has made a critical analysis of the issues related to irrigation water management and proposes performance improvement options between the two shames.

1.6 Significance of the study

In addition to long-standing, small-scale irrigation often flourished with the help of local governments and direct and indirect involvement of other NGOs in order to keep its sustainability. Therefore, this study contributes information regarding the condition of local farmers‟ irrigation operation, water management practice and policy options that could help guide community managed irrigation development. It also identifies and improves the problem of the study area to come up with appropriate irrigation water management and performance of the irrigation scheme.

2. Materials and Methods

2.1 Description of study areas

2.1.1 Location

This study was conducted in Derasheworeda which was found in the SNNPRS in Segen zone. It is endowed with natural forests, rivers, tourist attraction sites, minerals, crops, strong working culture, wildlife, and others. The total land area of the woreda is 1532.40 Sq. Km. Topographically of the woreda lies between 501-2500 meters above sea level. The total population of the woreda is about 133,543 (2007). Thus two communities managed small scale irrigation schemes were found in this Derasheworeda and separated by a distance of 20 km apart. Gatto small scale irrigation scheme was found in GattoKebele on Yanda River and 10 km far from Gidole town in south east and the diversion structure is weir which irrigates 200 hectare and Arguba small scale irrigation scheme was found in Argubatenaokebel on Arguba River and 10 km from Gidole town in north east and the diversion head is weir which irrigates 150 hectare.

2.1.2 Climate

Rainfall and temperature data for both irrigation were collected at the Arguba meteorological station, the closest to Arguba irrigation schemes, so the average annual rainfall was the same as for Gatto irrigation which is ranges between 601- 1600 mm/year and the mean annual temperature of the woreda ranges between 15.1 upto 27.50°C. The farmers in this woreda produces the product twice a year that means the climate is bimodal climatic zone and the first production was from March to July and the second term was from September to December.

2.1.3 Soils

Soil types are one of the most important factors to determine the productivity of irrigation schemes. In both irrigation schemes there are different types of soils thus includes clay soil, sandy clay, sandy loom and loom. In local term the four types soil are found in both irrigation schemes these are katuna this soil type is clay soil, fafura this soil type is loom, buska this soil type is silt and shahata this soil type is sandy soil. Buska and shahata soil types are found mostly around river bank.

2.1.4 Hydrology

The irrigation scheme of Gatto irrigation was located in the Yanda Basin. The river that supplies water to the head work collects water from the sources from Sidawa River and Hitawe River. Both rivers started under Gardula Mountains and join together at the downstream of the water shed. The Gatto irrigation scheme was located along the river, therefore it exposed to the erosion problems and flood destroys the head work structures and the local farmer construct to divert water in to the intake to community manage the water for irrigation. The irrigation scheme of Arguba was located in the Arguba River, this river also started under Gardula Mountain. The mountain in the north part was the water shed for Arguba River and in southern part was the water shed for Yanda River.

2.2 Description of the schemes

2.2.1 Gatto irrigation schemes

The Gatto irrigation scheme was weir diversion head work structure which irrigates in both sides and when irrigation happen in one side the gate of the other side was closed. The discharges in the canals are controlled by manually operated gates and the discharge of the main canal varies from time to time, along with the parent source. The left main canal of the irrigation scheme was Angare main canal and Buh Kida right main canal which totally irrigate 200 ha. In this irrigation scheme there were 259 male users and 7 female users with the total of 266 users. On this river in the D/S of the head work other farmer use water from the main river by local diversion and use it as spat irrigation during high flooding. In the right D/S of the head work Baskenta and Orayto main canal which irrigates 162 ha and there were 365 male users and 5 female users with the total of 370 users. On the left side Maga, Dawra, Harharayto and Orosho local main canals were found and they irrigate 506 ha. There was 1075 male user and 15 female users with the total of 1090 users.

2.2.2 Arguba irrigation schemes

The Arguba irrigation scheme was also weir diversion head work structure which irrigates in one side direction. The discharges in the canals were also controlled by manually operated

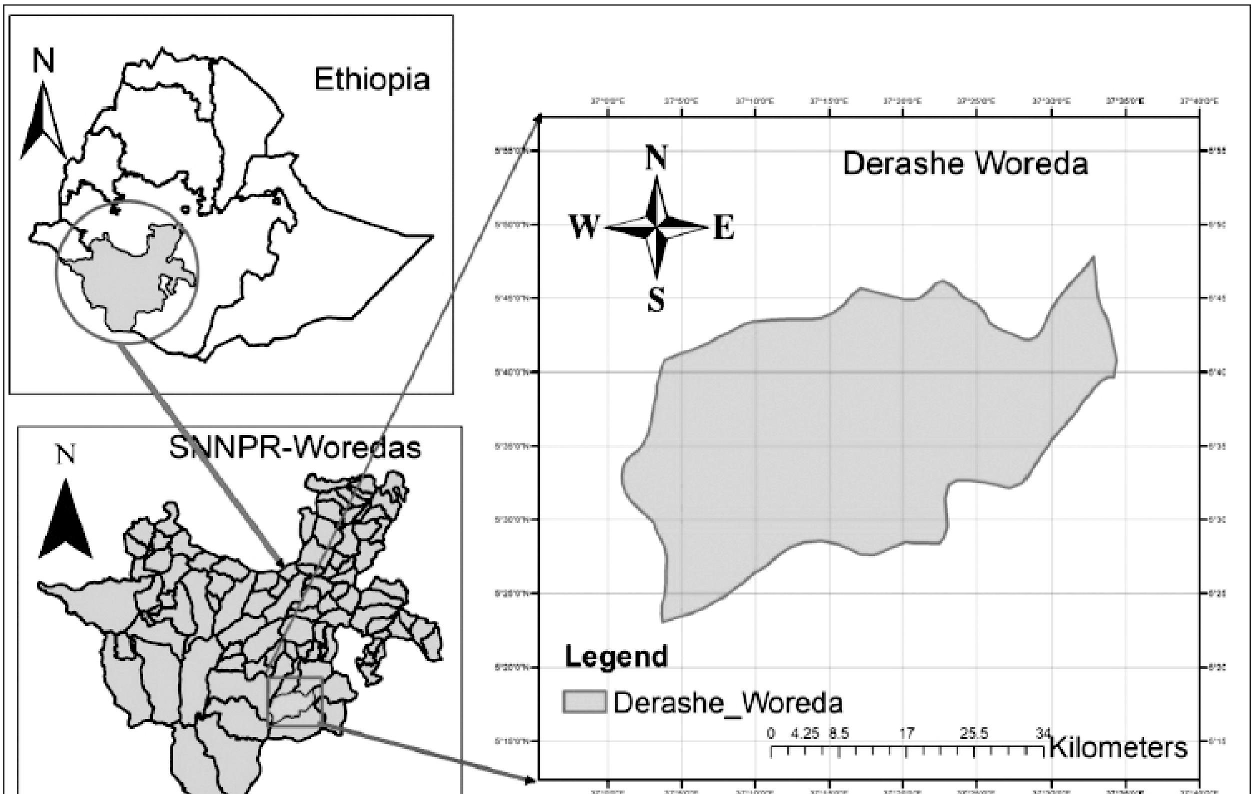


Fig 2.1 Derasheworeda.

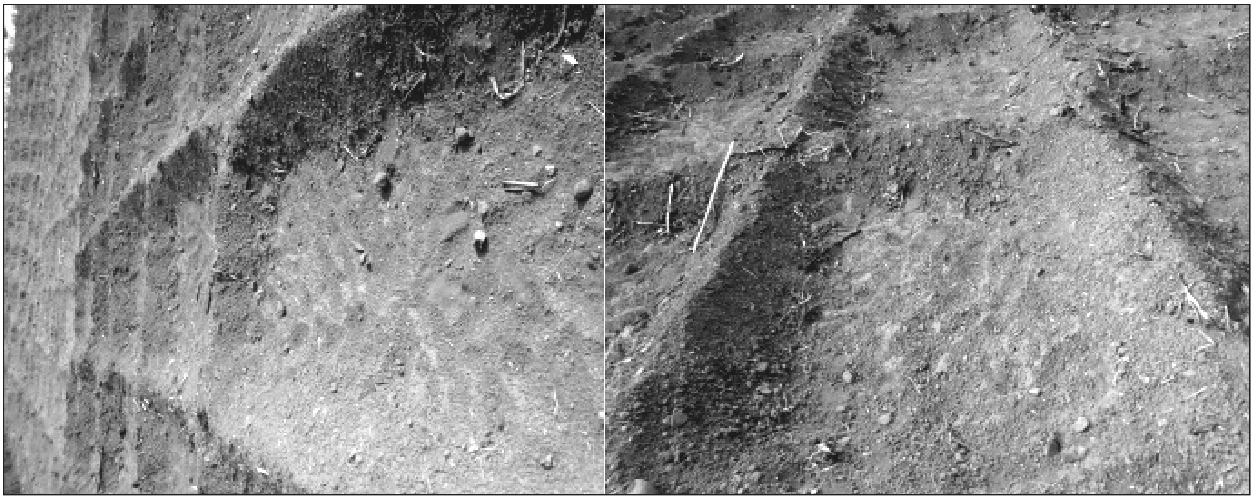


Fig. 2.2 Tarka and botaya.

gates and the discharge of the main canal varies from time to time, along with the parent source. This irrigation scheme irrigates an area of 150 ha. In this irrigation scheme there were 148 male users and 2 female users with the total of 150 users.

All farmers are using short furrow like structure called Tarka and Botaya having an average length of 8 meters, 2meter width and 3meter length and 2meter width with 0.6 meter spacing respectively. It is constructed by human labor and they use equipment to open and close Tarka and Botaya while they are irrigating their crops in both irrigation schemes.

The main crops grown in the irrigation project area are onion, maize, teff, carrot, bean, banana, cabbage and sorghum. Among the mentioned crops, maize was the dominant crop produced covering around 50-60% of the irrigable land during the study.

These crops are grown during both rain and dry seasons. During the rainy season, even if the rain is sufficient for the crop, irrigation water is supplemented when vegetable crops are transplanted. The farmers themselves, including their family, do all the farming practices. However, during peak times like harvesting and weeding farmers are forced to hire additional labor in daily wage basis.

In the irrigation project there is no any rule or restriction on the farmers what type of crop to produce. The farmers have the right to choose what type of crop to plant as far as the crop is profitable and the water allocation is adequate to produce the selected crop. Farmers sell their produce by themselves based on the market price.

Figure 2.2 shows that Tarka and botaya that the Gidolefarmer use as Furrow for their irrigation system. This structure was also important for the conservation of soil and water. This Tarka and botaya have an average length of 8 meter, 2 meter width and 3 meter length and 2 meter width with 0.6 meter spacing respectively. It is constructed by human labor and they use equipment to open and close Tarka and Botaya while they are irrigating their crops in both irrigation schemes.

Water distribution system: A representative farmer assigned by the association throughout the year manipulates the gate at diversion weir. Once it is opened, it stays till all farmers irrigate their farm on one side and the gate was closed and representative of other side open the gate and all farmer irrigate their farm in that side. The representative of the committee makes water allocation it is basically governed by the discharge of the Yanda River. The distribution can be allocated day and night rotation or for specific period (days interval) within a week. As the schedule of irrigation water allocation, farmers have the right to apply the water as much as they want. That means there is no any restriction how much water a farmer can divert for his field regardless of the size of his farm, especially for head end users. From field observation and results of the questionnaire, due to unwise use of water by the head end users and siltation problems of the main canal the tail end user faced water shortages frequently.

Command area: According to the design document land suitable for irrigation in Gatto irrigation scheme was designed to be 200 ha. It is designed to irrigate in both sides, Angare main canal which found in the Left side of the head work and Buhkida main canal which found in the right side of the head work. It also contains branched canal said to be Masaya canal. Taking into consideration the beneficiary capacity, labor availability and input requirement, a gravity irrigation system that can irrigate a gross area of 200 ha in both sides was designed. About 44 ha of the land are located on left side of the head work and 160ha of the land are located in the right side of the diversion head work. Although the original design is for 200 ha, only 176 ha of land are actually irrigated area. For Arguba irrigation the design document land suitable for irrigation scheme was designed to be 150 ha. It was designed to irrigate in one sides and it was also gravity irrigation system. The irrigable area was 150 ha and irrigated area was 118 ha.

Crop production: In order to increase their income farmers use different crops among the farming community. There are different sources of household income. Sources of household income in both schemes can be classified as income from grain production and income from cash crop production. The production from grain crop includes maize, teff, sorghum and bean in both irrigation systems. Cash crop refers to vegetable crops produced through irrigation for the purpose of market to increase household cash income. Therefore, farmers in both irrigation systems produce high value horticultural crops such as onion, tomato and mango. Papaya and mango are also grown around homestead and nursery site especially in Gatto SSI. But in both cases the major cash crops are onion and tomato. In general the type of crop grown in both irrigation schemes are maize, tef, sorghum, bean, onion, potato, carrot, cabbage, chickpea and tomato. However the most dominant crops grown in both irrigation schemes are maize. It takes the highest percentage in all schemes. Most of the products are sold to Konso, Arba Minch and Gidole town. The farmers have a relatively good exposure to irrigation practice. The types of crops to be grown are selected based on the market condition, the resistance of the crop for disease, water availability and ease of management.

Production constraint: farmer prefer to grow some of the selected crops to minimize risks like disease infection, high cost of pesticides and insecticide, market failure, unavailability of good quality seeds with reasonable price, fertility of the soil, access to surface water and so on. These constraints affect the most dominant crop grown in area to remain maize throughout the seasons and farmers are resistant to change these crops by high value crops. Besides, farmers don't have knowledge about the type and recommended rate of chemicals and water applied so they are forced to use their local knowledge and sometimes agricultural sectors give some information how they use the rate of chemical in order to produce crops.

2.3 The Materials used

The following materials and equipment were used for data collection and analysis of the data for this study: augur, soil sampling rings, graduated staff gauge, 6 inch Parshall flume, stopwatch, balance, GPS, Digital camera and others. CLIMWAT 2.0 for CROPWAT, CROPWAT VERSION 8.0 FOR WINDOWS software's was used for determining ET and water demand of the crop, Arc GIS software's was used.

2.4 Data collection techniques

Data required for the study were collected from primary and secondary sources and collect quantitative and qualitative information. Primary data was collected and analyzed on irrigation farming systems, socio-economy, institutional and management aspects from the farmers and other relevant stakeholders. This was done through personal observations and an evaluation survey based on semi-structured interviews and questioners.

2.5 Primary Data Collection

Primary data were collected by the use of formal and informal survey methods. A formal survey was carried out with the help of standard questionnaire designed to obtain information from selected sample households. Discussion were made with key farmers including committee members of local irrigation water user's, executive members of peasant associations, development agents and Derashe district irrigation development desk representatives and experts from cooperative desk. The leading questions prepared to guide the discussion with the focus group emphasis on policy issues, external support for the schemes, institutional and managerial issues, major problems and future plans to further develop the irrigation systems.

2.6 Sample selection and sampling techniques

The total household heads that are using irrigated agriculture at Gatto and Arguba small-scale irrigation systems are 266 and 150 respectively. Although the size of the population of the two study sites differs, equal number of sample water user was selected from each for the convenience of the study. Generally, irrigation users can be classified according to their location with respect to water source viz.., farmers located at head, middle and tail of the system. The classification was made based on idea that the head user uses more water and the tail users use less water. These approaches help to obtain different insights, thoughts and attitudes from farmers concerning the practice of irrigation. Simple random sampling technique was employed to select 3 water users from each group in both study area.

2.7 Designing questionnaire

Before designing the questionnaire, the two irrigation systems were repeatedly visited in September and November 2007 (2014). During those periods a number of informal discussions were conducted with the beneficiaries. Based on the information gathered and personal observation, interview questions was developed and then pre-tested before it was administered. In order to conduct the community managed irrigation survey, enumerators who have completed 12th grade and able to speak the local languages, Derashegna, were recruited from each study sites. The enumerators were also trained by the researcher before launching the survey to make them understand the purpose of the survey and to be familiarized with the questionnaire. The interviews were then conducted with the close supervision of the researcher.

2.8 Focus group discussion

The primary data collected from sample farmers need to be further enriched by additional information gathered through focus group discussion. Group discussion was held with committee members of water user's associations, peasant association executive committee members, development agents and Derashe district irrigation development desk. Individuals were also selected who were believed to be knowledgeable about the past and present history of the two schemes and interviewed by the researcher. Frequent field observations were made to observe and investigate the method of water applications, and practices related to water management techniques made by the assigned persons and farmers. Measurements of canal water flow at the diversion of both schemes were taken frequently. Moisture contents of the soils of the selected irrigation fields before and after irrigations were determined by taking soil samples at different depths of the profiles.

2.9 Secondary data collection

In addition to primary data collection, secondary data were collected from different sources. The data collected from the secondary sources include amount of water used, irrigated and irrigable area, agricultural production and price of agricultural outputs and other related data were collected from Derasheworeda agricultural office and SWWCE coordinating and district office of the Gatto and Arguba irrigation, collecting the detail data about the two irrigation system. Necessary documents, studies and other useful written materials needed for the study were also collected. Organizations contacted during the survey period were ministry of agriculture, ministry of water resources development, Derashe irrigation development authority and Christian relief and development association (CRDA).

2.10 Measurement of selected indicators

2.10.1 Irrigation supply and demand determination

Daily measurements of irrigation supply to the scheme were made by using a graduated staff gauge (Q-h) fixed at the bank, in the head reach of the main canal. Monthly and hence annual irrigation supplies to the scheme were determined as a sum of daily supplies for the irrigation and average annual supply was determined. A stage-discharge (Q-h) relation was used to determine flows for any other observed stage. The basic rating curve equation (Q-h relation) for open channel flow is (Dawdy, 1961):-

$$Q = K * h^n \qquad \text{.......................... 2.1}$$

Where, Q is discharge (m^3/s), h is stage in the canal (m) and k and n is constants. The coefficients k and n was determined from a linear plot of log Q versus log h by a linear regression. Irrigation water was measured at two locations in the canal. The volume of diverted (supplied) irrigation water from the source was measured at the head of the main canal. On the other hand, the volume of delivered irrigation water was measured at the head of the command. Irrigation water being a major input to agriculture, data on irrigation flow will be used to evaluate both indicators of water supply and water productivity, which are key for comparative performance assessment.

In order to determine the coefficients k and n, the power equation 3.1 can be transformed into a linear form by taking the logarithms of both sides:

$$Q = \log(k * h^n) = logk + n * logh \quad \text{.......... 2.2}$$

Now define log Q=Y and log (h) =X.

Substituting these in to Eq-3.2 and rearranging, we get

$$Y = n * X + \log k \quad \text{................ 2.3}$$

Now, this is the equation of straight line. This means that if we graph Y vs. X that is log Q and log (h), we were end up with a straight line, even if we do not know what n and k are. Furthermore, the slope of this line is the unknown exponent n in Eq-3.1. We can there for find the value of n by calculating the slope in the usual way. That is

$$n = \frac{Y2 - Y1}{X2 - X1} = \frac{\log Y2 - \log Y1}{\log X2 - \log X1} \quad \text{................. 2.4}$$

From the straight line plot of data of log Q versus log (h), log k and n can be easily determined from a linear regression. The value of the intercept which is the value Y=logQ when X=log (h) =0) is logk, so if we can find the intercept then we can find k. for example when Logk=a is the intercept of the straight line of the graph then the value of k is determined as follows.

$K=10^a$ 2.5

Where: Q is discharge (m^3/s), h flow depth (m).

2.10.2 Irrigable and annual irrigated area

Irrigable lands were fully or partly utilized for cropping throughout the year depending on various factors. Irrigable land, the land which nominally irrigated with the designed irrigation infrastructure for the schemes was available at local agricultural development offices. It was also determined by surveying the areas with the global positioning system (GPS) for each scheme. Annual irrigated area is the sum of the areas under irrigated crops during all cropping seasons in a year, and depends on irrigation intensity. While data on irrigated land are available at local agricultural development offices, thus was supplemented using the questionnaire survey (irrigated land holding of sampled farmers, irrigation intensity and total number of farmers). Irrigated cropped area is the sum of the areas under crops during time period of analysis and Command area is the nominal or design area to be irrigated. Thus data will be collected from the office and from the farmer by questioners.

2.10.3 Agricultural production

Irrigation water management is ultimately meant to enhance agricultural production through sustainable water use. Secondary data on agricultural production were commonly ambiguous for research purposes and these data were better collected from primary sources, specifically from the schemes under consideration. As such, data on the yield (agricultural output) were collected from the farmers at each scheme after harvesting. Data on agricultural produce are collected together with data on landholding from a sample of water users at different reaches. From the average landholding and total number of irrigators, total annual production and value of production was determined. Secondary data on agricultural produce from district agricultural development bureaus are also collected for comparison. Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices.

2.10.4 Determination of application efficiency

To determine water applied to the field partial flume was used at the two schemes. During the determination of the amount of water applied to the field, the average water depth irrigation water passing through the flume to the field and respective time intervals were recorded with the sizes of the fields being irrigated and depth of water applied to the field was determined. Then depth of water retained in the root zone of the soil based on the soil moisture contents of the soil before and after irrigation was determined by taking soil sample at 30 cm interval at different section from the intake of the field. So, the depth of water retained in the root zone of the soil profile was determined by (Doorenbos et al. 1986)

$$d = \frac{\sum_{i=1}^{n}(Qf - Qi)}{100} * Asi * Di$$ 2.6

Where: d= depth of water retained in root zone of the soil profile (cm)

Qf = moisture content of the ith layer of soil after irrigation on oven dry weight basis, %

Qi = moisture content of the ith layer of soil before irrigation on oven dry weight basis, %

Asi = apparent specific gravity of the ith layer of soil

Di = depth of ith layer and,

n = number of layers in the root zone

After determining the depth of water actually applied into the fields and the depth of the water retained in the root zone of the soil, the application efficiencies (Ea) of irrigation at the selected fields was calculated using the following equation (Small, 1992).

$$Ea = \frac{\mathrm{dr}}{\mathrm{da}}$$ 2.7

Where Ea= application efficiency (%)

dr=depth of water added to the root zone(cm) and

da=depth of water applied to the field (cm)

2.10.5 Determination of storage efficiency

The water storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation. Based on the FC, PWP, BD of the soils of the selected irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the crop was calculated at the 75% moisture depletion level. Net depth was determined by (Doorenbos et al. 1986)

$$d(net) = As * D * (FC\_Pwp) * p, m$$ 2.8

Where As = Apparent specific gravity of soil

D = Effective root zone depth in m

FC = water content of soil at FC at dry weight bases

PWP = Water content of soil at PWP at dry weight bases

P = depletion factor

d(net)=net depth

After determining the storage and the required depths, the storage efficiency was calculated using equation (Bos, 1979):

$$Er = \frac{\mathrm{Va}}{\mathrm{Vs}}$$ 2.9

Where Er= storage efficiency (%)

Va=volume of water added to the root zone staorage (m^3)

Vs=potential soil moisture storage (m^3)

2.10.6 Determination of distribution efficiency

Furrow irrigation is adaptable where soils and topography are reasonably uniform (Jensen, 1983) and furrows are sloping channels cut into the soil surface and into which a relatively large initial non-erosive stream of water is turned. The logic behind the evaluation of water distribution uniformity along the furrow is that when irrigation water is applied into a longer furrow with a given discharge, the upper and the lower ends cannot get equal amount of water (Michael, 1997). The length of furrow which can be efficiently irrigated may be as short as 45 m on soils which take up water rapidly, or as much as 300 m or longer on soils with low infiltration rates. For such long furrows the maximum allowable slope is 1% and the furrow stream varies from 0.5 to 2.5 liter per second.

To determine the distribution uniformity of irrigation water in these furrows layouts auguring was done at selected points, starting from the initial to the end of the furrows at regular interval. And at each selected points of the furrow soil samples were collected at different depths with an interval of 30 cm up to 90 cm. The soil moisture contents of the soils at the selected points were analyzed to determine the depth of water penetration. For calculating the distribution uniformity the root depth of the crop was taken as the zone of distribution and using (Christiansen's, 1942) equation which was expressed as.

$$Cu = 100 * (1 - \frac{\sum /d/}{nXm}) \qquad d=Xi-Xm...2.10$$

Where: Cu = Christianson Uniformity Coefficient;

d =deviation of observation from the mean;

n = number of observations;

Xm= Average depth infiltrated;

Xi = Depth infiltrated at observation point i

2.11 Data analysis method

Generally primary data was gathered through field surveys, questionnaire, interviews and focus group discussions, practically participating in the operation and maintenance of the components of the irrigation system, attending farmers' meeting when decisions were made regarding water sharing and other, are among the methods used to understand the local water management of the two community managed irrigation system.

2.11.1 Gravimetric or oven dry method

Soil samples were collected in the field at desired depths using a core sampler or auger. Care must be taken to protect soil samples from drying before they are weighed. Samples were taken to the office work room, weighed (wet weight), oven dried, and weighed again (dry weight). An electric oven takes 24 hours at 105 degrees Celsius to adequately remove soil water. Excessive high temperatures can degrade the soil sample by burning organic material. The drying oven can exhaust moisture from several samples at one time. Percentage of total soil-water content on a dry weight basis is computed. To convert to a volumetric basis, the percentage water content is multiplied by the soil bulk density. Available soil water is calculated by subtracting percent total soil water at wilting point. Tools required to use this method are a core sampler or auger, soil sample containers, weighing scales, and a drying oven.

2.11.2 Selected performance indicators

To evaluate irrigation performance there are different types of performance indicators among these the following families of indicators was used:

2.11.2.1 Water supply indicators

The water supply indicators are based on irrigation and water supply/delivery measurements being related to water demands or irrigated area. The three indicators that were considered under this group are:

1. Annual irrigation water delivery per unit irrigated cropped area (AIDUIA)

The annual irrigation water delivery quantifies the volume of irrigation water actually delivered per unit area irrigated. The cropped area was the irrigated area of the schemes. It was given by (Molden and Gates, 1990).

$$AIDUIA = \frac{\text{AWD}}{\text{ICA}} (m3/ha) \qquad .... 2.11$$

Where: AIDUIA= Annual irrigation water delivery per unit irrigated cropped area (m^3/ha)

ICA=Irrigated cropped area (ha) is the sum of the areas under crops during the time period of analysis and

AWD= annual water delivered (m^3) is the volume of water delivered to the command area.

2. Annual Relative Water Supply (ARWS)

The annual relative water supply is the ratio of total annual water supplied to the annual crop water demand. It signifies whether the water supply is in short or in excess of demand (Molden and Gates, 1990):

$$ARWS = \frac{\text{AWS}}{\text{ACWD}} (m3/m3) \qquad ....2.12$$

Where: ARWS=Annual relative water supply (m^3/m^3)

AWS=annual water supply (m^3) is Surface diversions plus net groundwater plus effective rainfall and

ACWD=Crop demand (m^3) is potential crop ET, or the ET under well-watered conditions.

3. Annual Relative Irrigation Supplies (ARIS)

The annual relative irrigation supply is the ratio of annual irrigation supply to annual irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and may be a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/

abundance in relation to irrigation demand. It was given by (Molden and Gates, 1990).

$$ARIS = \frac{\text{AIS}}{\text{AID}}(m3/m3) \qquad \text{........................2.13}$$

Where: ARIS=Annual relative irrigation supplies (m^3/m^3)

AIS=annual Irrigation supply (m^3) is only the surface diversions and net groundwater draft for irrigation and

AID= annual Irrigation demand (m^3) is the crop ET less effective rainfall.

2.11.2.2 Agricultural output indicators

Agricultural output indicators can be subdivided into land productivity and water productivity indicators. Six relevant indicators, two for land productivity and four for water productivity were considered under this group of indicators for this study. The outputs of agricultural production in this paper were based on local prices.

1. Output Per Unit Irrigated Cropped (Harvested) Area (OPUIA)

The output per unit irrigated cropped area (output per unit harvested area) quantifies the total value of agricultural production per unit of area harvested during the period of analysis. The annual harvested area depends on the intensity of cropping (irrigation intensity). This indicator is not affected by the intensity of cropping (irrigation). However, it can also indirectly indicate the degree of irrigation water availability. In addition to water availability, soil type and fertility, land suitability, crop variety and agricultural inputs do have significant impact on output and hence on land productivity. It was given by (Molden and Gates, 1990):

$$OPUIA = \frac{\text{VAP}}{\text{Ha}}(birr/ha) \qquad \text{......................2.14}$$

Where: OPUIA= Output per unit irrigated cropped (harvested) area (birr/ha)

VAP=Production (birr) is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and

Ha= harvested area is the total area under the crop (ha).

2. Output Per Unit Command Area (OPUCA)

The output per unit command area is the value of agricultural production per unit of nominal area which can be irrigated. Smaller values of this indicator can also imply, although not necessarily, less intensive irrigation and vice versa. It is particularly important where land is a constraining resource for production. It is given as (Molden and Gates, 1990):

$$OPUCA = \frac{\text{VAP}}{\text{Na}}(birr/ha) \qquad \text{.........................2.15}$$

Where: OPUCA= Output per unit command area (birr/ha)

Na= Nominal (ha) is Command area or design area to be irrigated, and irrigated area is the sum of the areas under irrigation during the time period of analysis and

VAP=Value of annual Production (birr) is the output of the irrigated area.

3. Output Per Unit Irrigation Water Supply (OPUIS)

The output per unit irrigation water supply tells on how well the total annual diverted irrigation water from a source is productive. Irrigation water supply includes conveyance (seepage) losses in canals, and hence it is generally measured at the intake from the source or at diversion. In areas where water is scarce, water management aims to increase the output per drop of irrigation water: It is given as (Molden and Gates, 1990):

$$OPUIS = \frac{\text{VAP}}{\text{DAIS}}(birr/m3) \qquad \text{...........2.16}$$

Where: OPUIS= Output per unit irrigation water supply ($birr/m^3$)

VAP=Production(birr) is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and

DAIS=Diverted irrigation supply (m^3) is the volume of surface irrigation water diverted to the command area.

4. Output Per Unit Water Consumed (OPUWC)

The output per unit water consumed informs on the output per unit annual volume of water consumed by actual evapotranspiration (ET). Its value is highly dependent on climate. Moreover, less consumptive use coefficient due to water losses does not affect its value; as only the water consumptively used by the crops is considered. It is given as (Molden and Gates, 1990).

$$OPUWC = \frac{\text{VAP}}{\text{VET}}(birr/m3) \qquad \text{......................2.17}$$

Where: OPUWC= Output per unit water consumed (birr/m^3)

VAP= Production(birr) is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and

VET= Volume of water consumed (m^3) by ET is the actual evapotranspiration of crops

2.11.2.3 Physical sustainability indicators

Two indicators are of relevance under the group of physical sustainability indicators.

1. Irrigation ratio

Irrigation ratio is the ratio of currently irrigated area to irrigable command (nominal) area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinization/water logging, etc., could result in underutilization of land. On the other hand, cropping intensity, a ratio of annual cropped area to nominal area is indicative of annual land utilization. Burton et al., (2000) state that cropping intensities from 100 to 200% are considered good; whereas an inferior figure is low. Irrigation ratio is expressed as Burton et al., (2000):

$$Irrigation.ratio = \frac{\text{IA}}{\text{CA}}(ha/ha) \qquad \text{...................2.18}$$

Where: CA=Command area (ha) is the nominal or design area to be irrigated, and

IA=irrigated area (ha) is the sum of the areas under irrigation during the time period of analysis.

2. Sustainability of irrigated area

Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area when designed (Bos, 1997). It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation (Bos, 1997):

$$Sustainability.of.irrigated.area = \frac{\text{CIA}}{\text{IIA}}(ha/ha)$$

$$\text{..................2.19}$$

Where: CIA=currently irrigated area (ha) is the area under the irrigation during the analysis of this study and

IIA= initially irrigated area (IIA) is an area under irrigation at the beginning of the project.

2.11.2.4 Irrigation water efficiencies

In order to evaluate the irrigation water use efficiency of farmers at field level and to compare each other in the same irrigation projects, three different farmer fields were selected from each irrigation project. These fields were selected from the head, middle and tail end water users of the irrigation projects. The assumption behind the selection criterion of the farmer's fields was that there was a tendency of the head end users to overirrigate their crops while the tail end users were in short supply of irrigation water.

Infiltration of water into the furrow is the most important variable affecting the characteristics of flow in furrows. According to Michael (1997), in order to evaluate furrow irrigation performance gravimetric method of measuring soil moisture content, which was done by taking the moisture contents of the soil before and after irrigation, is more accurate but time consuming. Application efficiency, storage efficiency and distribution efficiency were used under this study to evaluate irrigation efficiency.

3. Results and Discussion

3.1 Soil moisture content and soil physical properties

The soil physical properties of each selected field was obtained and shown below

Table 3.1
Physical soil properties of selected fields of Gatto irrigation scheme.

Farmer's Field	Soil depth (cm)	Bulk Density (gm/cm^3)	FC (%)	PWP (%)	Soil texture class
Field 1	0-30	1.25	33.60	12.4	Sandy clay
	30-60	1.255	36.25	17.68	Silt clay
	60-90	1.28	42.14	28.35	Silt clay
Field 2	0-30	1.130	24.65	13.62	Silt loam
	30-60	1.210	25.13	15.40	Silt soil
	60-90	1.270	32.72	22.37	Sandy clay
Field 3	0-30	1.02	35.18	19.50	Sandyclay Loam
	30-60	1.043	43.82	28.00	Clay soil
	60-90	1.30	38.95	24.88	Sandy clay

Table 3.2
Textural class for gatto irrigation scheme.

	Soil type	Mass of soil (gm)	% particle	Soil texture
Field 1 Soil sample		94.8	100	
	Sand	54.984	58	Sandy clay
	Silt	22.33	23.56	
	Clay	17.5	18.44	
Field 2 Soil sample		136.25	100	
	Sand	28.4	20.84	Silt loam
	Silt	86.08	63.18	
	Clay	21.77	15.98	
Field 3 Soil sample		76.456	100	
	Sand	47.52	62.15	Sandy clay loam
	Silt	10.24	13.4	
	Clay	18.7	24.45	

Table 3.3
Average soil moisture contents before and two days after irrigation Gatto scheme.

Farmer's field	Time of soil sampling	Soil moisture contents,(% volume)		
		Soil depths in cm		
		0-30	30-60	60-90
Field 1	Before irrigation	29.752	28.923	31.553
	After irrigation	33.60	36.25	42.14
Field 2	Before irrigation	18.409	21.322	27.258
	After irrigation	24.65	25.13	32.72
Field 3	Before irrigation	26.803	28.237	30.153
	After irrigation	35.18	43.82	38.95

Table 3.4
Textural class for Arguba irrigation scheme.

	Soil type	Mass of soil (gm)	% particle	Soil texture
Fild 1 Soil sample		86.87	100	
	Sand	27.5	31.65	
	Silt	49.7	57.21	Silt loam
	Clay	9.67	11.14	
Fild 2 Soil sample		58.93	100	
	Sand	23.572	40	
	Silt	21.1	35.8	Clay loam
	Clay	14.26	24.2	
Field 3 Soil sample		124.6	100	
	Sand	69.1	55.43	
	Silt	9.72	7.75	Sandy clay
	Clay	45.88	36.82	

Table 3.5
Physical soil properties of selected fields of Arguba irrigation scheme.

Farmer's Field	Soil depth (cm)	Bulk Density (gm/cm^3)	FC (%)	PWP (%)	Soil texture class
Field 1	0-30	1.27	35.16	17.4	Silt loam soil
	30-60	1.27	33.78	20.13	Sandy clay
	60-90	1.29	38.48	29.60	Sandy clay
Field 2	0-30	1.067	41.69	13.62	clay loam
	30-60	1.21	36.5048	15.40	Silt clay
	60-90	1.26	38.022	22.37	Sandy clay
Field 3	0-30	1.23	37.35	17.90	Sandy clay
	30-60	1.25	45.62	30.00	Clay
	60-90	1.26	34.85	22.91	Silt clay

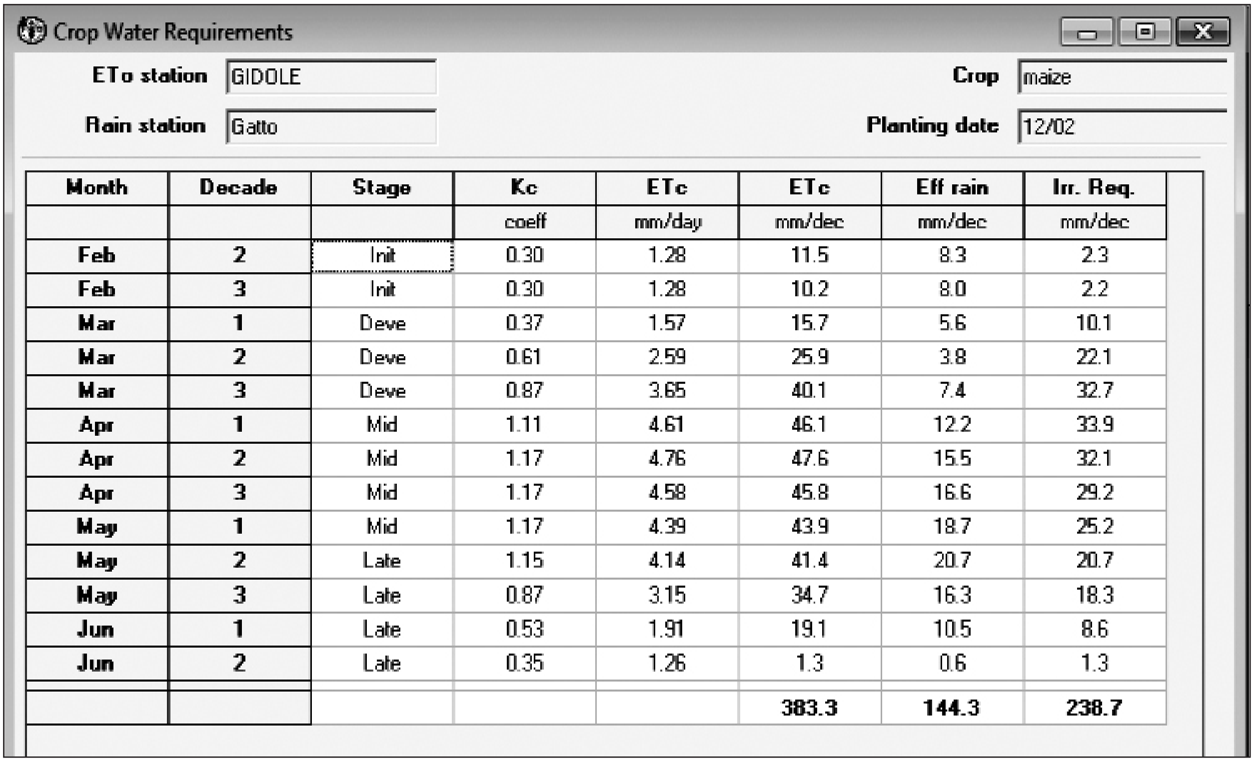
Table 3.6
Average soil moisture contents before and two days after irrigation for arguba scheme.

Farmer's field	Time of soil sampling	Soil moisture contents, (% volume)		
		Soil depths (cm)		
		0-30	30-60	60-90
Field 1	Before irrigation	30.253	27.980	26.482
	After irrigation	33.60	36.25	42.14
Field 2	Before irrigation	29.41	30.175	28.210
	After irrigation	41.69	36.5048	38.022
Field 3	Before irrigation	25.12	26.109	24.651
	After irrigation	35.18	43.82	38.95

3.2 Crop water requirement and irrigation requirement

The crop water requirement and irrigation requirement of each crop was calculated and listed below in Table.

Table 3.7
The crop water requirement and irrigation requirement of maize crop.



Crop Water Requirements

ETo station: GIDOLE
Crop: maize
Rain station: Gatto
Planting date: 12/02

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.30	1.28	11.5	8.3	2.3
Feb	3	Init	0.30	1.28	10.2	8.0	2.2
Mar	1	Deve	0.37	1.57	15.7	5.6	10.1
Mar	2	Deve	0.61	2.59	25.9	3.8	22.1
Mar	3	Deve	0.87	3.65	40.1	7.4	32.7
Apr	1	Mid	1.11	4.61	46.1	12.2	33.9
Apr	2	Mid	1.17	4.76	47.6	15.5	32.1
Apr	3	Mid	1.17	4.58	45.8	16.6	29.2
May	1	Mid	1.17	4.39	43.9	18.7	25.2
May	2	Late	1.15	4.14	41.4	20.7	20.7
May	3	Late	0.87	3.15	34.7	16.3	18.3
Jun	1	Late	0.53	1.91	19.1	10.5	8.6
Jun	2	Late	0.35	1.26	1.3	0.6	1.3
					383.3	**144.3**	**238.7**

For all crops that are grown in both irrigation schemes under respective area crop water requirement are calculated in similar ways and are shown below.

Table 3.8
Results of CWR and IR of Gatto irrigation schemes.

Crop	Area(ha)	Effective rain fall (mm/season)	Crop water requirement (mm/season)	Irrigation requirement (mm/season)
Maize (local)	64.5	144.30	383.3	238.7
Maize (AS11)	27.85	154.85	437.42	331.74
Sorghum (red)	15.7	186.160	462.97	382.45
Cabbage	14.5	112.18	343.16	308.16
Carrot	19.4	97.85	321.83	202.35
Tomato	9.25	130.83	3501.68	256.89
Onion	16.45	112.56	382.92	208.82
Total	176			

For Arguba irrigation scheme the crop water requirement and irrigation requirement was calculated and shown below

Table 3.9
Results of CWR and IR of arguba irrigation schemes.

Crop	Area (ha)	Effective rain fall (mm/season)	Crop water requirement (mm/season)	Irrigation requirement (mm/season)
Maize (local)	32.4	102.42	437.19	332.18
Sorghum (red)	18.17	140.90	443.8	364.09
Cabbage	23.12	97.00	413.28	328.29
Carrot	18.83	99.81	371.87	315.96
Potato	6.5	142.4	348.23	287.12
Onion	17.98	115.09	442.8	282.67
Total	118			

The total crop water demand for the 2015 cropping season of both irrigation projects was calculated and the result for both schemes was as follow.

For Gatto irrigation scheme result is 574.926 mm/season. To change the depth to volume of CWR multiply it by the total irrigated area, i.e. 176 * 10^4 * 574.926 *10^{-3} m^3 =1011869.77 m^3 /season. The total irrigation requirement is calculated in the same way and the result is 532.074 mm/season i.e. 176 * 10^4 * 532.074 *10^{-3} m3 / season=936450.2 m^3 /season and for Arguba irrigation scheme the result is 488.9823mm/ season. To change the depth to volume of CWR multiply it by the total irrigated area, i.e. 118 * 10^4 * 488.9823 *10^{-3} m^3 =576999.1 m^3 /season. The total irrigation requirement is calculated in the same way and the result is 446.288 mm/season i.e. 118 * 10^4 * 446.2884 *10^{-3} m3 / season=526620.3 m^3 /season.

3.3 Water application

Water applied to each field was calculated for field one, field two and field three which are located at head, middle and tail of the system respectively by using 6 inch Parshall flume and the result was shown in Table below.

Table 3.10
Applied irrigation water for gatto irrigation scheme.

Farmer's field	Time elapsed (sec)	Flume height (cm)	Discharge (l/sec)	Area of fields (m^2)	Total volume (m^3)	Depth applied (mm)
Field 1	14680.3	14	22.890	2400	336	140
Field 2	17854.8	13.6	18.281	2400	326.4	136
Field 3	16394.4	13.8	17.202	2400	331.2	138

Table 3.11
Applied irrigation water for arguba irrigation scheme.

Farmer's field	Time elapsed (sec)	Flume height (cm)	Discharge (l/sec)	Area (m^2)	Total volume (m^3)	Depth applied (mm)
Field 1	28630.1	12.17	15.303	3600	438.12	121.7
Field 2	32352.3	9.84	10.949	3600	354.24	98.4
Field 3	24635.1	11.29	9.498	3600	406.44	112.9

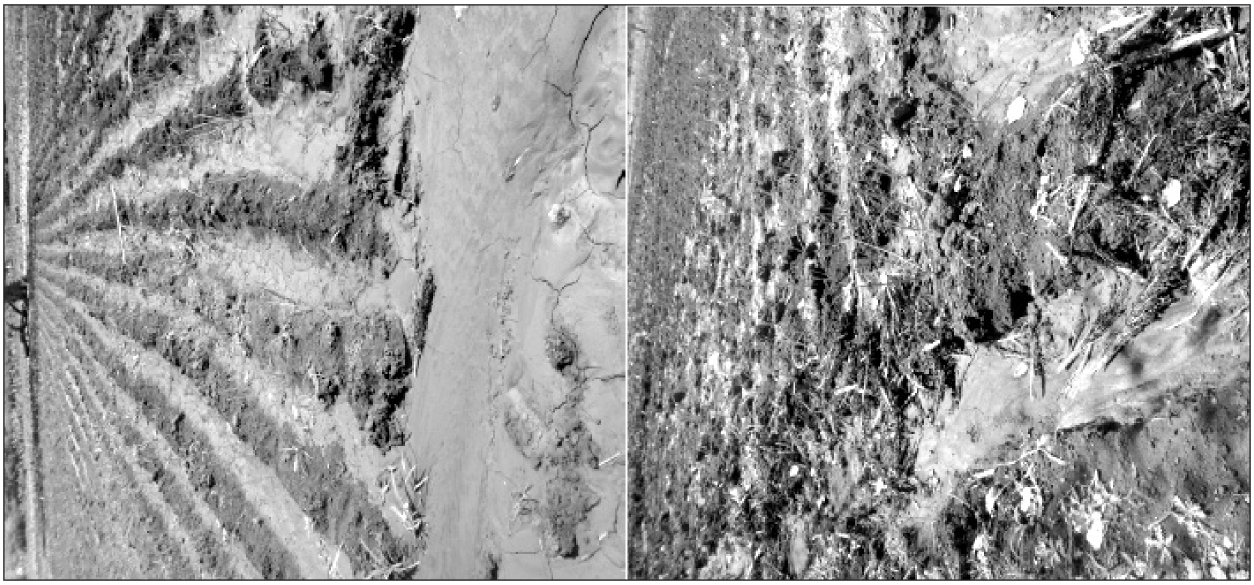


Fig. 3.1 Furrow layout for both irrigation schemes.

3.4 Flow measurement

The calculated result for the flow measurement was shown below. This result was for the agricultural year of 2015

a. Gatto irrigation scheme **b. Arguba irrigation scheme**

Fig. 3.2 Flow measurements for developing rating curve equation.

Table 3.12
Water supply indicators for gatto and arguba irrigation schemes.

Parameter	Gatto irrigation	Arguba irrigation
Total water supply, m^3	1,893,272.39	936,924.74
Total water delivery, m^3	1,630,928.64	758,719.25
Crop water demand, m^3	1,011,869.77	576999.1
Irrigation supply, m^3	1,423,692.62	856,895.31
Irrigation demand, m^3	936450.2	526620.3

Table 3.13
Irrigable lands, initial irrigated land and current irrigated land.

Scheme	Irrigable Land (ha)	Initial irrigated Land (ha)	Current irrigated Land (ha)	Irrigation ratio (ha/ha)	Sustainability of irrigated area (ha/ha)
Gatto	200	182	176	0.88	0.967
Arguba	150	134	118	0.787	0.881

3.5 Irrigation performance evaluation

The result of irrigation performance evaluation for 2015 by using performance indicators where shown below for three water supply indicators, four agricultural indicators, two physical sustainability indicators and irrigation water efficiencies.

3.5.1 Physical sustainability indicators

The two physical indicators were used are irrigation ratio and sustainability of irrigation. Data related to area of the land at each scheme was shown on Table 3.13 above and calculated by using equation 2.18 and 2.19 and the value was shown above.

In the community managed small-scale irrigation schemes sustainability has been a critical issue. Without sustainability of irrigation scheme it is difficult to find sustainability indicators. So, sustainability in small-scale irrigation schemes in Ethiopia is a key issue for food security and rural livelihood enhancement. Issues constraining sustainability in these schemes are in general a collective result of non-sustainable irrigation area, defective irrigation scheduling, size of landholding, decreasing land productivity, etc.

3.5.1.1 Sustainability of irrigated area

The values for sustainability of irrigate area for the two schemes are shown in Table 3.13 above. In the result the value for sustainability of irrigation area for Gatto irrigation scheme was 0.967 which is 96.7% of area was currently under irrigation and the value was less than one that means in comparison with initially irrigated area currently irrigated area was reduced by 3.3%. For Arguba irrigation the result for sustainability irrigated area was 0.881 which indicates that 88.1% of area was currently under irrigation compared to initially irrigated area it means currently irrigated area of Arguba irrigation scheme was reduced by 11.9%. In this two irrigation schemes the sustainability of irrigated area was reducing and this were happening due to flooding, natural drainage, and water shortage and soil fertility degradation. In both irrigation schemes flooding were happen and damages the farmer’s field by loading stones on the field and affects the soil fertility. The flood erodes the fertile soil of the field and also it causes valleys that are not important for irrigation. This leads to reduction of irrigation area.

3.5.1.2 Irrigation ratio

The result for this indicator for both irrigation schemes were 0.88 and 0.787 for Gatto and Arguba irrigation scheme respectively. This result shows that 88% and 78.7% of irrigable land has been currently under irrigation respectively. In this result the irrigation ratio of Gatto irrigation was higher than that of Arguba irrigation. In both irrigation scheme the irrigation ratios in these schemes are much better compared to Hayrabolu irrigation scheme in Turkey. For this two irrigation schemes the result shows that it is under utilization this is due to shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinity/waterlogging, etc., could result in under utilization of land, soil fertility degradation, flooding and other factors that reduces currently irrigation area and leads to less return and reduce productivity.

3.5.2 Water delivery indicators

Water supply indicators for Gatto and Arguba Scheme were given in Table 3.12 and the calculated value of water delivery performance indicators, that means annual relative irrigation supply, Annual irrigation water delivery per unit irrigated cropped area (AIDUIA) and annual relative water supply were given in Table 3.14. These indicators evaluates water supply of the irrigation system. If their values of the indicator were equal to one then the system was

Table 3.14
Water supply indicators for gatto and arguba irrigation schemes.

Parameter	Gatto irrigation	Arguba irrigation
Area developed (ha)	176	118
Crop water demand (m^3)	1,011,869.77	576999.1
Crop type	(Maize, onion, tomato..)	(Maize, potato, sorghum..)
Total water supply, m^3	1,893,272.39	936,924.74
Total water delivery, m^3	1,630,928.64	758,719.25
Irrigation supply, m^3	1,423,692.62	856,895.31
Irrigation demand, m^3	936450.2	526620.3
AIDUIA (m^3/ha)	9266.64	6429.824
ARWS (m^3/m^3)	1.871	1.624
ARIS (m^3/m^3)	1.520	1.630

optimal but if the indicators were less or greater than one then the water supply of the irrigation system was under or oversupply of the water respectively. The values are shown below

3.5.2.1 Annual Relative Water Supply (ARWS)

The result for annual relative water supply (ARWS) In both irrigation schemes for this indicator were 1.871 and 1.624 for Gatto and Arguba irrigation schemes respectively. It shows that Gatto irrigation scheme has higher annual relative water supply than that of Arguba irrigation scheme.

3.5.2.2 Annual Relative Irrigation Supplies (ARIS)

The result for annual relative irrigation supply was shown in Table 3.14. In this Table it can be observed that ARIS value of Gatto was less than ARIS value of Arguba irrigation scheme. It is better to have RIS close to 1 than a higher or lower value (Molden et al., 1998). These indicates that if their values would be equal to one then irrigation water supply was evaluated as optimal and if their values are less or greater than one it would mean under or over supply of water respectively. It can also be observed that the ARIS values for each scheme are higher than 1.0 depicting on the distribution of the supply over the field which is 1.52 and 1.63 for Gatto and Arguba schemes respectively and this value indicates that for both irrigation schemes there was over supply of water at both irrigation schemes. The main reason for over supply was the fact that at each scheme, the volume of water diverted is totally decided by the water users themselves. This indicates that water were diverted without due consideration of demand and due to that over supply were occurred in both irrigation schemes and also there is no water fee in both schemes due to that farmer supplies water in to their field as they want and due to that over irrigation supply was happen.

3.5.2.3 Annual Irrigation Water Delivery Per Unit Irrigated Cropped Area (AIDUIA)

The result for this was shown in Table 3.14. In this case the result for annual irrigation water delivery per unit irrigated cropped area in both irrigation schemes were 9266.64 and 6429.824 for Gatto irrigation and Arguba irrigation schemes respectively. The total area for this irrigation was 179ha. The result shows that in Gatto irrigation scheme the Annual irrigation water delivery per unit irrigated cropped area was higher than that of Ariguba irrigation scheme.

3.5.3 Agricultural output indicators

The data and calculated result under respective area was shown in Table below for both irrigation schemes

The production per unit of harvested land in both irrigation schemes is different for the same crops. The production of maize, carrot and onion per hectare of land for Gatto irrigation scheme were higher than that of Arguba irrigation scheme and the production of sorghum and cabbage for Arguba irrigation scheme were higher than that of Gatto irrigation scheme and this variation is due to production constraints such as farmers have lack of knowledge in using inputs such as

Table 3.15
Crop type and yield for Gatto irrigation schemes.

Crop type	Area (ha)	Yield (Qt/ha)	Yield (Qt)	Price (Birr/Qt)	Revenue (Birr)
Maize (local)	64.5	42	2709.00	471.75	1277970.75
Maize (AS11)	27.85	38	1058.30	511.00	540791.30
Sorghum (red)	15.7	35	549.50	483.17	265500.00
Cabbage	14.5	48	696.00	235.58	163965.77
Carrot	19.4	26	504.40	527.25	265944.90
Tomato	9.25	9.5	87.87	875.45	76930.20
Onion	16.45	17.8	292.81	2351.26	688472.44
Total	176				3279575.59

Table 3.16
Crop type and yield for arguba irrigation schemes.

Crop type	Area (ha)	Yield (Qt/ha)	Yield (Qt)	Price (Birr/Qt)	Revenue (Birr)
Maize (local)	32.40	36	1166.40	511.00	596030.40
Sorghum (red)	18.17	41	744.970	597.83	445367.70
Cabbage	23.12	60	1387.20	235.58	326800.00
Carrot	18.83	23.6	444.388	527.25	234303.60
Potato	6.50	12.5	81.25	189.87	15426.94
Onion	17.98	8.7	156.43	2351.26	367798.20
Total	118				1985727.49

fertilizers, seeds, chemicals, water availability, soil type and fertility, land suitability and using natural manure. Weed infestation and crop diseases are one of the production constraints that decrease crop yield, but the price per quintal are the same, because the production in both schemes were sold in the same market (Gidole town, Gatto and Holte). From Table 3.15 and 3.16 the total revenue for Gatto irrigation scheme was 3279575.594 birr and 1985727.49 birr for Arguba irrigation scheme. The total revenue for Gatto irrigation scheme was higher than the total revenue of Arguba irrigation scheme. This indicates that the production level for Gatto irrigation scheme was good and the production level for Arguba irrigation scheme was law. The production difference was due to farming practice, soil fertility, crop adaptability and others. This was improved by sharing farming practice, using fertilizer and planting crops adaptable to the farmer field in order to increase the productivity of Arguba irrigation scheme.

For evaluation of agricultural indicators the main crops grown in both irrigation schemes and the total value of annual production were listed in Table 3.15 and 3.16 including areal allocation of each crop for agricultural year of 2015 and were summarized in Table 3.17. Information on area was obtained from Table 3.13 and water related information was summarized in Table 3.12. Four agricultural performance indicators for the two schemes were calculated by equation 2.14, equation 2.15, equation 2.16 and equation 2.17 for OPUIA, OPUCA, OPUIS and OPUWC respectively and the results for those all parameter including performance indicator were also shown in Table 3.17.

3.5.3.1 Output Per Unit Irrigated Cropped (Harvested) Area (OPUIA)

The result for this indicator was 18633.95 birr/ha for Gatto irrigation scheme and 16828.20 birr/ha for Arguba irrigation scheme. Based on this information as a datum it is possible to say that the response or income per cropped area in Gatto was higher than as compared to Arguba irrigation scheme. That means the return from Arguba irrigation scheme is smaller than Gatto irrigation scheme. This is due to soil fertility,

Table 3.17
Agricultural indicator for gatto irrigation and ariguba irrigation schemes.

Parameter	Gatto irrigation	Arguba irrigation
Irrigation supply, m^3	1,423,692.62	856,895.31
Crop water demand, m^3	1,011,869.77	576999.1
Nominal area, ha	200	150
Harvested area, ha	176	118
Value of annual production, birr	3279575.594	1985727.49
OPUIA in (Birr/ha)	18633.95	16828.20
OPUCA in (Birr/ha)	16397.90	13238.2
OPUIS in (Birr/m3)	2.30	2.32
OPUWC in (Birr/m3)	3.241	3.441

water availability, land suitability and crop variety and agricultural inputs do have significant impact on land productivity. It is given as (Malano et al., 2004; Molden et al., 1998). If the soil is fertile and water is available then the output per unite irrigated cropped area are high.

3.5.3.2 Output Per Unit Command Area (OPUCA)

This parameter indicates the average retunes of each design command area and it is different from scheme to scheme. The output per unit command of Gatto irrigation scheme was higher than Arguba irrigation scheme. The irrigated area of Gatto was 176 ha and that of Arguba was 118ha respectively. This indicator also works with water availability, soil type and soil fertility, land suitability and crop variety. So, due to water availability, soil type and soil fertility, land suitability and crop variety the production crops are different from scheme to scheme and even it varies from frame lands in the same irrigation scheme and this trend was applicable in this research and the result for Gatto irrigation scheme was 16397.90 birr/ha and 13238.2 birr/ha for Arguba irrigation scheme. So, the result for this indicator for Gatto irrigation scheme was higher than that of Arguba irrigation scheme. This was due to water availability, soil type and soil fertility, land suitability and crop variety. When land is limiting relative to water, output per unit land may be more important. Where water is a limiting factor to production, output per unit water may be more important (Molden et al., 1998).

3.5.3.3 Output Per Unit Irrigation Water Supply (OPUIS)

As it obtained from the calculation in Gatto scheme it is about 2.30 birr for one meter cube of irrigation water supply and for Arguba scheme it was 2.320 birr for the same meter cube of water supplied. This result shows that the output per unit irrigation water supply for Arguba irrigation scheme was higher than that of Gatto irrigation scheme.

3.5.3.4 Output Per Unit Water Consumed (OPUWC)

The result of this output was 3.241birr/m^3 for Gatto irrigation scheme and 3.441 birr/m^3 for Arguba irrigation scheme. Its value is highly dependent on climate. Moreover, less consumptive use coefficient due to water losses does not affect its value; as only the water consumptively used by the crops is considered (Molden et al., 1998). This parameter also shows the return on the water consumed in each irrigation scheme. So, the value for Arguba irrigation scheme was higher as compared to the Gatto irrigation scheme. This is mainly gives due attention to the water consumed by each scheme and tells us how water is efficiently utilized by the scheme from economic point of view.

3.5.4 Irrigation efficiencies

All data used to evaluate the irrigation efficiency were shown in Table 3.1, 3.3 and 3.10 for Gatto

Table 3.18
Calculated efficiencies of selected fields at gatto and arguba irrigation schemes.

Farmer's field	Efficiencies (%)					
	Gatto irrigation scheme			Arguba irrigation scheme		
	Application	Storage	Distribution	Application	Storage	Distribution
Field 1	49.08	92.986	99.471	54.6712	97.832	99.639
Field 2	40.397	95.734	99.920	45.7374	89.0132	97.2740
Field 3	38.466	81.779	99.1561	44.685	91.2954	98.396

irrigation scheme and in Table 3.5, 3.6 and 3.11 for Arguba irrigation scheme. The result calculated for irrigation efficiency for both irrigation schemes were shown in Table 3.18.

3.5.4.1 Irrigation efficiencies for Gatto irrigation scheme

For Gatto irrigation project it ranges from 38.466-49.1% in above Table 3.18, which was considered as inefficient and indicated that the farmers were applying excess water to their fields. Field 1 was located at the head of the project while field 2 was located at the middle of the irrigation project and field 3 was at the end of the irrigation project. Farmers were applying water regardless of the water requirements of the crop.

For the three plot based on their application efficiency, field 1 have higher application efficiency than field 2 and field 3 also have lower application efficiency as compared to the rest two fields because land level for field one was good as compared to the rest two fields . The comparison made above could be more convincing if the values of their storage efficiencies were considered integrally. Field 2 that has less application efficiency than field 1 has higher storage efficiency. These phenomena can be explained as follow. Even though the aim of applying irrigation water to a field is to re-fill the soil with moisture that will be easily available to the crop, care must be taken not to over irrigate. So, in this case higher water was applied to the field and due to that the field has higher application efficiency this does not indicate that the field has best application efficiency.

From application efficiencies of the three farmers and the depth of water applied by the farmers (Table 3.18 and Table 3.11), we can conclude that water application was excessive. The application efficiency of the three fields was considered as poor. The storage efficiencies of these fields can be regarded as high. These however need to be interpreted together with the application efficiency. Low application efficiency results in non-beneficial use such as leaching, it will result in low irrigation efficiency. This illustrates the importance of maximizing application efficiency throughout the season to obtain maximum irrigation efficiency where beneficial use is restricted to the field level.

Water storage efficiency determines the percentage of water stored in the root zone to the water required to fill the root zone to field capacity. It was difficult to define the root zone which changes during the season and it was different for each crop. This also requires determination of available soil water at the time of irrigation application. When application efficacy was high the storage efficiency may be low. If large irrigation was given to raise storage efficiency the application efficiency may go down. From the calculated result above in Table 3.18 the storage efficiency was larger than application efficiency for all fields. As it was shown in Table 3.18 the storage efficiency for field 2 was higher than the rest and field 3 has the list storage efficiency than the other two fields. This was due to field layout, slope and furrow/ tarka or botaya layout.

In order to determine distribution efficiency of each field for the two schemes depth of penetration for each field by auguring was done at selected points, starting from the initial to the end of the furrows at regular interval. And at each selected points of the furrow soil samples were collected at different depths with an interval of 30 cm up to 90 cm. And the soil moisture contents of the soils at the selected points were analyzed to determine the depth of water penetration. The calculated result of that distribution efficiency of Gatto scheme was found in Table 3.18. From this figure the distribution efficiency for all three fields were evenly distributed. The values were little varying that means field 2 has higher distribution efficiency than the other fields. In general the distribution efficiencies were high. This indicated that, after irrigation, the effective root zones of the crop in the furrow were uniformly saturated. The possible reason can be the layout of the furrows and tarika or botaya in this irrigation scheme. The furrow and tarka or botaya were short and closed. Although no water was allowed to escape from the furrows and every portion of the furrow might get water. The water trapped in the furrow was forced to percolate into the soil so all parts of the furrow have the chance to get equal amount of water in each irrigation time.

3.5.4.2 Irrigation efficiency for arguba irrigation scheme

As it was shown in Table 3.18 for Arguba irrigation scheme the application efficiency of the three field was range from 44.685%-54.67%. This also indicates that the farmer was applying high amount of water to their fields and it make inefficient irrigation efficiency. The storage efficiency of these fields can be regarded as high. For this irrigation scheme the application efficiency for field 1 was higher than field 2 and field 3.

For this irrigation scheme Field 1 have the highest storage efficiency than field 2 and field 3 and field 2 was the list efficient one. As it was shown in Table 3.12 the depth of application for field 1 was higher than field 2 and field 3 was also higher than field 2. That means high water was stored in field 1 and field 3. Even though water was distributed in rotation among the members in the project, the interval of water distribution, unlimited availability of water and taking water as a free resource with the wrong perception of farmers about the depth of water applying, they were favored to apply excess water to their fields.

As it is shown in Table 3.18 the distribution efficiency of the three fields was nearly the same. In field 1 it was evenly distributed than field 2 and field 3. Also field 3 was the list evenly distributed one as it was compared with the other two fields.

In general the variation in efficiency illustrates the fact that application efficiency varies with every irrigation event, depending on how the water is applied and the conditions existing at the time of the irrigation event. These values (Table 3.18) were obtained from soil moisture measurements taken over each of the irrigation seasons. Distribution efficiencies were high. The possible reason can be the layout of the furrows. The other advantage of these furrows is that a single farmer can control and irrigate the whole field without any problem.

3.6 Performance gape

As it was seen in the all results above the comparative indicators rely on the availability of secondary data. Getting complete data required to calculate all the external indicators for each small-scale irrigation project was very difficult. Hence, to compare the two-irrigation projects minimum sets of external indicators were applied with the available information and comparative analyses were made within and across the irrigation projects. But, in order to be more accurate number of indicators must.

As it was shown in all result and desiccation above comparative performance assessment in irrigation schemes is possible through the use of comparative indicators. External indicators are those indicators based on outputs and inputs from and to an irrigated agricultural system (Molden et al., 1998). Internal indicators on the other hand relate performance to internal management targets. This indicator evaluates the management of irrigation water indirectly in order to say the system was performing well and the management system was good. It was difficult to say this irrigation scheme was performing better than the other one because there are different factors in addition with performance indicators to give the production of the schemes more or less than the other schemes. For this community managed irrigation schemes the community does not participate for management of the irrigation water, operation and maintenance of irrigation structure. If the individuals in the community could participate in the activities of the system then the system may be sustainable and performs better.

In Table 3.1, 3.3, 3.10 and 3.18 for Gatto irrigation and 3.5, 3.6, 3.11 and 3.18 for Arguba irrigation the farmers were applying irrigation water based on their traditional belief. Farmers were applying water regardless of the water requirements of the crop. Because they do not have any idea about crop water requirement due to the fact that they believe that by applying more water to the field they may increase the production of certain crops but in realty applying more water to the field lead to over irrigation and accumulation of salts take place. Due to this the production of crops per meter cub of water was below optimal condition and irrigation performances were low.

3.7 Improvement Options

To improve the water usage create effective organizational structure of the Water Users Association in both irrigation schemes to facilitate working relationships between various entities and to improve the working efficiency within the organizational units. Without the WUA, the efficient irrigation scheme management is impossible. By strengthening the management capacity of WUA, legal and smooth handover of schemes after the construction are critical to sustain performances. So, it is possible to create effective organizational structure and institutional set up for all types of irrigation.

To achieve sustainable production and good irrigation performance it was obvious that the utilization of the important resources in irrigated agriculture, water and land, must be improved. According to Peter (1988), where several farmers are carrying out irrigated cultivation on adjacent farms or plots of land using a common source of supply and draining to a common drainage system, certain tasks and activities should be properly coordinated.

As Peter (1988), noted where issues of organization and management of irrigation are not well considered problems may arise such as:

- Existence of indefinite regulations or instructions about the share of responsibilities,
- Lack of coordination between different work groups,
- Absence of common meeting point for discussing and settling differences,
- Absence of an effective association to represent the irrigators interests,

So, if this problem was replaced by good activity then the production of the farmer was increased

There are several approaches for improving the crop productivity (yields) of water including replacing high water consuming crops with lower-consuming ones and adopting management and systems improvements to increase productivity per unit of water consumed. Reallocation of water from low-value crops to higher-value crops can increase the economic productivity of water; however this conserves water only if the high-value crop has a shorter growing season, and the land is not re cropped the same year. Thus, the most significant sources of “new” water will be through improvements in productivity per unit of water with the adoption of appropriate management and water application systems. Each basin and watershed may have different solutions depending on specific socioeconomic, soils, water supply and climatic characteristics.

Efficiencies must be considered in terms of both the diverted water that is consumed and the proportion that is not consumptively used. Efficiencies are increased when the total amount of water consumed by crops, evaporation and other users can be reduced. The available water resource within a basin or sub basin can also be effectively conserved for other uses by improving efficiencies to reduce the un-usable water losses.

Relocating specified crops to climatic regions and soil types best suited to maximal output would be the most economically efficient use of resources. For each field, farm, irrigation district, watershed, or region, relocation concerns what is produced, what could be produced, and what should be produced.

In order to increase production of crops it is possible to use fertilizers, chemicals, pest side and select seeds free from any disease. This increases the performance of crops predations in the study area. The problem of inefficiency in irrigation systems can be emanated from technical and non-technical factors. Therefore, it is essential to accord due consideration for these issues in order to properly address the problems and to design correct operational strategy.

Farmers would train in topics related to irrigation water management and other related topics. This helps farmers to participate every management activity which found in irrigation scheme. Farmers trained will be done by project holders in collaboration with the concerned government organizations during the period of handing over the project. Training should be a continuous process. A one-time training cannot bring about a desired effect on the production and productivity of irrigation agriculture. So, if this option is given for the community then the communities understands the idea of irrigation water management and manage their water uses.

3.8 Summarized discussion for both Irrigation schemes

For physical sustainability indicators the values of physical indicators for the two schemes are shown in Table 3.13 In this result the value of irrigation ratio of Gatto irrigation scheme was higher than that of Arguba irrigation scheme. It indicates that high irrigable land was irrigated in Gatto irrigation scheme as compared to Arguba irrigation scheme because irrigation ratio and sustainability of irrigated area shows the degree of utilization of available irrigable area and under irrigation of the command area. For sustainability indicator Gatto irrigation scheme was less contracting than that of Arguba irrigation scheme.

For agricultural output indicators four agricultural performance indicators for the two schemes were calculated and the calculated results for those all performance indicators were shown in Table 3.17. As it was shown in the Table 3.17 the OPUIA and OPUCA of Gatto were higher than that of Arguba irrigation scheme. That means Gatto irrigation scheme gives more revenue per hectare of land than that of Arguba irrigation scheme thus was due to good irrigation practice in Gatto as it compared to Arguba. It shows that the production per hectare of land for Gatto irrigation was higher than that of Ariguba irrigation this is due to soil fertility, water availability, land suitability and type of crops. In the case of OPUIS and OPUWC the calculated value for these two indicators of Arguba irrigation scheme was less than that of Gatto irrigation scheme this has an implication on the proper utilization of water in Arguba irrigation scheme as it compared to Gatto irrigation scheme. That means the production per meter cube of water for Gatto irrigation scheme was less productive than that of Arguba irrigation scheme.

For water delivery indicators the result was shown in Table 3.14. In this result the value of AIDUIA and ARWS of Gatto irrigation scheme was higher than that of Arguba irrigation scheme. The value of ARIS for Gatto irrigation scheme was lower than that of Arguba irrigation scheme. But for both irrigation scheme ARWS and ARIS indicates that excess water was supplied to both irrigation schemes. This was due to low management of irrigation supply.

In order to evaluate the irrigation water use efficiency of farmers at field level and to compare each other in the same irrigation projects three farmers were selected from each irrigation projects in relation to their location (From the head, middle and tail end water users). The parameters used to compare the efficiencies at field level were application, storage and distribution efficiencies.

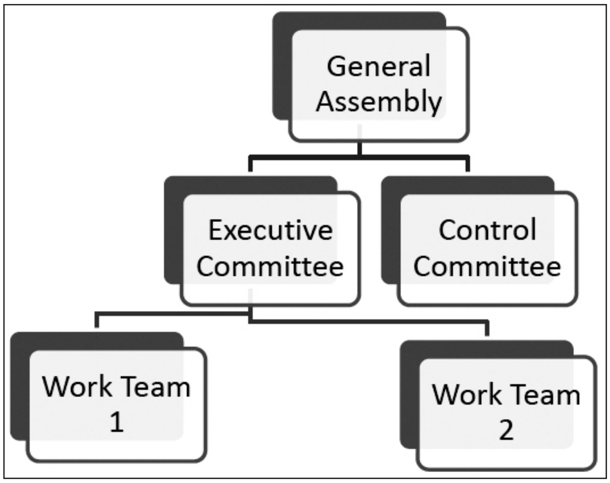
The calculated result for all irrigation efficiency for both scheme were shown in Table 3.18. For those schemes the application and storage efficiency of Arguba irrigation scheme was higher than that of Gatto irrigation scheme. But, the distribution efficiency of Gatto irrigation scheme was evenly distributed than that of Arguba irrigation scheme. The application efficiencies of the selected farmer’s field was 38.50% to 49.08% and storage efficiencies were in the range of 81.78 to 95.734 for Gatto irrigation scheme and for Arguba irrigation the application efficiency was range from 44.685 to 54.671% and storage efficiency was between 97.83 to 91.30%. For those schemes the application and storage efficiency of Arguba irrigation scheme was higher than that of Gatto irrigation scheme but, the distribution efficiency of Gatto irrigation scheme was evenly distributed than that of Arguba irrigation scheme. The possible reason can be the layout of the furrows and tarka/botaya. The other advantage of these furrows and tarka/botaya is that a single farmer can control and irrigate the whole field without any problem. From the analyses irrigation water efficiencies as a whole, farmers were doing good job in terms of water distribution uniformity. This does not mean that they were using the water efficiently; there is room for improvement.

3.9 Qualitative desiccation

3.9.1 Irrigation management issues

Both irrigation schemes have local water user associations. These water user associations have the responsibility on irrigation turn, operation and maintenance of irrigation structure, opening and closing of gates and others. The byelaws were formulated by the executive committee of irrigation staff and experts from extension organizations.

As shown in the Fig 3.3 chart, the organizational structure of both irrigation system is similar that comprises General Assembly, Executive Committee, Work Teams and the Controlling Committee. The general Assembly is the highest body in which all members of the irrigation systems collectively discuss the highest-level issues and give the final decision. The executive committee is a body elected by the general assembly, which is responsible to undertake day to day activities of the general assembly. Generally, the committee is responsible for the following major activities. Takes care of physical structures such as water gates, canals and other properties of the association and supervising water distributions and execute other related issues specified in the by-laws. Accordingly the irrigation land has been divided into blocks that constitute a work team and all members of the association are grouped in one of it. Every team elects its own team leader, accountable to the executive Committee in any matter concerning their respective team. The most important function is distributing irrigation water for the team members and ensures the activities are under taken in accordance with the established water use schedule.



Source: Offices of irrigation staff in Derasheworeda.

Fig. 3.3. Organizational structure of gatto and arguba irrigation schemes.

In this result more than half of the water management systems were not good. It also confirmed that efficient water management is found to be a major challenge in both irrigation schemes. management problems observed at a scheme level include: Lack of an efficient WUA, Water management problems, such as equitable water use, high water loss due to seepage as a result of a poor maintenance strategy, uncontrolled water use, vandalism and water theft and Scheme management issues, such as lack of structural maintenance, lack of proper operation of the structures and lack of the ownership sense are the major constraints in all schemes.

3.9.2 Issues related with irrigation water use

The result from quaternary for irrigation water use was shown below 12 water user was selected from each irrigation schemes.

3.9.2.1 Reliability of irrigation water supply

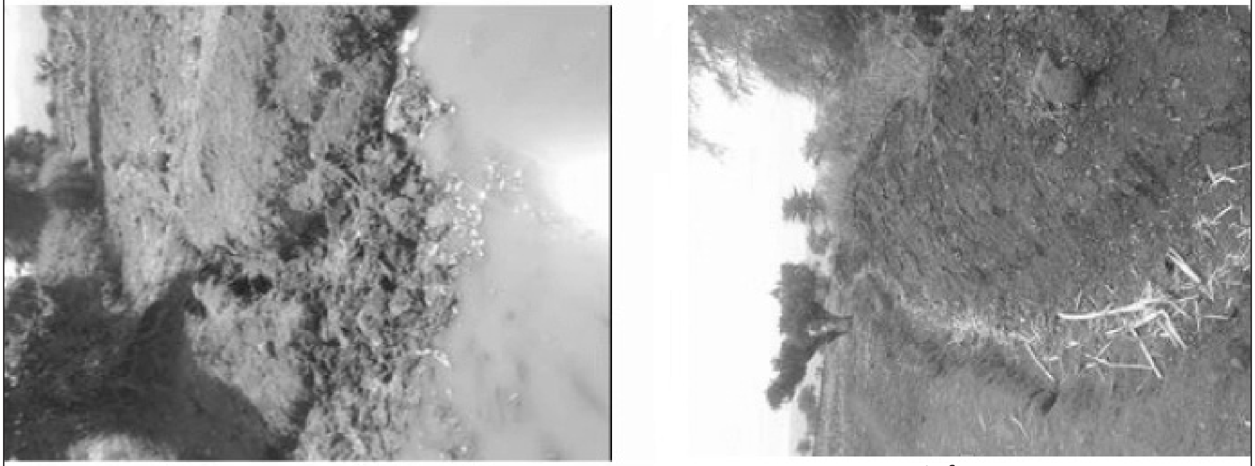
A result for reliability of water was shown in Table 3.20. From this result there was unreliability of irrigation water supply due to the poorly functioning irrigation infrastructure and night illegal water users (vandalism) is sometimes

Table 3.19
Water management.

		Gatto irrigation scheme		Arguba irrigation scheme		
Item		Number	%		Number	%
WUA		12	100		12	100
	Strong	4	33.33	Strong	3	25
	Weak	8	66.67	Weak	9	75
Equitable water use		12	100		12	100
	Equal	2	16.67	equal	5	41.67
	Un equal	10	83.33	Un equal	7	58.33
Proper operation		12	100		12	100
	Good	1	8.33	Good	2	16.67
	Not good	11	91.67	Not good	10	83.33

Wrong use of water

Poor infrastructure



More seepage due to cattle

Poor infrastructure

Fig. 3.4 Wrongly water use.

Table 3.20
Water use indicators.

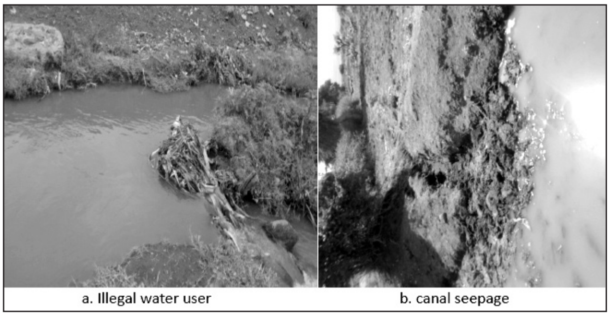
	Gatto scheme			Arguba scheme		Gatto scheme		Arguba scheme	
	Number	Fair	Unfair	Fair	Unfair	Fair (%)	Unfair (%)	Fair (%)	Unfair (%)
Water distribution	12	4	8	2	10	33.33	66.67	16.67	83.33
		Timely	Delayed	Timely	Delayed	Timely	Delayed	Timely	Delayed
Water delivery	12	2	10	3	9	16.67	83.33	25	75
		Reliable	Unreliable	Reliable	Unreliable	Reliable	Unreliable	Reliable	Unreliable
Water supply	12	5	7	4	8	41.67	58.33	33.33	66.67

observed that means for Gatto irrigation scheme 58.33% of the irrigation schemes users faces unreliable water supply and for Arguba irrigation scheme 66.67% was unreliable. Unauthorized water users, seepage, canal blockage for washing clothes, and herds of cattle drinking from the canals may also contributed to water supply unreliability.

a. more seepage

b. poorly function of irrigation structure

Fig. 3.5 Unreliability of irrigation water supply due to seepage and poorly function of irrigation structure.



a. Illegal water user

b. canal seepage

Fig. 3.6 Timely delivery of irrigation water.

3.9.3 Timely delivery of irrigation water

The result for delivery of water was shown in Table 3.20 above and it indicates that 83.33% of water delivery was delivery was delayed for Gatto and 75% for Arguba irrigation scheme. Irrigation is an essential component of agricultural water management where greater production of food and fiber is required under severe constraints of water resources. Humanity is challenged to increase production using the existing resources, mainly land and water, efficiently. Plants are efficient in sensing water stress and respond to it accordingly. Untimely delivery of water has a significant impact on performance of crops. The problem is mainly attributed to poorly functioning irrigation canals, seepage, illegal water users, and canal blockage to use the water for other purposes.

3.9.4 Water distribution

The result for irrigation water distribution was shown in Table 3.20. In both irrigation schemes more than half percent, in their field experience users occasionally faced unfair distribution of irrigation water. For Gatto irrigation 66.67% of user faces unfair distribution of water and 83.33% for Arguba irrigation scheme. In irrigation project, for instance, unfair distribution of irrigation water is a serious problem due to illegal water users and a weak Water Users Association. In both schemes, the unfairness is attributed to the corrupt Water Users Association and stake of headwater users.

3.9.5 Agriculture

The result of land size for Gatto and Arguba irrigation schemes 12 farmers from each irrigation scheme was shown below.

From the result above the land holding for Gatto irrigation various from 1.33 to 3.06 and for Arguba irrigation scheme it various from 1.56 to 5. The agro-ecological zone the both kebele was kola and the mean rain fall for crop predation was sufficient. The food grain production of both irrigation schemes is maize, teff, sorghum and cash crops are onion, potato, carrot, cabbage and tomato.

As it was shown in the Table above Gatto irrigation scheme was designed to irrigate 200 ha and 176 ha of land were currently under irrigation. In this irrigation scheme there were 259 male users and 7 female users with the total of 266 users and Arguba irrigation scheme was designed to irrigate an area of 150 ha and currently 118 ha of land was under irrigation. In this irrigation scheme there were 148 male users and 2 female users with the total of 150 users. For both schemes were found in bimodal agro ecological zone.

As indicated in Table 3.23 above, the estimated income obtained from food grain production was 50% for Gatto irrigation and 41.67 for Arguba irrigation and the estimated income obtained from cash crop production was 25% for Gatto irrigation scheme and 16.67 % for Arguba irrigation scheme.

The result for Livestock and other farm products was shown in Table 3.23. This result was 16.67 % for Gatto irrigation scheme and 25 % for Arguba irrigation scheme. Generally, this income from livestock include sales of animals such as oxen, cows, goat, donkeys, etc. and also livestock products like butter. Other farm products such as hens and eggs are sold to raise income to purchase food crops and other industrial products used for household consumption.

As it was shown in the Table 3.23 the result on non-farm and off farm activities undertaken by

Table 3.21
land uses.

	Gatto irrigation scheme			Arguba irrigation scheme		
	Mean	**Min.**	**Max**	**Mean**	**Min.**	**Max**
Total land size (ha)	1.33	0.44	3.06	1.56	0.5	5.13
Land under cultivation (ha)	1.24	0.38	3.00	1.37	0.25	5.00

Table 3.22
Area and irrigation users in both irrigation schemes.

		Gatto irrigation		Arguba irrigation
Irrigable (ha)		200		150
Irrigated (ha)		176		118
Users	Male	259	Male	148
	Female	7	Female	2
	Total	266	Total	150

Table 3.23
Household source of Income.

Item	Gatto irrigation scheme		Arguba irrigation scheme	
	Number	%	Number	%
	12	100	12	100
Food Grain Production	6	50	5	41.67
Cash Crop Production	3	25	2	16.67
Livestock and Other Farm Products	2	16.67	3	25
Off- Farm and Non-Farm Activities	1	8.33	2	16.67

Table 3.24
Available markets around both irrigation scheme.

Schemes	**No of user**	**Markets**					
		Gatto	**Arba Minch**	**Gidole**	**Konso**	**Gumaydemazoria**	**ArgubaTanao**
Gatto irrigation	12	4	1	4	2	1	0
%	100	33.33	8.33	33.33	16.67	8.33	0
Arguba irrigation scheme	12	0	0	4	2	1	5
%	100	0	0	33.33	16.67	8.33	41.67

some farmers to supplement their household income were 8.33 % for Gatto irrigation scheme and 16.67 % for Arguba irrigation schemes. The households' income indicated in Table 3.23 was obtained from different types of off-farm and non-farm activities such as sells of local beverages, sales of firewood and charcoal, petty trading, wage labour and hiring out oxen. Families that are engaged in such activities are mostly poor whose agricultural income is not enough for their annual consumption.

3.9.6 Marketing

The result for marketing was shown in Table 3.24 it show that in Gatto irrigation scheme 33.33% of the user sold their product on Gatto market and konso market and 41.67% of farmer sold in Tanao market in the case of Arguba irrigation scheme and 33.33% of user sold their product was sold in Gidole town. Related to the production of high value crops, both input and output side of marketing is considerably important. In light of various market constraints, inaccessibility and small size of market is the very important limiting factor for both irrigation systems. In relation to output marketing, even though both schemes are not far from the main road that access to major towns like Konso and Arba Minch, the marketing system is not well organized. The nearby local markets do not have the capacity to absorb the perishable produce of farmers. At the same time the price received by farmers in the primary markets is relatively lower than what they could have received in other big markets. Market information on the part of farmers is non-existent. As a result, farmers do not have the bargaining power to determine the price of farm produce; instead they accept the price given by the traders.

4. Conclusion

Despite the fact that every scheme has a contribution towards food production, the degree of its contribution will vary from scheme to scheme since production is affected by many factors. So, the comparison of this irrigation schemes indicates the weaknesses and strengths of these irrigation schemes, which are helpful for managerial and technical practices.

The study covered the minimum set of indicators that can be used to evaluate the health of a system. These are agricultural output indicators, water delivery indicators and physical sustainability indicators thus small number of indicators cannot permit a deep analysis of the indicators but the study showed the usefulness of the indicators. This performance indicator can be a useful tool in performance measurement.

For both irrigation schemes values of water delivery and supply performance indicators presented in this paper are based on data sets of one production season. It doesn't show also how adequately, uniformly, efficiently and timely the water distributed over the field and field units throughout the season and it is difficult to indicate exactly where the problems responsible for low performance of the system lie.

The relative water supply for both irrigation supplies was higher than one this indicates that there was high water supply in both schemes. The output per cropped area in Gatto irrigation was higher than Arguba irrigation scheme. This means that the irrigation practice in Gatto irrigation scheme was good as compared to Arguba irrigation scheme. The return from one meter cube of irrigation water for Arguba irrigation scheme was higher than that of Gatto irrigation scheme.

There was a marked deficiency in irrigation water management plot level at both irrigation projects. Low efficiencies were achieved because applications far exceed farmers' management know-how. This was due to the fact that the system permitted farmers to apply large volumes of water to their plots combined with poor knowledge about the crop water requirements of the farmers.

In both irrigation schemes the values of application efficiencies at field levels were reflected on the values of relative water supply of the irrigation projects as a whole. So there is some common ground to use them integrally. Even if it needs intensive data collection and close monitoring, irrigation efficiencies evaluations were good for farmers' field level.

Distribution efficiencies for both irrigation schemes were high. The possible reason can be the layout of the furrows and tarka/ botaya. The other advantage of these furrows and tarka/ botaya is that a single farmer can control and irrigate the whole field without any problem.

Acknowledgements

First of all I thanks to my God master Jesus to give normal health for my soul and give wisdom for me because the source of good health and wisdom is only from my lord God.

I would like to thank to my parents all the efforts and trust that always had on me. This research is the result of all the years of support and confidence. Thank you for everything.

For all his sincere, faithful and immense devotion to help me for the accomplishment of this thesis work and to bring me here from the start, much appreciation is expressed for my advisor Mekonen Ayana, PhD (Associate Prof.). His unlimited and sweet advice that smoothen my educational journey.

Acknowledgment is expressed to the staff of Gidole Irrigation Offices and GidoleWoreda Agricultural Offices.

In addition, the generous support and contribution of all my colleagues, friends, families and relatives are deeply acknowledged and emphasized in all cases of my future life.

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