EVALUATION OF SMALL SCALE IRRIGATION SYSTEM IN WESHA SOYAMA VILLAGE IN SIDAMA REGIONAL STATE

MSc THESIS

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EXAMINERS' APPROVAL SHEET

As member of the board of examiners of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by **Abel Iyasu Anchiso**, under the title "**Evaluation of Small Scale Irrigation System in Wesha Soyama Village in Sidama Regional State**", and examined the candidate. This is therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Irrigation and Drainage Engineering.

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DEDICATION

It is my great pleasure to dedicate this work to all beloved members of my family for their support and encouragement in finalizing this research.

STATEMENT OF AUTHOR

I, the researcher, Abel Iyasu Anchiso declare that, this MSc thesis is my original work and has not been presented for a degree in degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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LIST OF ABBREVIATIONS AND ACRONYMS

BIS	Basic Irrigation Scheduling
BS	Base Station
CRPSM	Crop yield and soil management Simulation Model
CWR	Crop Water Requirement
DEM	Digital Elevation Model
DU	Distribution Uniformity
Ea	Application Efficiency
Ec	Conveyance Efficiency
ER	Effective Rainfall
ET	Evapotranspiration
ETc	Crop evapotranspiration
ETo	Reference crop evapotranspiration
FAO	Food and Agriculture Organization
FC	Field Capacity
GA	Genetic Algorithm
GIR	Gross Irrigation Requirement
GUI	Graphical User Interface
H	Head
ISOM	Irrigation Simulation and Optimization model
IWR	Irrigation Water Requirement
Kc	Crop Coefficients
M	Middle
Mha	Million hectares
NB	Nota Bene

OPPUCA	Output per Unit Command Area
OPPUIA	Output per Unit of Irrigated Area
OPUIS	Output per Unit Irrigation Supply
OPUWC	Output per Unit Water Consumed
RFID	Radio Frequency Identification
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SIA	Sustainability of irrigated Area
SMD	Soil Moisture Deficit
SSIP	Small Scale Irrigation and Drainage Project
SSIS	Small Scale Irrigation System
SWD	Soil Water Deficit
T	Tail
TAM	Total Available Moisture
UAVs	Unmanned Aerial Vehicles
UCA	Unit Command Area
WDC	Water Delivery Capacity
WiMAX	Worldwide interoperability for Microwave Access
WLAN	Wireless local area network
WDC	Water Delivery Capacity
WUE	Water Use Efficiency
3GPP	3^{rd} Generation Partnership Project

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ABSTRACT

Field assessment to evaluate water use efficiency of small-scale irrigation projects plays a vital role in improving the existing projects and assist engineers in designing new systems so that irrigation practice becomes sustainable. Therefore, this study was carried out to evaluate the performance of Wesha SSIS using internal and external performance indicators. This study used primary and secondary data for assessing the irrigation performance. The primary data collected includes field observation, soil samples to characterize the soil in terms of physical characteristics and discharge measurement at main and field canals. Secondary data collected were total yield, area irrigated, crop type, and climate data. CROPWAT 8.0 model was used to calculate ETo and the crop water requirement. The analysis of internal performance indicators showed that the conveyance, application, storage efficiencies, distribution uniformity, and overall irrigation efficiencies were calculated and the results were 66.43, 46.70, 96.02, 91.88 and 31.02% respectively. Since the overall scheme efficiency at the study area was 31.02%, which was very poor; which mean that irrigation water loss was very large indicating need for scheme improvement. The analysis of water related indicators such as RWS and RIS were found to be 1.35 and 1.14 respectively. Since the value of RWS and RIS is greater than one this implies that, there were sufficient relative irrigation supply and high relative water supply which was beyond the crop demand. This shows that it could irrigate additional farm land with this delivery amount and available effective rainfall in the study area. The value for WDC at the study area was found 1.08 this implies that, the river diversion infrastructure is capable of delivering the necessary peak water demand. Agricultural related indicators such as, the output per unit command area is 38,939.2 Birr/ha and output per unit irrigated area is 139,068.6 birr/ha. Water productivity indicators such as, Output per unit water consumed and Output per unit irrigation water supplied are 45.24 birr/m^3 and 0.15 birr/m^3 in Wesha SSIS respectively. Based on the results obtained can be concluded that the agriculture production indicators are found to be reasonable. The potential evapotranspiration of the study area, calculated using CROPWAT Model, is more than the effective rainfall in most of the months calling for supplemental irrigation. The effective rainfall is more than ETo by 10.96 mm/month during July; meaning that no irrigation is required during this month. Therefore, those farmers who grow crops on July are less likely to apply supplemental irrigation. On the other hand, extensive irrigation is essential for crops planted particularly on October, November, December, January, February, March, April, May (with 84.67, 96.9, 100.16, 82.86, 93.2, 85.15, 88.07 and 53.95 mm of irrigation water requirements, respectively). During the study period, on-site soil erosion, temporary water logging and illegal canal breaching are the observed major problems associated with the farmers' irrigation practices. Weak operation and maintenance of the project is also witnessed. Since the current irrigable area is below the irrigable area at the initial period of the irrigation scheme, thus the project is not sustainable; due to the fact that SIA is much far from 100%. Settlement expansion is the major reason observed in the field as threat to the sustainability of the project.

Keywords: Wesha small scale irrigation system, Performance evaluation, Internal and external performance indicators

1. INTRODUCTION

1.1. Background

In Ethiopia, agriculture remains major economic activity that comprises high proportion of employment, foreign exchange and GDP. The traditional rain-fed agriculture, which is susceptible to the challenges of climate change, has been dominantly practiced for long time. This doesn't mean that irrigated agriculture is resistant to climate change; but it is less vulnerable than rain-fed agriculture. Irrigation is an energetic component of agricultural production in Ethiopia, and the modern irrigated cultivation was started in the country during 1960s in the middle Awash valley (Gebremedhin et al. 2015). Due to population burden and increasing request for food, supplementary irrigation gradually becomes vital in dry, cool and humid zones of Ethiopia (Chandrasekaran et al. 2009). Ethiopia has a huge cultivable land covering about 30–70 million ha, but only about 15 million ha is presently cultivated with recent irrigation schemes covering about 640,000 ha (Awulachew et al. 2007). However, the study estimates that total irrigable land potential in the country is 3.7 million ha assuming use of currently available technologies. Among the irrigation methods, surface irrigation, which is public in different part of the world, has been dominantly experienced in modern and traditional irrigation. Old-style surface irrigation accounts about 56% of the total countrywide irrigated zones (Awulachew et al. 2007).

Irrigated agriculture is one of the most critical human activities sustaining civilization. The current world population of 6.8 billion people is sustained in a large part by irrigated agriculture. United States Department of Agriculture statistics display that 17% of farm crop land in the USA is irrigated (Michael et al. 2010). Yet this acreage produces nearly 50% of total US crop revenues. According to the Food and Agricultural Organization, the approximately 1260 million ha under rain-fed agriculture, corresponding to 80% of the world's total cultivated land, supplies 60% of the Globe's food, while the 277 million ha cover by irrigation, the remaining 20% of land under agriculture, donates the other 40% of the food supplies. On average bases, irrigated crop yields are 2.3 times higher than those from rain-fed land. These figures prove that irrigated agriculture will remain to play an important role as an important donor to the worlds food supply (Michael et al. 2010).

Efficient and effective utilization of irrigation water has been major challenge in irrigation scheme. Long-lasting irrigation water supply technique and effective water management approaches are pressing needs nowadays with changing climate. Efficient and adequate dosage of irrigation water advances crop production and raises water use efficiency for future purposes (Taddesse and Peden et al. 2001). The aim of irrigation water management is to keep the water level in the root zone within a range where crop yield and quality are not damaged due to either inadequate or excess water (Geremew et al. 2008).

(Ashraf et al. 2007). However, irrigation water use has been dared by many factors including quality and accessibility of water, types of crop grown, struggle in sharing water, wasteful water use practices (Wolff et al. 1999).

Crops need water during growth period, and it is vital to uphold the amount of readily available moisture in the soil by irrigation (Modi et al. 1995). Different crops require different quantities of water at different growth stages. The irrigation system may not be designed to supply the total amount of moisture required for crop growth. Both excessive and deficit water applications have negative impacts including retarding of crop performances. As a matter of practicality, depth of water application under small scale surface irrigation practices may exceed or be less than the optimal depth of water required for a given crop. Management of water at field level is relatively low cost, more practicable, and simply workable and can be realized in short duration of time (Tagar et al. 2012). Benefit and hazard assessment of irrigation water has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that can be more effective.

1.2. Statement of problem

As the modern irrigation is not well developed and satisfies the demands of farmers due to financial limitation, role of small scale irrigation project is very important. There are still improvement options to make better in many aspects. Irrigation agriculture plays a crucial role in determining the future food security, poverty reduction and economical growth in most countries, thus effective management is an important issue in irrigation system. Irrigation system with poor management have the potential to degraded and waste the valuable land and water resources. There are a number of shortcomings to become the irrigation scheme below its potential such as poor operational and maintenance of the irrigation system and improper irrigation practices leads to poor water management which reduces the potential of the irrigation scheme and decrease the yield per unit of land and per unit of water applied. Evaluation of irrigation schemes performance has now an important to point out where the problem lies and also helps to identify alternatives that may be both effective and efficient in improving system performance. Hence, this study attempts to introduce the concept of performance indicators as a tool to evaluate the performance of small-scale irrigation endeavors at the Wesha small scale irrigation scheme.

1.3. Rational of the study

The target project area highly water demanding area related with high level irrigation practices by the local community mainly for chat and other perennial crops associated with good market access for those products. But most of the irrigation schemes are traditionally diverted with local resources; wood and mud and straw which are frequently washed away with a single flood at the expense of labor and irrigation water. The local community is suffering from construction of seasonal diversion structures along rivers with sand filled sacks and wooden materials. This frequent seasonal construction to harvest the seasonal water flow is another burden for the environment where large quantities of sand and soil field sacks are washed away with a single flood.

Moreover, the land is highly productive and suitable for irrigation crop production where maximum yield can be harvested. The land is well drained, with gentle slope currently producing barley, maize, wheat and perennials during the wet season by farmers' preference but can produce all types of crops. The area can also allow the farming community to produce two crops per year with optimum farm management.

To address high and potentially rising levels of vulnerability of the local community for water scarcity in the area both for livestock and irrigation purpose, constructing modern diversion structures is unquestionable that can increase efficient use of the available water. The demand of the farming community for the irrigation water is more than expected. Farmers are highly volunteer and willing to contribute for the construction of the diversion structure not only in kind and their labor force but also in monetary terms if the project is implemented on time. This is addressed during public consultation of the respective kebeles.

Hence, the construction of the irrigation structures with modern structures and modernizing development of the area have many justifications. First and foremost, livestock can access water within a reasonable distance; second, there is huge potential irrigable land that can transform the livelihood of the farming community just by availing irrigation water with optimum management practices. Moreover, the project can have a very high backward and forward linkage in the target area where many industries are available which demand the agricultural products.

1.4. General Objective

To evaluate the small scale irrigation system in Wesha Soyama village and to suggest possible improvement options to local administration of the Village for better productivity.

1.4.1. Specific Objectives

- To evaluate the performance of Wesha small scale irrigation system with the help of internal and external performance indicators.
- Assessment of CWR and IWR in the case study area for various crops using CROWAT model with the aim of reducing irrigation water loss.

1.5. Significance of the study

Increased availability of irrigation and less dependency on rain-fed agriculture is taken as a means to increase food production and self-sufficiency of the rapidly increasing population of the country. Irrigated agriculture is priority in the agricultural transformation and food security strategy of the Ethiopian government (Kaur, 2009). Moreover, the study will contribute the decision and policy makers, administrators, planners and water resource professionals, who are responsible for management of water resources, to support them in formulating and implementing effective and efficient water management systems in the country.

1.6. Scope of the Study

This study is to evaluate the performance of Wesha small scale irrigation system with the help of internal and external performance indicators. Those internal indicators were considered on the irrigation efficiencies and the external indicators were considered related to agricultural out puts, related to water indicators and financial indicators. Such studies reflect the condition of the small scale irrigation production process pre-unit irrigated area, command area and per unit water consumed intervention, and would have been helpful to compare more comprehensively and evaluate the relative effect of the technology intervention on small scale irrigation performance.

2. LITRATURE REVIEW

2.1. Concept of Irrigation

Irrigation is broadly defined as the culture of applying water to the soil to supplement the nature rainfall and provides moisture for plant growth (Uphoff, 1986). According to Wichelns, (2000). Irrigation is defined as the farmer's perspective to deliver the amount and quality of water required by plants throughout a growth period of the plant to optimize plant growth and crop production. And also irrigation is defined as human intervention to modify the spatial or temporal distribution of water to manipulate all or part of this water for the production of agricultural crop (Wichelns, 2000).

According to Garg (1989) irrigation is described as the degree to which water volume and quality, and the time of irrigation events match the requirements of plant throughout the season. Perfect success occurs when the volume, quality and timing of water deliveries would generate maximum crop yield given that non irrigation inputs are not limiting, irrigation may therefore, be defined as the science of artificial application of water to the soil, in accordance with the crop requirement throughout the crop period for full-fledged nourishment of the crops.

2.2. Historical Development of Irrigation Globally

In the world, irrigation may be considered to date back to the prehistoric times in Mesopotamia and Egypt where they were used to water crops. Irrigation is an ancient agricultural practice which was vastly used by a number of countries of those early civilized such as Egypt, china, India and Iraq (Gorantiwar S.D, 2005). Over 5000 years ago, runoff irrigation was practiced in Yava, Palestine. At the same time, so-called hydraulic societies developed in large river valleys, such as the Yangtse in China, Indus in India, Euphrates in Iraq and Nile in Egypt. Laws and by-laws regulated the distribution of irrigation water, which dominated the life cycle of farmers and citizens alike. Some 1500 years ago, the Marib dam in Yemen raised the water level of a non-perennial river to divert floods for irrigation purposes (FOA, 1999).

From the above, one can understand irrigation is an age-old art, perhaps as old as civilization. Nevertheless, the increasing need for crop production due to growing population in the world is necessitating a rapid expansion of irrigated agriculture throughout the world especially small-scale irrigation. Since then there have been numerous innovations that have helped improve the ease and efficiency of water application to crops.

2.3. Historical Development of Irrigation in Ethiopia

In Ethiopia, irrigation has long been in use; however, irrigated agriculture is far from satisfactory despite substantial investment, public interest, and strategic support through government policy. Irrigated agriculture comprises only 3% of the total national food production (Tilahun & Paulos 2004).

Modern irrigation development in Ethiopia is not having centuries age. Modern irrigation was started at the beginning of the 1960's by private investors and was concentrated in the middle of Awash valley (Zerihun and Ketema, 2006).

2.3.1. Irrigation Typology in Ethiopia

Irrigation systems can be classified according to size, source of water, management style, degree of water control, source of innovation and type of technology. In terms of management there are: governmental managed, farmer managed and jointly managed irrigation scheme in Ethiopia (Yusuf and Tena, 2007). Similarly Angelle, (2007) puts as traditional irrigation schemes, modern small-scale irrigation scheme, modern private irrigation and public irrigation depending on the size and type of technology, type of management, degree of water control and size of the land.

Turner (1994) points out that, irrigation system can be classified according to size, source of water, degree of water control, Source of innovation, landscape niche or type of technology. Most authors, however, agree that concepts of local management and simple technology should be combined with size, and the best working definition seems to be that used by the UK Working group on Small Scale Irrigation (SSI): small scale irrigation is usually on small plots, in which farmers have the major controlling influence and using a level of technology which the farmers can effectively operate and maintain. There is also a case for using the term farmer-managed irrigation systems (FMI S), as used by the International Irrigation Management Institute (IIMI), which removes the confusion with authority -managed small-scale irrigation.

2.3.2. Current Status of Small-Scale Irrigation Schemes in Ethiopia

According to FAO, (2002) report on irrigation market brief in Ethiopia; the current actions toward the challenge is promising, which focuses on community participation from medium to large scale in conjunction with small scale intervention at farmer's level. The report mentions irrigation activities in sugarcane production in Mathahara and Wonji Shoa irrigation schemes, which covers 8960 hectares and 10150 hectares respectively, are publically managed irrigation schemes which could be an indicator of present ongoing improvement of irrigation activities in the country. In Ethiopia, from the total land of the country which is about 112 million hectare, about 30-50 million hectare is cultivable (Awlachew et al, 2010). However, currently only 15 million hectare is being cultivated from which irrigation covers only 4-5% of cultivated land. That means a very small portion of land has been cultivated by irrigation water.

Small-scale systems may have advantages over large-scale systems. These advantages include that small-scale technology can be based on farmers existing knowledge; local technical, managerial and entrepreneurial skills can be used; migration or resettlement of labor is not usually required; planning can be more flexible; social infrastructure requirements are reduced; and external input requirements are lower (Underhill 1990).

According to Awulachew et al. (2010) the current estimates of irrigation schemes of the country cover about 640,000 ha. However, there is some uncertainty about the exact number and location of some schemes, particularly small-scale irrigation and rainwater harvesting.

2.4. Concept of Irrigation Performance and Evaluation

According to Ros (2013) the performance of irrigation system can be defined as its efficiency, understood as the relation between actual results versus the intended outcomes of the system (inputs and outputs). Studies in performance indicators indicate that whether, the expected outcome of the system would be the improvement of food security and of life conditions of farmers through irrigated agriculture. The purpose of performance evaluation is to achieve an effective and efficient use of resources. Performance evaluation is regarded as the most important element for improving irrigation management.

The concept of evaluating irrigation systems has undergone major development during the last three decades; Irrigation performance indicators range from water distribution to agricultural, economic, social, and environmental aspects (Bos et al, 1994).

Nevertheless, the concept of 'Irrigation system performance' is in continuous evolution. There is a need for a generic assessment framework in this sense. This requires methodological improvements of evaluation and new performance indicators (Chaponnière et al, 2012).

2.5. The Necessity of Performance Evaluation of Irrigation Schemes

The preeminent objective of evaluating the performance of irrigation systems is to identify the management practices and systems that should be effectively implemented to improve the irrigation efficiency (Molden et al., 1998). Performance is evaluated for a variety of reasons i.e. to improve system operations, to appraise progress against strategic goals, as an integral part of performance-oriented management, to evaluate the general health of a system, to evaluate impacts of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system with others projects or with the same system over time projects (Umm-e et al, 2012).

IWMI's minimum sets of performance indicators were used by many researchers to compare different irrigation schemes. Comparison helps to identify 'who is doing what right' and what lesson can be learnt or who can be a benchmark for a particular activity (Molden et al., 1998).

2.6. Past Works in Performance Evaluation of Irrigation in Ethiopia

Irrigated Agriculture will be thought to be one of the solutions to enhance food security in Ethiopia (Awulachew et al., 2010). 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 efficient in improving system performance (Mintesinot et al.,2005).

In Ethiopia different performance evaluation of irrigation researches have been studied from the many studies some of them are: performance evaluation of small scale irrigation in Tekeze basin Tigray region (Mintesinot et al. 2005). This study was conducted on the evaluation of the performance of May Nigus micro dam irrigation scheme used only the comparative (external) indicators basis on different cropping period for 1997/98 to 2001/02 and this study obtained varied values on different cropping periods the summarized results are shown in Appendix 2; performance evaluation at Bedene Alemtena small scale irrigation scheme in Hallaba Special woreda, southern Ethiopia (Dessalew, 2016). This study was conducted on overall performance evaluation indicators.

On farm performance evaluation at Adawa small scale irrigation scheme in Dire Dawa, Eastern Ethiopia (Zerihun and Ketema, 2006); Performance assessment at Shina-Hamusit and Selamko irrigation schemes in south Gonder Zone Amhara Region,Ethiopia (Abebe, 2015). For this study was conducted with some selected performance evaluation indicators and the obtained values is presented in Appendix 2. Technical performance evaluation at Midhegdu small scale irrigation scheme in western Hararge Zone, Oromia Region, Ethiopia (Worku, 2013) for Msc thesis and Assessment of small scale irrigation using comparative performance indicators in upper Awash River valley Oromia region, Ethiopia (Yusuf, 2004).

2.7. Internal Performance Indicators

The common efficiency terms used for on-farm irrigation system evaluation (internal performance indicators) include application efficiency, uniformity, storage efficiency and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jureims et al., 2001). The principal terms and their uses are described as follows.

Irrigation efficiency is defined as the ratio of the amount of water that needed for proposed purpose to the total amount of water diverted to necessary place (Mati, 2011). Irrigation efficiency is a critical method to evaluate the performance of irrigation water use (Howell, 2003). Irrigation efficiency is the ratio between the volume used by plants through evapotranspiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application to irrigation plots. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this scarce resource (Michael, 1997).The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application, storage, distribution and overall irrigation efficiencies (Michael, 1997).

2.7.1. Conveyance Efficiency (Ec)

The ratio, in percent, of the amount of water delivered by a canal or pipeline to the amount of water delivered to the conveyance system. Water conveyance efficiency is used to measure the efficiency of water conveyance system associated with the canal network, watercourses and field channels; it is also applicable where the water is conveyed in channels from the well to the individual fields. It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of the water conveyance by the irrigation system (Bos,1997) . According the Ramulu, (1998) conveyance efficiency (Ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals. Some indicative values of the conveyance efficiency (Ec), considering the length of the canals and the construction materials in which the canals are constructed has different values. For instance, for lined canals for all lengths of canals the recommended Ec is 95% (Mati, 2011 and FAO, 2002).

2.7.2. Application Efficiency (Ea)

Application efficiency sometimes called field application efficiency or on-farm application efficiency is refers as the ratio of the amount water applied as net increase in soil moisture in the crop root zone to the total amount of water applied at the field level (Mati, 2011). It is also can be defined as the ratio of the volumes (depth) of water stored in the root zone for use by the plant to the volume (depth) of water applied to the field to the amount of water needed for crop production compared with the amount applied to the field and depends on system uniformity and management. The major losses which affect the irrigation efficiency are drainage below the root zone and surface runoff (Walters and Berisavijevic, 1991). Values of application efficiency are different basis of the irrigation systems. The indicative recommended values for furrow irrigation is range 50-90% (Rogers et al., 1997) and ranged as 55-70% (FAO, 2002).

2.7.3. Water Storage Efficiency (Es)

For irrigation the soil water storage capacity is defined as the total amount of water that is stored in the soil within the plant's root zone. The soil texture and the crop rooting depth determine this; a deeper rooting depth means there is a larger volume of water stored in the soil and therefore a larger reservoir of water for the crop to draw upon between irrigations (Allen et al., 1998). Walker (1989) described that Knowing the soil water storage capacity allows the irrigator to determine how much water to apply at one time and how long to wait between each irrigation. For example, the amount of water applied at one time on a sandy soil, which has a low soil water storage capacity, would be less than for a loam soil, which has a higher soil water storage capacity. This is assuming the crop's rooting depth is the same for both soils. Applying more water to the soil than can be stored results in a loss of water to deep percolation and leaching of nutrients beyond the root zone. Storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone

(Allen et al., 1998). The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone.

2.7.4. Distribution Uniformity (DU)

Distribution uniformity (Du) is a measure of how evenly water is applied during an irrigation event. This uniformity of application can have a considerable effect on crop yield and optimum water application. There are several interpretations in the literature, but a common measure for surface irrigation systems is to divide the average depth infiltrated calculated from the quarter of the field with the lowest infiltrated depths, by the average infiltrated depths. This is called the 'low quarter' (Jensen, 1983).

2.7.5. Overall scheme efficiency (Eo)

The overall scheme efficiency (Eo) represents the efficiency of the entire physical system and operating decisions in conveying irrigation water from a water supply source to the target crop. It is calculated by multiplying the efficiencies of water conveyance and water application (Irmak et al., 2011). According to Savva and Frenken (2002b), field application efficiency (Ea) is the one that contributes most to the overall irrigation efficiency and is quite specific to the irrigation method; any efforts that are made to improve on this efficiency will impact heavily on the overall efficiency.

Irrigation efficiencies are evaluated at scheme or farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field (Jensen, 1983). As describe by the MoAFS (2002) for small irrigation schemes in Tanzania typical values conducted were 28 and 34% for poorly operated, and for well operated canals, respectively.

2.8. External indicators of Irrigation Performance

External indicators focus on outputs from a system derived from the main inputs of the system like land and water in to the system. The relative performance standards can be developed per type of irrigation scheme to facilitate evaluation of individual systems. The indicators might also prove useful to reveal about the relative health of the irrigation system (De Fraiture and Garces-Restrepo1997).

According to IIMI (1997) the irrigation performance indicators are grouped in to three groups these are the irrigated agriculture performance indicator, the water related performance indicator and the financial performance indicator. In fact the IWMI proposed a set of nine indicators to compare the agricultural irrigation from these the four are categorized as basic external indicators (output per unit cropped area, output per unit command area, output per unit irrigation supply and output per unit water consumed) are related to output to unit land and water. These external indicators provide the basis for comparison of irrigated agriculture performance (Molden et al., 1998). The other external indicators are identified as minimum comparative purpose. These are characterized to the individual system with respect to water supply. The related water supply indicators are RWS, RIS and WDC (Molden et al., 1998).

2.8.1. Irrigated Agriculture Performance Indicators

The irrigated agriculture performance indicators are used to evaluate the irrigation project performance in terms of the crop production. It shows that the output of the irrigated area in terms of gross or net value of production measured at local or world price (Abernethy 1991). According to Bos et al (1997) the agriculture performance indicators have categorized in to two groups, as production per unit area indicators and production per unit water indictors.

2.8.2. Water Related Indicators

Water related indicators describe the water supply indictors (relative water supply, relative irrigation supply and delivery capacity) are more suitable performance indicators related to water supply (Molden et al., 1998).

2.8.2.1. Relative Water Supply (RWS)

The relative water supply was originally developed by Livene, (1982). RWS is the measurement of total volume of water availability. The total volume is the applied water in form of the irrigation water plus the rainfall (De Fraiture and Garces-Restrepo 1997). RWS is useful to evaluate the degree of irrigation water stress or abundance in relation to irrigation demand. It is the inverse of irrigation efficiency presented by (Bos, 1997). Value for RWS greater than 1 indicates water supply is excess water supply of the demand; if it is less than 1, indicates that the water supply is a deficit of the demand. While if it is approach to 1, the supplied amount of water is optimum to the irrigation demand (Ingle et al., 2015). According Molden et al., (1998) investigation varied values for RWS were found to be between 0.8 and 4.1, from 18 different irrigation schemes in 11 countries of the world.

2.8.2.2. Relative Irrigation Supply (RIS)

The relative irrigation supply (RIS) is an indicator of how well crop water requirement is met or is satisfied in a scheme. Also stated that RIS is an inverse of the irrigation efficiency proposed (Molden et al. 1998). If the water requirement is met enough, the value of RIS is unity. While a value greater than one would indicate more water is supplied than required, and the value less than one would indicates that the crops are not getting enough water (Ingle et al., 2015). But according to Molden et al., (1998) reported that large variation of RIS values indicated between 0.4 and 4.8, among the studies of 18 different irrigation schemes in 11 countries of the world.

2.8.3. Physical performance indicators

It is a useful indicator for assessing the sustainability of irrigated agriculture. Ascertaining the likely sustainability of a system over time requires determining a variation with respect to time (season, year, etc) of key indicators, tracing the secular trends and understanding the processes causing these trends (Rao, 1993). Assessment of time dependent variation of adverse effects like water logging, salinity, flooding etc are important for monitoring a system's physical sustainability. Sustainability has many dimensions and they will probably be more country specific and project specific. For this study irrigation ratio and sustainability of irrigated area indicators were selected.

2.8.3.1. Irrigation Ratio

Sener et al., (2007) developed a relation between currently irrigated areas to the command (nominal) area to be irrigated; to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period. Lower utilization of the given irrigable area would be existed due to different constraints; i.e. lack of irrigation infrastructure, shortage of irrigation water, lack of interest on irrigation due to less return and market problems, and reduced productivity due to (soil nutrient depletion, lack of improved technologies, lack of inputs and water logging) etc. Furthermore cropping intensity is an illustrative for land utilization capacities. The cropping intensities from 100 to 200% are considered good, while lower ratio indicates poor intensities (Burton et al., 2000).

2.8.3.2. Sustainability of irrigated area

According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded. If the computed value is small or less than 1 it shows the irrigable area is contracted and if it is large i.e. greater than one, it shows the irrigable area is expanded from the designed irrigable area, through including nearby farm areas. The contraction of irrigable land may be appeared due to different reasons, i.e. water shortage, water logging, flooding problems etc. On the other hand expansion might be occurred due to interests coming from neighboring farmers to irrigate extra land addition to designed one. This expansion of irrigable area indicates there is more sustainable of irrigation.

2.9. Soil Plant Water Relationship

Plant growth depends on the use of two important resources, soil and water. Soil provides the mechanical and nutrient support necessary for plant growth. Water is essential for plant life processes. Effective management of resources for crop production requires the producer to understand relationship between soil, water and plants, knowledge about available soil water and soil texture will make deciding what crops to plant and when to irrigate, easier.

2.9.1. Physical Characteristics of Soil

There are many variable in the physical characteristics of soil. These include soil texture, soil structure, and bulk density.

Soil texture: according to Janine (2002) affirms that soil texture is determined by the size of the particles that make up the soil. The traditional method of determining soil particle size is done by separating the particles in to three convenient size ranges. These soil fractions or separates are sand, silt and clay. The soil texture is determined by the mass ratios or the percent by weight, of the three soil fractions.

Soil Bulk Density: soil dry bulk density is expresses as the ratio of the weight of a soil to its total volume. The soil bulk density is important because it is a measure of the porosity of the soil. The porosity of a soil is defined as the volume of pores in a soil (USDA NRCS 2014).

2.9.2. Soil and Water Interaction

Soil and water interaction is important to understand the interactions between the soil and water, which include soil water content, how the soil holds water and soil water tension. Understanding these interactions can be very helpful when making planting and irrigation decision (USDA NRCS 2014).

Soil water content: The capacity of a soil to retain moisture that is readily available for plant growth is an important factor in irrigation and land use planning. This applies not only where there is adequate rainfall, but also in irrigation projects, where irrigation water has to be applied at the right time and at the right quantity. The amount of water available for plant uptake has been related to a soil's water budget (Allen et al, 1998).

The three terms associated with the water budget are field capacity (FC), wilting point (WP), and available water (AW). The WP, also called the permanent wilting point, may be defined as the amount of water per unit weight or per unit bulk volume in the soil, expressed in percentage that is held so tightly by the soil matrix that roots cannot absorb this water and a plant will wilt (Diallo and Mariko 2013). The field capacity (FC) and the permanent wilting point (PWP) are two levels of moisture that are used to calculate available water for plant and water depth to be applied by irrigation. Generally, field capacity is defined as the amount of water after excess water has drained away and the rate of downward movement has materially decreased. The permanent wilting point is defined as the value of soil wetness when plants wilt. Plant TAW may be defined as the difference between FC and WP. TAW is the amount of water that a crop can extract from its root zone, and its magnitude depends on the type of soil and the rooting depth (Diallo and Mariko 2013).

2.10. CROPWAT Model

According the Thorsten; (2006) CROPWAT model is described as decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements using the inputs of climatic crop and soil data.

Estimation of crop water and irrigation water requirements: The CROPWAT model requires ETo, effective rainfall and crop data for estimating CWR and IR.

Reference evapotranspiration (ETo): the FAO Penman-Monteith equation has been adopted as the globally best performing method of estimating ETo based on the inputs geographical coordinates (latitude, longitude and elevation) of the nearby metrological station, monthly climatic data(minimum and maximum temperature, relative humidity, sunshine duration and wind speed). ET0 for each month was calculated for a 'decade' (every ten days) (Supe et al., 2015).

Effective Rainfall: there are about four available options for calculating effective rainfall. These are: Fixed percentage, dependable rainfall (FAO/AGLW formula), empirical formula and USDA soil conservation service methods. Effective rainfall is calculated based rainfall inputs data collected from the nearby station gage (Supe et al., 2015).

Crop data: A Crop data consisting of the planting date, growth stage in day's crop coefficient (Kc) values, root depth, depletion fraction and the cropped area in percent (%) of the total area. The crop coefficient integrates the effects characteristics that distinguish a typical field crop from the grass reference, which has a constant appearance and complete ground cover. Consequently, different crops will have different crop coefficients. Growth stage as the crop develops, the ground cover, crop height and the leaf area change. Due to difference in in evapotranspiration during the various growth stages, the Kc for a given crop will vary over the growing period. (Allen et al.,1998).

3. METHODOLOGY

3.1. Description of the Study Area

Wesha River Project is located in Soyama village of Wondogenet woreda, in Sidama Regional State of Ethiopia. Soyama village is bordered on the south by Wetera Kechema village, on the west by Shasha Kakalo village, on the north by Gutu Anoma village, and on the east by Gike Atoye village. Wondogenet Woreda is found at a distance of 260 Km south of Addis Ababa and 35 km from Hawassa, capital of Sidama Regional State.

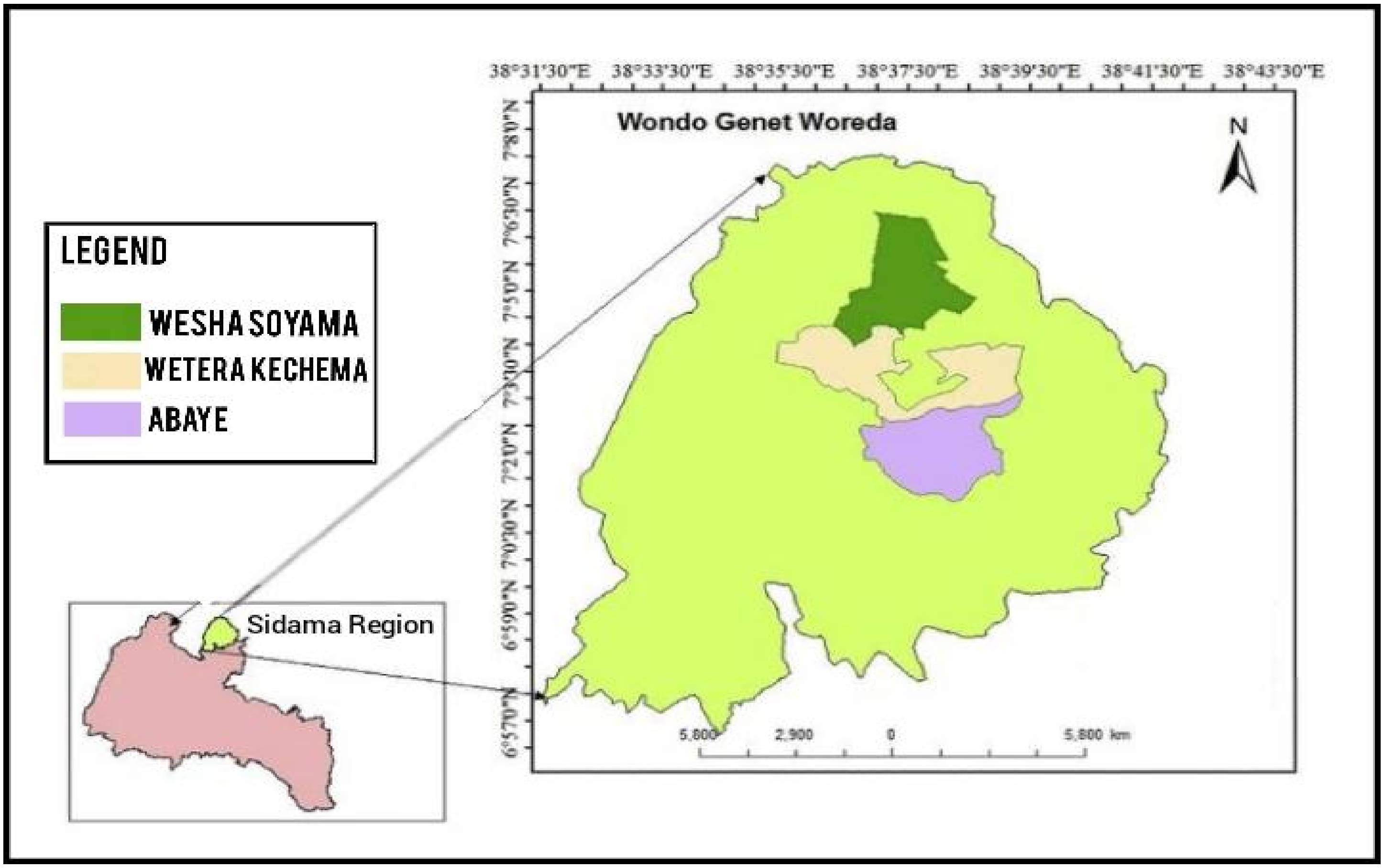

Figure 1: Description of the Study Area

Geographically Wesha small scale irrigation project is located at 7°08’ N latitude and 38°35’ E longitude. The altitude of the district ranges from 1880 Meter above sea level. The average annual rainfall is 1141 mm. The mean monthly maximum and minimum temperatures of 27.25°C and 11.97°C, respectively.

Construction of the Wesha small-scale irrigation project was concluded in the late 1980s for satisfying the demands of the farmers located within the peasant association. Prior to the construction of the diversion weir, farmers in the area had been practicing irrigation by diverting the Wesha River traditionally. Construction of the new diversion weir was done under the authority of a Lutheran Church organization called ‘Mena’, which in turn was funded by the World Vision Ethiopia. The diversion weir has a crest length of 12.45 m and 1.7 m top width. The weir height, up to the crest level, is estimated to be 2.2 m. The main canal is branched into secondary canal after a length of 300 m. About 240 m length of the main canal is lined with masonry and concrete works having a rectangular shape of 1.08 m width and 1.12 m depth. The irrigation project can be categorized as partially modern. Only the headwork and 240 m canal length are designed and constructed carefully, while the rest of the project is left to be operated traditionally. Canal structures are constructed only at few spots despite the existence of a number of canal branches and crossroads. Therefore, the irrigators normally use bund breaks as a mechanism to divert and deliver water to their fields.

Figure 2: Wesha SSIS diversion weir structure

The main agricultural crops practiced by farmers are sugarcane and chat. Besides, vegetables like tomato, onion, cabbage, carrot are practiced in small amounts. Others maize, sweet potato, potato and coffee are cultivated in small quantities in the form of inter cropping, early growing or crop rotation due to the scarce land.

Agro forestry is also a dominant practice of Wondo Genet and the Wesha watershed. Different fruit tree species are grown around the homesteads and the farm boundaries. Fruit trees like Persia Americana, Pszgjium gujava, Ctirus species are grown around the homesteads. Tree species like Ecucalyptus camadulenessis, cordial Africana, juniperus procera are grown on farm land boundary, and farm forestry around the command area.

Wondo Genet Woreda is a main potential area for the irrigation practice and agricultural use due to its topographic condition, suitability of the soil and the climate for growing different crops. Hence people of different tribes inhabited in the area. The Sidama and Oromo are the dominating tribes around the vicinity and other tribes like, the Amahara, Wolita, kembata, hadya and other. Due to tribal differences and competition for the land resources, tribal conflicts arise frequently between the dominating tribes. Especially, this area also needs a critical focus of political intervention and administration for the management of the watershed in particular as it is located in the boundary of both tribes.

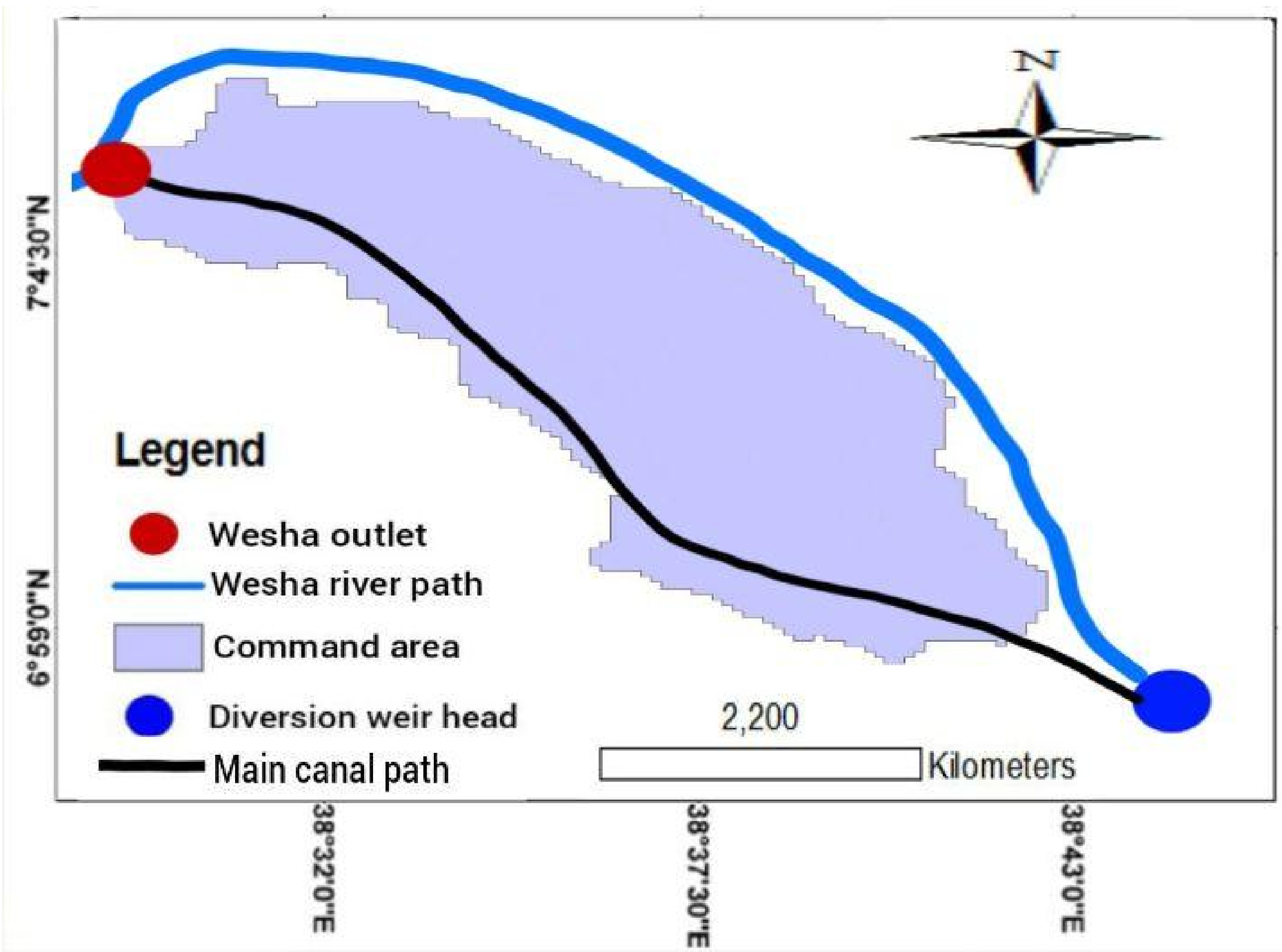

Figure 3: Location map of the scheme

3.1.1. Watershed Geomorphology

The rate and volume of runoff and sediment yield from the watershed have much to do with shape, size, slope and other parameters of the landscape. These suggest that there should be some important relations between basin form and hydrologic performance. If the basin and hydrologic characteristics are to be related, the basin form must also be represented by quantitative descriptors. These parameters can be measured from maps. The following are brief descriptions on important watershed forms and relief parameters.

3.1.1.1. Area and Shape of the catchment (Shape index)

The watershed has a total area of 31.5 km^2. It has a length of 10.5 km and width of 3 km. The shape of the catchment is mostly of elongated geometric arrangement. This type of shape arrangement contributes less runoff to the out let area than area type of circular type. So it is determined by shape index or ratio. The shape of the watershed affects the stream flow hydrograph and peak flow rates. The shape of Wesha watershed is almost elongated type which indicates the run off response is somewhat slow and show low peak flow. It is a common practice to express the watershed shape by index. The dimensionless index B is most commonly used to characterize the shape of the watershed.

The value of B is mostly greater than unit. It is given as $B = Lw^2 /A= [10.5 \times (3)^2]/31.5 = 3$

3.2. Topography

The watershed has different topographic condition. Most the land escape arrangement is almost irregular type with undulating and rugged topographic feature. Continuous ladders of small ridges are common Feature. Therefore it is highly liable to the erosive agents if not managed. At the low elevation there exists some moderate type of slope condition and the slope increases as going to the upper part of the catchment.

3.3. Layout of sample fields and field measurements

Three farmers' fields were selected to undertake evaluation of the irrigation project performance. These three farmers' fields were selected from the head, middle and tail end of the command area. The assumption behind the selection criteria of the farmers' fields is that there is tendencies of the head-end users (farmers at the top) to over irrigate their crops while the tail-end users (farmers at the bottom) are in short supply of irrigation water. The size of the selected fields were measured and field preparations made according to the existing farmers' practices; some used oxen ploughs while others used hand digging. The evaluation was done on farmers who planted potato crop.

3.3.1. Measurements of soil and water in the field

Real performance is based on water uses over a specified period, rather than observation of a single irrigation event. Taking this into account, the field assessment on water utilization efficiency, and therefore, the performance of the selected farmers' fields in the project was made on three irrigation events for each farmer. As measuring water use and soil moisture is crucial for calculating irrigation efficiencies, during each irrigation event, water flows into the fields, moisture contents of the soil profile (before and after each irrigation).

3.3.2. Measurement of soil moisture

The moisture status was measured to determine how much water depleted below the field capacity before irrigation and how much water applied to the root zone after irrigation. To collect representative soil samples, three rows were selected along each field (one row from the center and two rows from opposite sides) and three sampling points were identified starting from the beginning to the end of each row at regular interval. Then, at each selected points of the rows, soil samples were collected from two depths (i.e., at 0-30 cm and at 30-60 cm). These depths were preferred because root distribution of Potatoes is heavily concentrated near the soil surface. Therefore, from each field, a total of 36 samples, 18 from the top soil (i.e., 0-30 cm) and 18 from the sub-soil (i.e., 30-60 cm) were collected before and after irrigation at each time. This procedure was repeated in each of the three farmers' fields with three replications for each field (because three irrigation events). Therefore, 108 from each field, a total of 324 soil samples were collected to measure the moisture status of the fields.

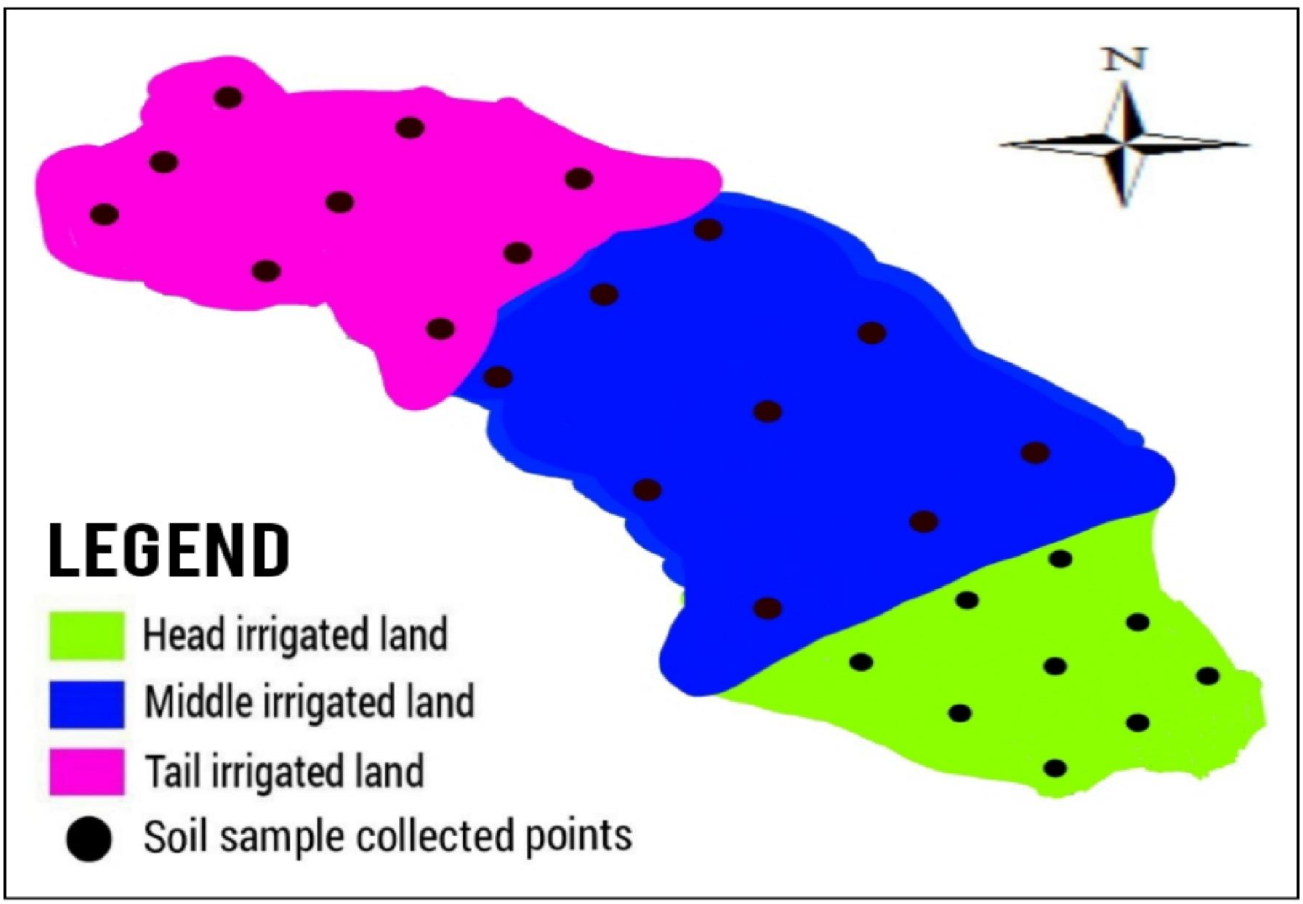

Figure 4: Location of points where soil sample collected

To this end, soil samples of each field were collected using manually driven soil auger. Though numerous techniques have been developed for evaluating soil moisture content, the standard method known as the gravimetric moisture determination method was used. To achieve a relative accuracy, initial weights of the collected soil samples were immediately measured in the field using digital sensitive balance to determine moisture contents before oven-dry.

3.3.3. Total moisture content stored at sampling points

Total moisture content stored at sampling points of the three irrigation events before and two days after irrigations was calculated as:

$$Tot_{MCS}\,(mm) = (\frac{Tot_{SMW}}{100}) \times Bulk\ density \times Depth\ of\ soil\ layer\ in\ the\ root\ zone\ (mm) \quad \ldots..(1)$$

Where:

$\boldsymbol{Tot_{MCS}}$ **:** Total moisture content stored at sampling points (mm)

$\boldsymbol{Tot_{SMW}}$**:** Total soil mass wetness (%) (The sum of differences between soil mass wetness before and after irrigation

Moisture content stored at sampling points is within the two soil layers (i.e. 0-30 cm and 30-60 cm). The depth of soil layer in the root zone is taken as 300mm: which is equal to 30cm.

3.3.4. Soil texture

The particle size distributions in the soil profiles were determined using the hydrometric method as indicated by Stanley and Bernard (1992). Composite soil samples in the head, middle and tail reach of the study area were taken using Auger at 0-30cm, 30-60cm, 60-90cm and 90-120 cm soil depth. The soil samples were first air dried and grinded using pestle and mortar, and then sieved using 50 and 250 micron size sieves. After that 25 gm of soil and 50 ml dispersing agent (40 gm sodium Hexametaphosphate, $Napo_3$ and 10 gm of Sodium carbonate, Na_2co_3) was mixed in distilled water in 500 ml flask. The soil and solution were then transferred to mechanical stirrer and shake for 5 minutes. The dispersed soil suspension was then transferred to hydrometer jar and the volume in the hydrometer was adjusted to 500 ml by adding distilled water. The readings were taken after 40 seconds and after 2 hours.

The hydrometer reading results were corrected to a 20^0C. For temperature readings above 20^0C correction values are added to the hydrometer reading, but for temperature readings below 20^0C correction values are subtracted to the hydrometer reading ISRIC (2000). This is because, for example for the 40 second readings when the temperature is above 20^0C the movement of particles are high. So, some sand particles may suspend in addition to the clay and silt particles.

3.3.5. Bulk density

Bulk density of the soil profile was determined using undisturbed soil samples at 0 - 30 cm depth interval collected by using 4.8cm internal diameter and 4cm height, 4.4cm internal diameter and 4cm height and 4.6cm internal diameter and 4cm height core sampler from head, mid and tail reaches respectively. The analysis was undertaken in Soil Laboratory. The bulk density was determined using (Jaiswal, 2003), equation.

$BD = Ws/Vc$……………………………………………………………………………………….(2)

Where:

BD: soil bulk-density (g/ cm^3)

Ws: mass of dry soil (g) and

Vc: volume of soil in the core (cm^3) and

$Vc = A * h$……………………………………………………………………………………..(3)

Where:

A: area of the core (cm^3)

h: height of the core (cm)

The area of the core was calculated as the following equation, because the core was circular.

$A = \pi d^2/4$…………………………………………..…………………………………………(4)

d: internal diameter of the core (cm)

3.3.6. Soil field capacity and permanent wilting point

Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the laboratory. Soil samples were saturated for one day and a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point) were exerted until no further change in soil moisture content was observed. After getting soil moisture values, available water holding capacity of the soil was calculated. The total available water (TAW) for crop use in the root zone was calculated using Allen et al.(1998) equation.

The total available water in percent based (volumetric based):

$TAW \% = \Sigma FC\% - PWP\%$...(5)

Where:

TAW (%): total available water in percent

FC%: soil moisture at field capacity in percent

PWP%: soil moisture at permanent wilting point in percent

The total available water content in volumetric based:

$$TAW = 1000\, \Sigma(\theta FC - \theta PWP) * BD * Zr \quad (6)$$

Where:

TAW: volumetric total available water in the root zone (mm/m)

FC: volumetric moisture content at field capacity (m^3/m^3) and

PWP: volumetric moisture content at permanent wilting point (m^3/m^3).

BD: bulk density (gm/cm^3)

Zr: root zone depth (m) = 1m

3.3.7. Measurement of water in the field

The flow of water into each field was measured using Parshall flume installed at the entrance of the water flow to the field. Before taking measurements, the Parshall flume was calibrated using volumetric method of discharge measurement. Discharge and the irrigation time were based on farmers' practices and irrigation was allowed to continue until the farmers perceive that enough amount of water is applied to their fields. To collect the tail water, a pit and runoff collecting channel were excavated and known volume of runoff collector bucket was put inside the pit. To prevent seepage of the tail water into the runoff collector channel, plastic sheet was laid. In cases large tail water was expected, one-inch Parshall flume (which was made of prefabricated plastic) was installed to measure the depth of tail water flow.

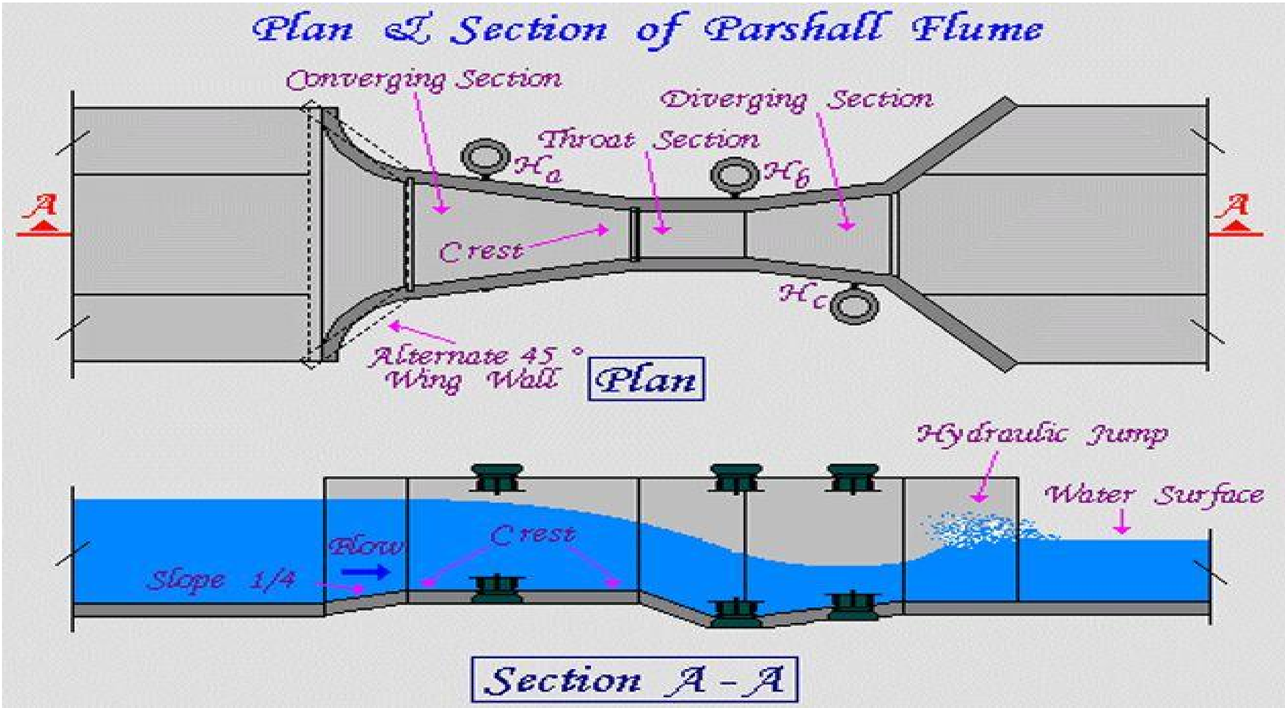

Figure 5: Plan and section view of sheet metal partial flume showing its component parts

3.3.8. Discharge measurement

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others, and could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge in the canal.

3.3.9. Float method to determine discharge at main canal

According to Joy and Marlies, (2005) floating methods is the inexpensive and simple method for measurements of an open channel discharge. The discharge at an open channel is a function of the cross-section area and flow velocity. Thus requires the measurement and calculation of the cross section area of the canal as well as the time it takes a float object to a designated distance. The method consists of estimating the average flow velocity and measuring the area of the cross-section, called the wetted cross-section. The discharge was calculated by continuity equation (7).

$Q = V * A$ ……………………………………………...………………………..………………….. (7)

Where: Q: the discharge (m^3/s)

V: the average flow velocity (m/s)

A: the area (m^2) of the wetted cross-section.

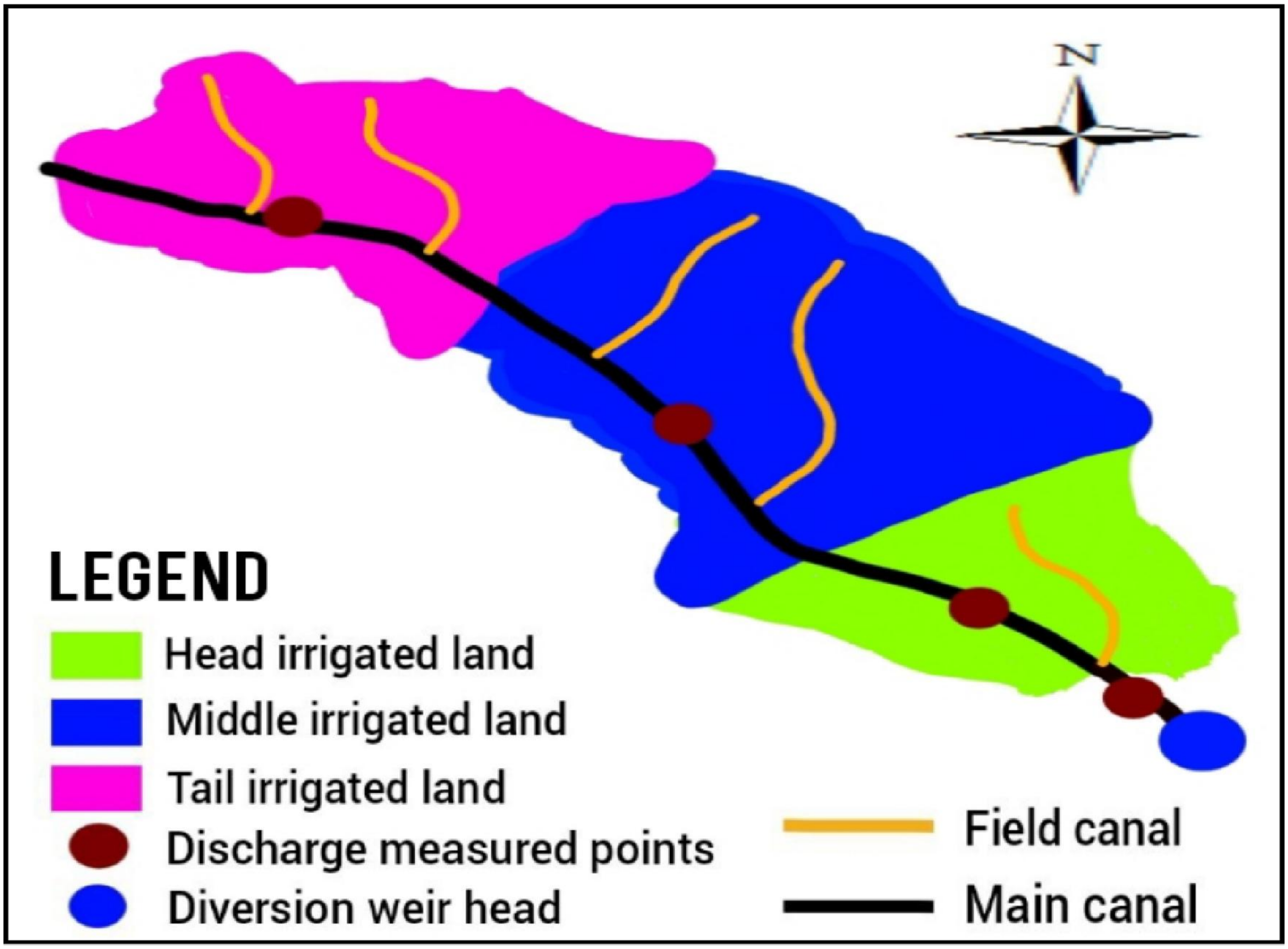

Figure 6: Layout of irrigated land and flow rate measurement points

3.3.9.1. Flow estimation procedure

The following procedures were applied for measuring the discharge using a floating method.

1. Select a straight section of the canal at 10 meters long.

2. Place two stakes, one each side, at the upstream end of the selected portion of the canal. They should be perpendicular to the centerline of the canal. These correspond to point A

3. Measure 10 meters or more along the canal.

4. Place two stakes at the downstream end of the selected section of the canal, also perpendicular to the centerline of the canal. These correspond to point B

5. Place the floating object on the centre line of the canal at least 5 m upstream of point A, and start the stopwatch when the object reaches point A.

6. Stop the stopwatch when the floating object reaches point B, and record the time.

7. Repeat steps 5 and 6 at least three times in order to determine the average time necessary for the floating object to travel from point A to point B.

8. Measure the following in the selected canal section the surface water width and the water depth

9. Calculate the surface velocity and then the average flow velocity using the previous equations (8) and (9) respectively.

10. Calculate the wetted area of the cross-section using equation (10).

11. Calculate the discharge in the canal using equation (7).

3.3.10. Average flow velocity

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs was first determined. The surface velocity was determined by measuring the time it takes for a floating object along the canal. The floating object was placed in the centre of a canal and the time measurement was repeated three times to avoid mistakes. The stretch of canal used for measurement should be straight and uniform in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation.

To determine the velocity of surface water of the channel, the length of trail section was divided by the average time taken by the float cross it. Since the velocity of the float on the surface of the water was greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying by a constant factor (velocity correction factor) which was usually assumed to be 0.85 (Harrelson, 1994). To obtain the rate of flow, this average velocity (measured velocity * correction factor) was multiplied by the average cross-sectional area of the stream. To compute the surface velocity, Vs the selected length, L was divided by the travel time, t:

$$Vs = \frac{L}{t} \qquad (8)$$

Where: Vs: the surface velocity (m/s)

L: the distance in meters between selected points and

t: the travel time in seconds between selected points

The surface velocity must be reduced in order to obtain the average velocity, because surface water flows faster than subsurface water.

$$V = 0.85 * Vs \qquad (9)$$

Where:

V: the average flow velocity (m/s);

Vs: the surface velocity (m/s) found from equation (2).

3.3.11. Area of the wetted cross-section

For measuring the flow with the floating method, the area of the wetted cross-section (A) was determined for a selected straight and uniform portion of the canal. The area was calculated from measurements of the surface water width and the water depth using equation (10).

$A = w1 * h1$………………………………………………………………………………..……….…..... (10)

Where: A: area of wetted cross-section (m^2)

w1: surface water width (m)

h1: water depth (m)

The area of the cross-section was measured three times to get the average area.

3.4. Internal Performance indicators

Even though, various authors have suggested many performance indicators, the types of indicators chosen depend on the purpose of performance assessment (Allen et al., 1998). In this study, on field water management was assessed in terms of conveyance efficiency, application efficiency, storage efficiency, distribution uniformity and overall irrigation efficiency.

For the analysis of irrigation efficiencies, composite soil samples at 0-30, 30-60 cm depth in head, middle and tail canal reaches were taken before and after each irrigation event. Then soil moisture contents of the sampled soil were determined gravimetrically. Based on data obtained from measurements of inflow, tail water and soil moisture, project performance was evaluated based on conveyance efficiency, water application efficiency, water storage efficiency and water distribution uniformity. Sustainability of the irrigated area was also calculated to determine the trend of yearly shrinkage of total area put under irrigation.

3.4.1. Conveyance efficiency (Ec)

Conveyance efficiency (E_C) parameter is used to evaluate how efficient are the water delivery and conveyance systems. To determine conveyance efficiency, flows at the field canals were measured using the three-inch Parshall flume. Since the flume was not big enough, float (Velocity-Area) method was used at the primary, secondary and tertiary canals to measure the corresponding discharges. After determining the amount of water supplied by the conveyance system and total inflow into the conveyance system, the conveyance efficiency of each canal section was then calculated as:

Conveyance efficiency, $E_C(\%) = \frac{\text{Total water supplied by the conveyance system } (m^3)}{\text{Total inflow into the conveyance system } (m^3)} * 100$……..(11)

3.4.2. Application efficiency (Ea)

As a measure of how much of the water that is applied is actually retained in the root zone after irrigation, application efficiency was calculated. It is a function of design and effective management. The depth of water applied to each field (D_a) was measured using a 3-inch Parshall flume and considering the overall size of the field. Two days after irrigation, the depth of water stored in the root zone (D_s) was determined as the difference between the after- and before- irrigation moisture contents of the soils from 18 soil samples (9 samples each from the top and sub soil layers) taken at regular intervals over the entire field. Then neglecting the leaching requirement, the application efficiencies (E_a) of irrigation at the selected fields were calculated as:

$$E_a = \frac{\text{Depth of water stored in the root zone (Ds,cm)}}{\text{Total Depth of water applied to the field (Da,cm)}} * 100 \qquad (12)$$

The depth of water retained (stored) in the soil profile of the root zone, Ds, and the total depths applied to the field, Da, were determined by using the following equations:

$$D_s = \sum_{i=1}^{n} \left(\frac{W_{ai} - W_{bi}}{100}\right) \times AS_i \times D_i \qquad (13)$$

$$D_a = \frac{\bar{Q}\,\Delta t}{A} \qquad (14)$$

Where:

W_{ai} = moisture content of the i^{th} layer of the soil after irrigation on oven-dry weight basis, %

W_{bi} = moisture content of the i^{th} layer of soil before irrigation on oven-dry weight basis, %

AS_i = apparent specific gravity of the i^{th} layer of soil (unit less)

D_i = depth of i^{th} layer of the soil ($D_1$and D_2 are 30 cm each for this study)

n = number of layers in the root zone (n=2 for this study)

$\bar{Q}$ = average stream size during the irrigation (cm3/s)

Δt = duration of the irrigation (s)

A= area irrigated (cm^2)

3.4.3. Water storage efficiency (Es)

To evaluate how effectively the irrigation practices satisfied the water requirement of the soil to compensate the moisture depleted by evapotranspiration, the evaluation parameter called water storage efficiency (Es) was calculated. While the amount of water added to (stored in) the root zone (Ds) was calculated for each field using equation (7), the amount of water potentially required to fill the root zone to field capacity (Dreq) was estimated using equation (10). After knowing the values of Ds and Dreq, equation (9) was employed to calculate the water storage efficiency (Es), which is sometimes referred to as water requirement efficiency (Es).

$$E_S(\%) = \frac{D_S}{D_{req}} \times 100 \qquad (15)$$

$$D_{rec} = SMD = \sum_{i=1}^{2} 1000(W_{fci} - W_{bi}) \times AS_i \times D_i \qquad (16)$$

D_S =Amount of water added to (stored in) the root zone during the irrigation (mm)

D_{req} =Amount of water potentially required to fill the root zone to field capacity (mm)

SMD = Soil moisture deficit within RZ below field capacity before irrigation (mm)

W_{fci} = Moisture content of the i^{th} layer of the soil at field capacity (FC) on oven-dry weight basis (in fraction)

W_{bi} =Moisture content of the i^{th} layer of soil before irrigation on oven-dry weight basis (in fraction)

D_i = root depth (m).

3.4.4. Water distribution uniformity (DU)

Distribution uniformity is used to measure the variation or non-uniformity of water applied to the entire field. For calculating distribution uniformity, the effective root depth of the crop (i.e., up to 60 cm) was taken as the zone of water distribution. After calculating the depth of water stored (as the difference between the after and before moisture contents) in the top soil (0-30 cm) and sub-soil (30-60 cm), the depth of water stored at each particular sampling point was calculated as the sum of the two. Distribution efficiency of the irrigation project was evaluated using the Distribution Uniformity (DU) parameter and the determination was based on mean values of the total soil moisture contents stored at the nine sampling points. The depths of water stored at each sampling point were arranged in descending order and the Distribution Uniformity (DU) parameter was determined. The Distribution Uniformity (DU) is defined as the percentage of average application amount received in the least-watered quarter of the field. It is the ratio of the average depth infiltrated in the lower quarter of observations to the average depth of all observations.

$$DU(\%) = \frac{\bar{X}_{Lq}}{\bar{X}_m} \times 100 \qquad (17)$$

Where, $DU(\%)$ = Distribution Uniformity

$\bar{X}_{Lq}$ - is the mean of lower-quarter depth of water stored (mm) and

$\bar{X}_m$ - is the mean depth of all water stored (mm)

3.4.5. Overall Irrigation efficiency (Eo):

The overall scheme efficiency was calculated as the product of conveyance and application efficiency (Ramulu, 1998).

$$Eo = Ec * Ea \qquad (18)$$

Where, Eo is overall scheme efficiency (%), Ec is conveyance efficiency (%) and Ea is application efficiency (%).

3.5. External Performance Indicators

Generally different groups of performance indicators; Agriculture indicators, Water related indicators and physical sustainability indicators; have been used in this study to assess and compare the performance of the Wesha small scale irrigation scheme at system level. Under each group a number of minimum performance indicators have been used during evaluation.

3.5.1. Agricultural output indicators (water-land productivity)

A number of indicators are developed regard to irrigated agricultural systems. Water, land and finance are the main inputs for output of crop production. Five of them are relating to output to land and water were selected, i.e., two from land productivity and three from water productivity. These external indicators provide the basis for the evaluation of irrigated agricultural performances. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important (De Fraiture and Garces-Restrepo 1997).

3.5.1.1. Output per unit command area (birr/ha):

This indicator quantifies the value of production that obtained per unit command irrigable area. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. High value result shows there is good intensive irrigation. Meanwhile small values are not pertinent from land productivity point of view; less intensity of irrigation could not increase the production amount per unit of land. Furthermore this is more relevant for land is the major constraint factor for production. Command area is the nominal or design area to be irrigated.

$$Output\ per\ unit\ command\ area = \frac{Value\ of\ production\ (birr)}{Command\ area\ (ha)} \ldots\ldots\ldots\ldots\ldots\ldots(19)$$

3.5.1.2. Output per unit irrigated cropped area (birr/ha)

It is computed as the total value of production per harvested area in the irrigation seasons. The harvested /irrigated area includes the areas that were irrigated in the irrigation seasons.

$$Output\ per\ unit\ irrigated\ area = \frac{Value\ of\ production\ (birr)}{Irrigated\ croped\ area\ (ha)} \ldots\ldots\ldots\ldots\ldots\ldots(20)$$

3.5.1.3. Output per unit water consumed (birr/m^3)

This indicator derived from the general water accounting frame work (Molden, 1998). Consumed water is the actual evapotranspiration or process consumption from only irrigated crops (ET); it excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapotranspiration relative to the diverted and delivered amount of irrigation water. It has a contribution for irrigation management aspects; to take measurements those minimize evapotranspiration losses.

$$Output\ per\ unit\ water\ consumed = \frac{Value\ of\ production\ (birr)}{Volume\ of\ water\ consumed\ by\ ETc\ (m^3)} \ldots(21)$$

3.5.1.4. Output per unit irrigation supply (birr/m^3)

This is one of the water productivity indicators and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons; it includes the conveyance losses in the irrigation systems. It illustrates the productivity of diverted water from the source. It is an important parameter where water is a scarce resource. Diverted/supplied irrigation water is the volume of surface irrigation water diverted to the command area.

$$Output\ per\ unit\ irrigation\ supply = \frac{Value\ of\ production\ (birr)}{Diverted\ irrigation\ supply\ (m^3)} \ldots\ldots\ldots(22)$$

3.5.2. Water supply indicators

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

As Marinus G Bos et al., (1993), states that these indicators deal with the main task of irrigation managers in the capture, allocation and conveyance of water from source to field by the management of irrigation facilities. Indicators address numerous aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently and the service aspects of water delivery which include such concepts as predictability and equity.

3.5.2.1. Relative Water Supply (RWS)

Bases on the relative water supply described by Levine (1982) and relative irrigation which is set by Perry (1996) are the basic water supply indicators. It is the ratio of total water supplied by irrigation and rainfall to total water demanded by crop (i.e. actual crop evapotranspiration (ETc).determine using the formulas below:

$$Relative\ water\ supply = \frac{Total\ water\ supply}{Total\ Crop\ water\ demand} \qquad (23)$$

Where, Total water supply = diverted water for irrigation plus rainfall (m^3),

Total Crop water demand = potential evapotranspiration or the real evapotranspiration (ETc) when full crop water requirement is satisfied (m^3).

3.5.2.2. Relative Irrigation Supply (RIS)

This is the second water supply indicator and described as the ratio of irrigation supply to irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and it is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance/ in relation to irrigation demand and was calculated using the formulas (Molden et al., 1998)

$$Rlative\ irrigation\ supply = \frac{Irrigation\ supply}{Irrigation\ demand} \qquad (24)$$

Where, Irrigation supply is only the surface diversion of irrigation (m^3)

Irrigation demand is the crop ET minus effective rainfall (m^3).

RIS relates irrigation supply to irrigation demand of the irrigation scheme in the production season. The calculated value shows some indication as the condition of water abundance or scarcity and how tightly supply and demand are coordinated. If the value is greater than one, it indicates irrigation supply was beyond the irrigation demand, if it is less than one, the supplied amount of irrigation was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to save a RIS near one than a higher value. However, the indicator did not show the monthly relation between irrigation supply and irrigation demand (Wondatir, 2016).

3.5.2.3. Water Delivery Capacity (WDC)

The water delivery capacity ratio indicates whether the system design is in anyway a constraint to meet the maximum crop water requirement. WDC was estimated using equation below (Molden et al., 1998).

$$WDC = \frac{Actual\ canal\ capacity}{Scheme\ peak\ demand} \qquad (25)$$

Actual canal capacity was measured at the diversion outlet and the scheme irrigation water requirement was calculated with CROPWAT 8.0.

3.5.3. Physical performance indicators

Under this, two important physical performance indicators were selected to measure the sustainability and irrigation intensities of the systems.

3.5.3.1. Irrigation Ratio (IR)

The intensity with which the irrigated area is cropped traditionally is a function of the number of crops per year grown on an irrigated area.

$$Irrigation\ ratio\ (IR) = \frac{Irrigated\ area\ (ha)}{Command\ area\ (ha)} \qquad (26)$$

3.5.3.2. Sustainability of Irrigated Area (SIA)

According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area.

$$SIA = \frac{Currently\ irrigable\ area\ (ha)}{Itially\ irrigated\ area\ (ha)} \qquad (27)$$

3.6. Determination of CWR and IWR in the case study area

To find out the crop water requirements (CWR) and irrigation water requirements (IWR) through CROPWAT model the following steps and information is required.

- Decade or monthly climate data that is minimum and maximum air temperature, relative humidity, sunshine duration and wind speed is required by the model.
- Reference crop evapotranspiration (ETo) equation based on Penman-Monteith method

Rainfall data (daily/decade/monthly) is required to calculate effective rainfall, for this study USDA Soil Conservation Service method has been chosen for the calculation of effective rainfall; following criteria have to be followed.

ER = Total R*(125-0.2 TR) / 125………………………………………….………………..……….. (28)

(For Total Rainfall < 250mm)

ER = 125 +0.1 * Total Rainfall……………………………………………..………..………. (29)

(For Total Rainfall > 250mm)

A cropping pattern consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area) and also a set of typical crop coefficient data files are provided in the program.

CWR and IWR computes due to the following formula, on the account of CROPWAT model.

CWR = ETo* Kc ……………………………………………………………….….…….. (30)

IWR = (ETo* Kc) – ER ……………………………………………..………..……… (31)

CROPWAT is taken in account for simulating the net irrigation requirement of each crop in the study area and canal flow is estimated based on the rectangular weir formula. The result of this scenario helps to quantify that which crops are suffering from water shortage which is an important factor for yield reduction and which crops are not facing water scarcity and what are farmers' measure in case of water shortage.

3.6.1. Required meteorological data for assessment of CWR and IWR

3.6.1.1. Rainfall

The rainfall patterns of the project area is bi-modal type in which one is the main rainy season, which occurred during the summer season mostly from June to August while the Belg rain usually starts in the beginning of march and extends up to end of October. The maximum mean monthly rainfall received is 113.0 mm in July.

Table 1: The mean monthly rainfall of the area (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
25	12	35	26	53	87	113	75	58	13	5	8	43

Source: - SNNPR Water, Irrigation and Mines Development Bureau

3.6.1.2. Temperature

The mean maximum annual temperature of the area is 28.7^{0}c while the mean minimum annual temperature is 10.7 ^{0}c, in which the highest mean maximum temperature recorded during April and that of mean minimum temperature were recorded in December months. All temperature ranges are favorable for the growth of various crops in the area.

Table 2: Mean maximum and minimum temperature (^{o}c)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Average*
Mean Min. Temp.	6.5	8.8	9.3	8.8	9.5	9.6	9.6	9.5	8.8	8.6	7	6.1	8.5
Mean Max. Temp.	21.2	21	21.6	20.7	20	18.8	17.7	17.3	18.2	19.2	19.7	20.2	19.6

Source: - SNNPR Water, Irrigation and Mines Development Bureau

3.6.1.3. Wind speed

Wind speed and direction are useful in crop water requirement and crop productivity. Thus, by taking into account such a role in affecting the actual crop water need as well as the crop productivity, we have assessed the recorded data which represent the study area. According to the collected data the mean maximum wind speed is 95.0 (km/d) and the mean minimum wind speed is 34.6km/d, during June and august months respectively. The following table shows us the recorded data's of wind speed in detail.

Table 3: Wind speed data's of the representative climate station of the study area

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Average wind speed(km/d)	138	138	147	173	173	156	138	130	112	190	173	147	151

Source: - SNNPR Water, Irrigation and Mines Development Bureau

3.6.1.4. Relative Humidity

Relative humidity with other climatic parameters is used mainly to estimate the potential evapo-transpiration of a given area. In that, the representative relative humidity data for the study area was collected. According to the data, the mean maximum relative humidity of the area is about 68.0% while 48.2% is that of the mean minimum relative humidity, these data recorded during July and February months respectively. The table below shows the relative humidity data's in detail.

Table 4: Relative humidity data's of the representative climate station of the study area

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Average Humidity (%) Relative	68	63	67	70	82	82	83	82	84	79	67	64	74

Source: - SNNPR Water, Irrigation and Mines Development Bureau

3.6.1.5. Sunshine hour

Daily length/sunshine hours and radiations are very important in photosynthetic plant growth and estimation of crop water requirements. Thus, by taking into account their role in affecting the actual crop water need, we have assessed the recorded data which represent the study area. According to the collected data the mean maximum sunshine hour is 8.6(hr) and the mean minimum sunshine hour is 5.1(hr) while 21.7 and 17.2 is that of the mean maximum and minimum solar radiation of the representative climate station of the study area respectively. These data's recorded during November and September months for sunshine hour duration and April and September months that of for solar radiation respectively. The following table shows us the recorded data's of sunshine hour and solar radiation in detail.

Table 5: Sunshine hour data's of the representative climate station of the study area

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Average Sunshine hour(hr)	8.2	8.1	7.2	7.3	7.1	5.6	4.4	5.4	6	6.4	8.1	8.2	6.8

Source: - SNNPR Water, Irrigation and Mines Development Bureau

3.6.1.6. Crop data

In the study area almost all the households are dependent on subsistence agriculture where the average productivity has been substantially decreased due to the major constraints particularly moisture stress and crop pest attacks as well as the back ward system of crop production, in which plowing, harvesting and threshing is done by human and animal power only. N.B cropping practices of the farming communities almost similar for both traditional irrigation farming and rain fed crop production system; this is because of the inadequate knowledge and lack of skill on irrigation agronomy.

Table 6: Crop data of the study area

Crop name	Coverage Area (ha)	% Area Coverage
Maize (Grain)	12	17.14
Dry bean	10	8.57
Potato	6	14.28
Tomato	7	10
Pepper	5	7.14
Fruit(mango)	8	11.43
Sugarcane	22	31.43

Source: - Wondogenet Woreda agronomist, farmers and DA's of the project area

3.6.1.7. Existing cropping calendar of the study area

The major agricultural activities that should be considered in designing cropping calendar includes, land preparation, time of planting, weeding, inputs application and finally harvesting and trashing. Land preparation and other consecutive factors practices depend on the rain fall distribution of the study area. However, there is no arranged cropping calendar in the office to take as a data. While in interviewing farmers about their tradition, they prepare land for sowing at May and planting after a few days, except wheat, it's sowing date applied after 4 month. Harvesting time in of these crops varies with farmers need.

Generally, cropping colander of the study area varies with farmers as well as rain fall and other agro-climatic condition. The following table shows us the current program used as a cropping calendar for a few crops.

Table 7: Traditional cropping calendar of the study area

Crop type	Land preparation	Planting/sowing	Weeding/cultivation	Harvesting
Maize	Feb	March	Apri-May	Jun-Jul
Dry bean	March	Apri-May	Jun-Jul	Sep
Vegetables	Mid-sep	Oct	Nov-dec	Jan
Chat	Mid-sep	Oct	Nov-dec	Jan
Sugarcane	Mid-sep	Oct	Nov-dec	Jan
Cereals	Mid-sep	Oct	Nov-dec	Jan
Fruit (mango)	Mid-sep	Oct	Nov-dec	Jan

Source: - Wondogenet Woreda agronomist, farmers and DA's of the project area

3.7. Assessment of CWR and IWR in the case study area for various crops using CROPWAT model

In irrigated agriculture one of the most important pre-requisites which need great concern is determination of Crop Water Requirements of recommended crops to be included in the irrigation production system. Crop Water Requirement is defined as the depth of water needed to meet the water lost through Evapo-transpiration (ETo) of a disease free crop grown in large scale under non restricting soil and environmental conditions to achieve the full production potential of the crop.

The irrigation requirement is amount of water which is supplied through the irrigation system to ensure that the crop receives its full crop water needs. In a situation where irrigation is the only source of water supply for the crop, then the irrigation requirement should be almost equal to water requirements of the crop in question. In general, the irrigation requirement should be more than the actual requirements of the crop in order to compensate for inefficiencies caused by a variety of factors.

Currently rainfall is becoming highly unreliable for crop production which makes rain fed farming a risky venture in the target area in particular and in the country in general. Its amount and distribution are of paramount importance to support successful crop production in a situation where rain fed agriculture is predominant. Its variability and unreliability is becoming a frequent visitor for project area affecting crop production schedule of the farming community. Farmers were complaining on climate change and climate variability in the past two decades which affects the farm planning and cropping pattern. Hence, availing irrigation water by harvesting water is the only means to supplement this rainfall variability.

Climatic data including wind speed, relative humidity, sun shine hours, maximum & minimum temperature are used from the same meteorological station, located in the nearby target project area. Since all climatic data are available directly from stations and by interpolating for some areas, penman monteith method of ETo calculation is used which is the recent and accurate method of ETo calculation. It is calculated by using CROPWAT Software version 8.0 which is the recent version of the software.

4. RESULT AND DISCUSSION

4.1. Laboratory analysis of soil samples

Results of physical and chemical analysis of the soil samples in the study area are presented in Table 8. It shows that the top 30 cm soil depth of the fields located at top and tail end of the command area has a sandy loam textural class while the middle one is characterized as loamy soil. The textural class of the subsoil was variable from Sandy Clay Loam, Loam, and Sandy Loam at top, middle and tail end, respectively. From this analysis, we can conclude that the first 30 cm soil profile of the command area is dominated by sandy loam.

Table 8: Results of physical and chemical analysis of the soil samples in the study area

Soil characteristics	Soil depth (cm)					
	0 - 30			30 - 60		
	Head end field	Middle field	Tail end field	Head end field	Middle field	Tail end field
Sand (%)	58	32	56	54	26	58
Silt (%)	25	43	23	24	47	23
Clay (%)	15	23	19	22	26	19
Textural class	SL	L	SL	SCL	L	SL
Average bulk density (g/cc)	1.12	0.85	1.12	1.13	0.90	1.12
Field capacity (%)	18.73	33.05	18.43	23.78	35.20	24.09
Permanent wilting point (%)	14.43	25.18	14.95	15.17	24.17	14.45
PH (H_2O	7.1	7	7	7.6	7.4	7.2

Abbreviations: SL: Sandy Loam; L: Loam; SCL: Sandy Clay Loam

4.1.1. Total moisture content stored at sampling points

Total moisture content stored at sampling points of the three irrigation events before and two days after irrigations are presented in Table 9. As seen in Table 9, the moisture content stored at sampling points is within the two soil layers (i.e. 0-30 cm and 30-60 cm). The depth of soil layer in the root zone is taken as 300mm for each layer: which is equal to 30cm.

Table 9: Total moisture content stored at sampling points of the three irrigation events before and two days after irrigation

Field code		Average soil mass wetness, w (%) before irrigation		Average soil mass wetness, w (%) after irrigation		Difference between soil mass wetness before and after irrigation			Average bulk density (g/cc)	Total moisture content stored at sampling points (mm)
		Soil depth (cm)		Soil depth (cm)						
		0 - 30	30 - 60	0 - 30	30 - 60	0 - 30	30 - 60	Total		
Head	H_1	15.46	17.67	18.48	23.57	3.02	5.90	8.92	1.12	29.97
	H_2	15.30	17.42	19.05	23.35	3.75	5.93	9.68	1.08	31.36
	H_3	16.02	18.2	18.89	24.06	2.87	5.86	8.73	1.13	29.59
									Average	**30.31**
Middle	M_1	28.52	29.85	32.90	35.02	4.38	5.17	9.55	0.91	26.07
	M_2	28.25	29.52	32.45	35.01	4.20	5.49	9.69	0.73	21.22
	M_3	29.05	30.06	33.12	36.11	4.07	6.05	10.12	0.88	26.72
									Average	**24.67**
Tail	T_1	15.96	17.98	18.45	24.25	2.49	6.27	8.76	1.12	29.43
	T_2	16.06	18.15	19.11	25.21	3.05	7.06	10.11	1.10	33.36
	T_3	15.45	17.53	18.65	24.03	3.20	6.50	9.70	1.14	33.17
									Average	**31.99**

The higher the depletion fraction, the drier is the soil prior to irrigation. Table 10 shows that the middle farmer has the least moisture deficit before irrigation. This is because the soil is characterized as loam, which has the highest water holding capacity than the others (predominantly sandy loam). Therefore, the middle field had better moisture content before irrigation. The relatively low water holding capacity of the head and tail end fields caused the soil to be drier more than recommended for potato production.

Table 10: Depletion fraction within the root zone before irrigation

Field position	FC (mm)	Average moisture content before irrigation (mm)	SMD before irrigation (mm)	TAW (mm)	Deplation fraction (%)
Head	143.95	114	32.05	44.01	**72.82**
Middle	182.43	153.98	27.13	50.67	**53.54**
Tail	142.79	115	28.95	43.98	**65.83**

4.2. Performance evaluation of Wesha SSIS with the help of internal indicators

4.2.1. Conveyance efficiency

Due to lack of canal-crossing structures and division boxes, the water flowing in the canals is wasted at several spots when heavy trucks that frequently come to the command area to transport agricultural products, bicycles of the community members residing in the project and passengers who pass-by on foot frequently disturb the normal course of water in the secondary canals. Much water spills over the broken canals that contribute to the minimized irrigation water amount to the tail end users. Water is rotated from one farmer to the other by means of bund break. They use mud, wood and trashes of different plants to obstruct the flow of water and divert it to the next farmer. However, as this mechanism is not quite efficient in obstructing the flow of water, still much water leaks and flows to the undesired canals. This by itself has contributed to the low share of water to tail Enders and the associated low conveyance efficiency (Table 11).

Figure 7: Loss of water due to canal breaking on secondary canal

Table 11 shows that the average conveyance efficiency of the scheme was 66.43%. Where the main canal efficiency was 76.84%. Nearly similar result was reported by Tesfaye (2018) at Wesha small scale irrigation scheme. This result is higher than FAO which recommend an efficiency value of 70% for canal length 200-2000 meters. This shows that the main canal is relatively efficient because 242.54m of it is lined with concrete and masonry works that minimized seepage of water.

FAO recommends 80% on sandy soils and 85% on loam soils as indicative values for canal conveyance efficiencies. Compared to these indicative values of FAO, conveyance efficiencies of the secondary and tertiary canals are so small (47.46% and 53.78%, respectively) indicating that a lot of water is lost as steady-state and transient losses. During the study period, water is seen to be lost at several spots signifying that the water delivery structures are inadequate and poorly maintained. However, though the field channel efficiency was found to be relatively high (87.65%). The overall conveyance efficiency of the project has become 66.43%. The main canal and the field channel efficiencies appear to be high because, (1) 242.54m length of the main canal is lined so the water loss through the canal bed and wall is low, and (2) field channels are usually so short that water travels only short distances inducing only little amount of seepage loss.

Table 11: Conveyance efficiency of the scheme

Canals	General soil type	Canal length category (m)	Average canal inflow (l/s)	Average canal outflow (l/s)	Conveyance efficiency, Ec (%)
Main canal	Lined with concrete	200-2000	20.51	15.76	**76.84**
Secondary canal	Sandy	<200	16.56	7.86	**47.46**
Territory canal	Loam	<200	15.06	8.10	**53.78**
Field channel	Sandy Loam	<200			**87.65**
Average conveyance efficiency of the scheme					**66.43**

4.2.2. Water application efficiency

The measurements of depth of water applied to each field (D_a) and the depth of water stored in the root zone (D_s) are presented in Table 12. The water application efficiency computation is made based on the results of Table 12. FAO (1989) suggested 60% as attainable water application efficiencies for surface irrigation system. Value below this limit would normally be considered unacceptable. In this study, the water application efficiencies (Ea) in the three fields were in the range of 37.68% - 62.34% that is considered as inefficient because farmers applied excess water to their fields. The result was disagreed with FAO (1989) reported that the maximum attainable application efficiency ranges from 55%-70%.

Considering three farmers' irrigation practices at the head, middle and tail end of the command area, the average application efficiency of the irrigation project was found to be 46.70%. The result obtained agrees with Environmental who concluded that in most traditional irrigation projects the application efficiency is typically less than 50% and often as low as 30%. However, according to the studies of FAO (1989) the water application efficiency of the command area is considered as lower than the acceptable range of 60-85%.

From the field observations and measurements, the major cause for the low water application efficiency is the existence of high deep percolation losses. This can be proven from the field observations of the farmers' shallow water wells scattered at several spots over the entire command area. During the irrigation season, the water table in the shallow wells had a depth of 1.5-2 m below the surface and suddenly dropped below 2.5 m after the irrigation season and in the middle of rainy season. Table 12 also shows that the application efficiency of farmers increases as the shortage of water increases from head to tail end of the command area. This is because as the supply of water decreases, farmers tend to become more efficient in their water use. The application of water by many farmers is generally more than the required depth for crop use and leaching of excess salts. Therefore, slight decrement of water supply can improve the application efficiency particularly by decreasing the deep percolation and runoff ratios as excessive application of water generally entails losses due to surface runoff from the field as well as to deep percolation below the root. If water is expensive, then a most efficient system with minimum loss can be ascertained. Similar results can be expected when labour is expensive.

However, it should be noted that decrement of the water supply less than the perception of farmers as sufficient for their crops results in abandoning of crop production using irrigation and shifting the land to non-irrigated local crops like ‘Enset’ (according to their attitude). During the field assessment period, many farmers located at the bottom (tail) of the command area are seen to abandon their irrigation practice and shift to ‘Enset’ crop which they consider the crop as drought resistant that does not need any irrigation application. Many tail enders also constructed houses on such lands.

Table 12: Parameters and calculated application efficiencies

Field position	Field size (m2)	Irrigation event	Vol. of applied water (m3)	Depth of applied water, Da (mm)	Mean depth of root zone storage, Ds (mm)	Application efficiency, Ea (%)
Head	400	1st	33.22	83.05	24.09	29.01
		2nd	31.14	77.85	32.97	42.35
		3rd	31.33	78.33	33.09	42.25
Total			**95.69**	**239.23**	**90.15**	**37.68**
Middle	1200	1st	128.96	107.47	28.07	26.12
		2nd	45.65	38.04	29.98	78.81
		3rd	53.15	44.29	18.02	40.68
Total			**227.76**	**189.80**	**76.07**	**40.08**
Bottom	1000	1st	61.65	61.65	24.02	38.96
		2nd	36.94	36.94	32.87	88.98
		3rd	44.89	44.89	32.56	72.53
Total			**143.48**	**143.48**	**89.45**	**62.34**
Average Application efficiency of the scheme						**46.7**

4.2.3. Storage efficiency

From Table 13 we see that the storage efficiency of the sample fields ranges from 96-99% with an average of 96.02% for the project. The storage efficiencies of the middle and tail end fields are found to be high because the depletion fractions of the fields before irrigation were lower than the head end field (Table 13).The overall water storage efficiency of the irrigation project (i.e., 96.02%) was in line with the range of 85-100%, which is assumed to be the potential achievable value for furrow irrigation. This shows that irrigation water application successfully met its objective of refilling the root zone to field capacity. Depending on weather, type of soil and time span considered, storage efficiency might be as high as 90% (FAO, 1992).

Table 13: Calculated storage efficiencies over the fields

Field position	Mean depth of moisture stored, Ds (mm)	Mean depth of moisture requirement to refill to FC, Dreq (mm)	Storage efficiency (Es)%
Head	31.03	32.05	96.82
Middle	24.76	27.13	91.26
Tail	28.94	28.95	99.97
Average storage efficiency of the scheme			96.02

4.2.4. Water distribution uniformity

The evaluation of water spreading uniformity of each field was carried out using three irrigation events. The average of the three was taken to compute the distribution uniformity and the result is summarized in Table 14. The DU at the head, middle and tail end fields are 97.62, 86.02 and 92%, respectively. From this, it can be concluded that 86-97% of the irrigation fields received and stored equal amount of water at their rooting depths. The higher the value of DU, the better the uniformity of water application and the higher is the distribution efficiency. The results indicate that the distribution uniformities of all the three fields are by far higher than the value categorized as sufficient (i.e., 65%) by FAO (1992). Compared to others, the head end farmer applied water more uniformly (97.62%). This is because he had an access to apply more water than the others did; because he is located nearest to the main intake (weir site). The extra large volume of water he applied helped him to water much of his field uniformly. The middle farmer applied water least uniformly to his field (86.02%). The reason behind is that, his field size was the largest so he could not be able to manage to spread water uniformly over his field.

Table 14: Parameters and calculated water distribution uniformities

Field code		Total moisture content stored at sampling points (mm)	Field size (m²)	The mean lower-quarter depth of water stored ($\bar{X}_{Lq}$) (mm)	The mean depth of water stored at field points ($\bar{X}_m$) (mm)	Distribution uniformity (DU)%
Head	**H_1**	29.97	400	29.59	30.31	**97.62**
	H_2	31.36				
	H_3	29.59				
Average		**30.31**				
Middle	**M_1**	26.07	1200	21.22	24.67	**86.02**
	M_2	21.22				
	M_3	26.72				
Average		**24.67**				
Tail	**T_1**	29.43	1000	29.43	31.99	**92**
	T_2	33.36				
	T_3	33.17				
Average		**31.99**				
Average distribution uniformity of the scheme						**91.88**

4.2.5. The overall Scheme efficiency

The overall scheme efficiency at the study area was 31.02%, which was very poor; which mean that irrigation water loss was very large indicating need for scheme improvement. Therefore, this result indicated that the overall irrigation efficiency is inefficient as compared with values ranged 50 -60% stated by FAO, (1989) for surface irrigation.

4.3. Performance evaluation of Wesha SSIS with the help of external indicators

4.3.1. Agricultural Performance Indicators

Seven crops are common at Wesha SSIS were taken into account. Maize (Grain), Dry bean, Potato, Tomato, Pepper, Mango and Sugarcane were taken as the common crop, respectively because they were the most tradable and cultivated crops. The irrigated area in Wesha SSIS is 70 ha and total command area is 250 ha. The area allocation for each crop, intensity, productivity values were calculated for the scheme for the year 2021/22 by local prices as presented in Table 15.

4.3.1.1. Output per unit command area (OPPUCA)

The OPPUCA in terms of monetary was calculated using equation [19] in section 3.5.1.1 the output per unit command area for the period 2022 was obtained 38,939.2 Birr/ha. This result obtained was higher than the values 1277.7 – 29360.8 Birr/ha which was obtained by Mintosnot et al. (2005).

4.3.1.2. Output per unit of irrigated area (OPPUIA)

As the OPPUA was calculated in terms of monetary using equation [20] in section 3.5.1.2 and presented in table 15 the result was obtained 139,068.6 birr/ha for the 2022 cropping year. This result is higher when compared with values 2000-41,291.7 and 58,940.24 Birr/ha obtained by Mintosnot et al. (2005) and Dessalew et al. (2016) for May Nigus irrigation scheme in tekeze basin and Bedene Alemtena irrigation irrigation schemes respectively. This is because of the irrigators of the study area was covered with high value cash crops around 91.42% of the irrigated land were covered with the high value cash crops (Sugarcane, Dry bean, pepper, Maize (Grain), Tomato and Fruit (Mango) the remain only about 8.58% of the irrigated land was covered by Potato which has relatively low local price in the study area as presented in table 15. And also the reason to be varied this result is the fluctuation of crops price over time.

Table 15: Total crop yield, total income and area coverage by each crop at the irrigation scheme

Crop type	Area		Production (qtl/ha)			Total production (qtl) Or (birr/ha)	Income (birr/qtl) Or (birr/ha)			Total price in birr	OPPUIA (birr/ha)
	ha	%	Min	Max	Mean		Min	Max	Mean		
Maize (Grain)	12	17.14	30	45	37.5	450	3200	3500	3350	1,507,500	125,625
Dry bean	10	8.57	13	15	14	140	4600	5000	4800	672,000	67,200
Potato	6	14.28	30	35	32.5	195	1200	1500	1350	263,250	43,875
Tomato	7	10	27	35	31	217	2400	2500	2450	531,650	75,950
Papper	5	7.14	22	30	26	130	3300	3500	3400	442,000	88,400
Fruit (Mango)	8	11.43	30	36	33	264	3000	3200	3100	818,400	102,300
Sugarcane	22	31.43	250,000 birr/ha			5,500,000 birr/ha	250,000 birr/ha			5,500,000	250,000
Total	70									9,734,800	**139,068.6**

Where: qtl is for quintal and OPPUIA is for output per unit irrigated area

4.3.1.3. Output per unit water consumed (OPUWC)

The average values of water productivity with respect to CWR was calculated using equation [21] described in section 3.5.1.3 the average result in terms of monetary was found to be 45.24 birr/m^3. This result is higher when compared with 14.59 birr/m^3conducted by Dessalew et al., (2016) in

Hallaba zone Southern Ethiopia. This might be attributed to good management practices of farmers. The detail results are presented in table 16.

4.3.1.4. Output per unit irrigation supply (OPUIS)

The output per unit irrigation supply was calculated using the equation [22] described in section 3.5.1.4. As presented in table 16 the calculated result was obtained in the range of 0.06 – 0.34 birr /m^3. The average value of output, per unit of irrigation supply for the Wesha SSIS was obtained 0.15 birr/m^3. The farmers in Wesha small scale irrigation scheme are less stressed in water and they are not expected to pay for irrigation water. Their management would be poor. When land is a limiting factor relative to water, output per unit land may be more important, when water is a limiting factor for production, output per unit water supplied may be more important (Molden et al., 1998). Since water is a limiting factor relative to land in Wesha small scale irrigation scheme, the value of water has to be given more emphasis.

Table 16: Output per unit actual water consumed of the irrigation scheme

Crop type	Area (ha)	Production (Qtl/ha)	Income (birr/ha)	CWR (mm/s)	CWR (m^3)	Irrigation supply (m^3/season)	OPUWC (birr/m^3)	OPUIS (birr/m^3)
Maize (Grain)	12	37.5	125,625	374.2	3742	737520	33.57	0.17
Dry bean	10	14	67,200	331.5	3315	737520	20.27	0.09
Potato	6	32.5	43,875	426.4	4264	737520	10.29	0.06
Tomato	7	31	75,950	487.6	4876	737520	15.58	0.10
Pepper	5	26	88,400	392.1	3921	737520	22.54	0.12
Fruit (Mango)	8	33	102,300	1139.3	11393	737520	8.98	0.14
Sugarcane	22		250,000	1217	1217	737520	205.42	0.34
Average							**45.24**	**0.15**

OPUWC, output per unit water consumed; and OPUIS, output per unit irrigation supply

4.3.2. Water Related Indicators

The analysis of water related indicators RWS, RIS and WDC were calculated using equations [23], [24] and [25] respectively as described in sections 3.5.2.1, 3.5.2.2, and 3.5.2.3 respectively. And the values are presented in table 17.

4.3.2.1. Relative Water Supply (RWS)

The value for RWS at the study area was found 1.35 which is greater than one. This shows that it could irrigate additional farm land with this delivery amount and available effective rainfall in the study area.

Perry (1996), also categorized relative water supply (RWS) values ranging from 0.9 to 1.2 as adequate and from 1.2 to 1.8 as excessive. According to Perry (1996), the result of relative water supply (RWS) at Wesha small scale irrigation scheme is excessive.

The result was helpful for planning to construct a canal branched from the existing main canal to make the remaining command area under irrigation.

4.3.2.2. Relative Irrigation Supply (RIS)

The value for RIS at the study area was found 1.14 which is greater than one. According to Wondatir (2016), the value for relative irrigation supply (RIS) greater than one show that, irrigation supply was beyond the irrigation demand. If it is less than one, the irrigation supply was below the irrigation demand. Based on the result at Wesha small scale irrigation scheme, farmers were applying more water than the required amount. In order to maximize water use efficiency of the scheme, it is essential to reduce the amount of water supplied to the scheme.

4.3.2.3. Water Delivery Capacity (WDC)

The value for WDC at the study area was found 1.08 which is greater than one. The result shows that the river diversion infrastructure is capable of delivering the necessary peak water demand.

Table 17: Water related indicators for Wesha SSIS

Parameters	Values
Irrigation supply (m^3)	737520
Total water supply (m^3)	878520
Total crop water demand (CWD) (m^3)	648520
Total irrigation demand (m^3)	647920
Canal capacity to deliver water at system head (l/s)	20.51
Peak consumptive demand (l/s)	19
RWS	1.35
RIS	1.14
WDC	1.08

4.3.3. Physical performance indicators

Two basic physical indicators, irrigation ratio (IR) and sustainability of irrigated areas (SIA) were selected and computed based on equations [26] and [27], to evaluate the status of Wesha SSIS. The result is indicated in table 18.

Table 18: Physical performance indicators computed values

Command area (ha)	Initially irrigated area (ha)	Currently irrigated area (ha)	IR (%)	SIA (%)
250	200	70	28	35

IR is for irrigation Ratio, SIA is for Sustainability of irrigated area

4.3.3.1. Irrigation Ratio (IR)

The irrigation ratio shows the level of utilization of a given irrigable area in the specific production season. As calculated using equation H the irrigation ratio of Wesha SSIS was found to be 0.28 this elaborates that about 0.72 (72%) of the command area of the irrigation scheme was not under irrigation during the study period. The current irrigated area was under irrigated below the proposed command area due to lack of proper designed irrigation infrastructure.

4.3.3.2. Sustainability of irrigated area (SIA)

As shown in table 18 the computed value of sustainability of irrigated area at the study scheme was found to be 0.35 this is below one, which indicates that the current irrigable area is below the irrigable area at the initial period of the irrigation scheme. Thus the irrigable area in Wesha SSIS showed decreasing trend; about 65% of initial irrigated area has not been irrigated. This indicates that the project is not sustainable, since SIA is much far from 100%. Settlement expansion is the major reason observed in the field as threat to the sustainability of the project. Due to increasing population residing in the command area, many previously irrigated lands are used for house constructions.

4.4. Climatic water balance of the study area

Figure 8 shows the monthly climatic water balance of the study area based on CLIMWAT data and average rainfall data of 20 years (1991-2010). The potential evapotranspiration of the study area, calculated using CROPWAT Model, is more than the effective rainfall in most of the months calling for supplemental irrigation. The effective rainfall is more than ETo by 10.96 mm/month during July; meaning that no irrigation is required during this month. Therefore, those farmers who grow crops on July are less likely to apply supplemental irrigation. On the other hand, extensive irrigation is essential for crops planted particularly on October, November, December, January, February, March, April, May (with 84.67, 96.9, 100.16, 82.86, 93.2, 85.15, 88.07 and 53.95 mm of irrigation water requirements, respectively).

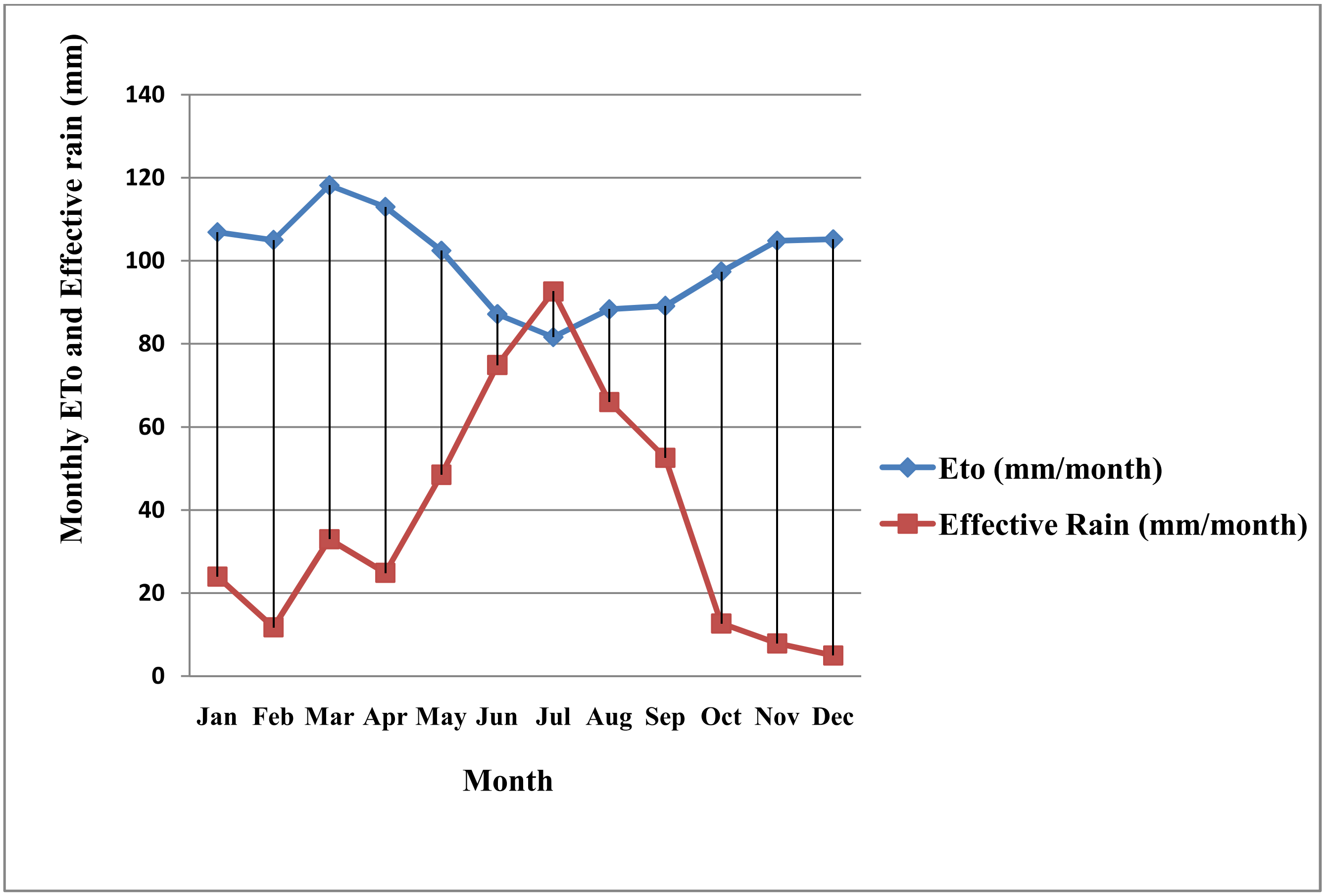

Figure 8: Monthly distributions of reference evapotranspiration (ETo) and effective rainfall of the study area.

Table 19: Monthly ETo Penman-Monteith

Country: Ethiopia **Station:** Hawassa
Altitude: 1697.13 meter(s) above M.S.L.
Latitude: 7.062 Deg. (North) **Longitude:** 38.476 Deg. (East)

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	Eto mm/month
January	6.5	21.2	68	138	8.2	20.1	**106.86**
February	8.8	21	63	138	8.1	21	**105.00**
March	9.3	21.6	67	147	7.2	20.5	**118.15**
April	8.8	20.7	70	173	7.3	20.7	**112.97**
May	9.5	20	82	173	7.1	19.8	**102.45**
June	9.6	18.8	82	156	5.6	17.1	**87.16**
July	9.6	17.7	83	138	4.4	15.5	**81.64**
August	9.5	17.3	82	130	5.4	17.5	**88.31**
September	8.8	18.2	84	112	6	18.5	**89.13**
October	8.6	19.2	79	190	6.4	18.6	**97.37**
November	7	19.7	67	173	8.1	20.1	**104.80**
December	6.1	20.2	64	147	8.2	19.6	**105.80**
Average	8.5	19.6	74	151	6.8	19.1	**99.97**

Table 20: Effective Rain in mm

	Rain mm	Eff rain mm
January	25	24
February	12	11.8
March	35	33
April	26	24.9
May	53	48.5
June	87	74.9
July	113	92.6
August	75	66
September	58	52.6
October	13	12.7
November	8	7.9
December	5	5
Total	510	453.90

4.5. Assessment of CWR and IWR in the case study area for various crops using CROPWAT model

To reduce irrigation water loss in irrigation system, determination of crop water requirements of recommended crops to be included in the irrigation production system is important. Figure 9 shows the result of the CROPWAT 8.0 analysis; it shows that, Maize (Grain) and Dry bean which are consuming the minimum water 357.2 and 319.0 mm respectively, due to low CWR and high effective rainfall in the study area. Sugarcane has the highest water consumption than others, because it has the longest age than all others, which is calling (Perennial crop). Vegetable crops (Potato, Tomato, and Pepper), are consuming 408.5, 467.3, and 357.1 mm water respectively. The Crop water requirement for these crops is relatively higher because of high evapotranspiration and less effective rainfall during their age period.

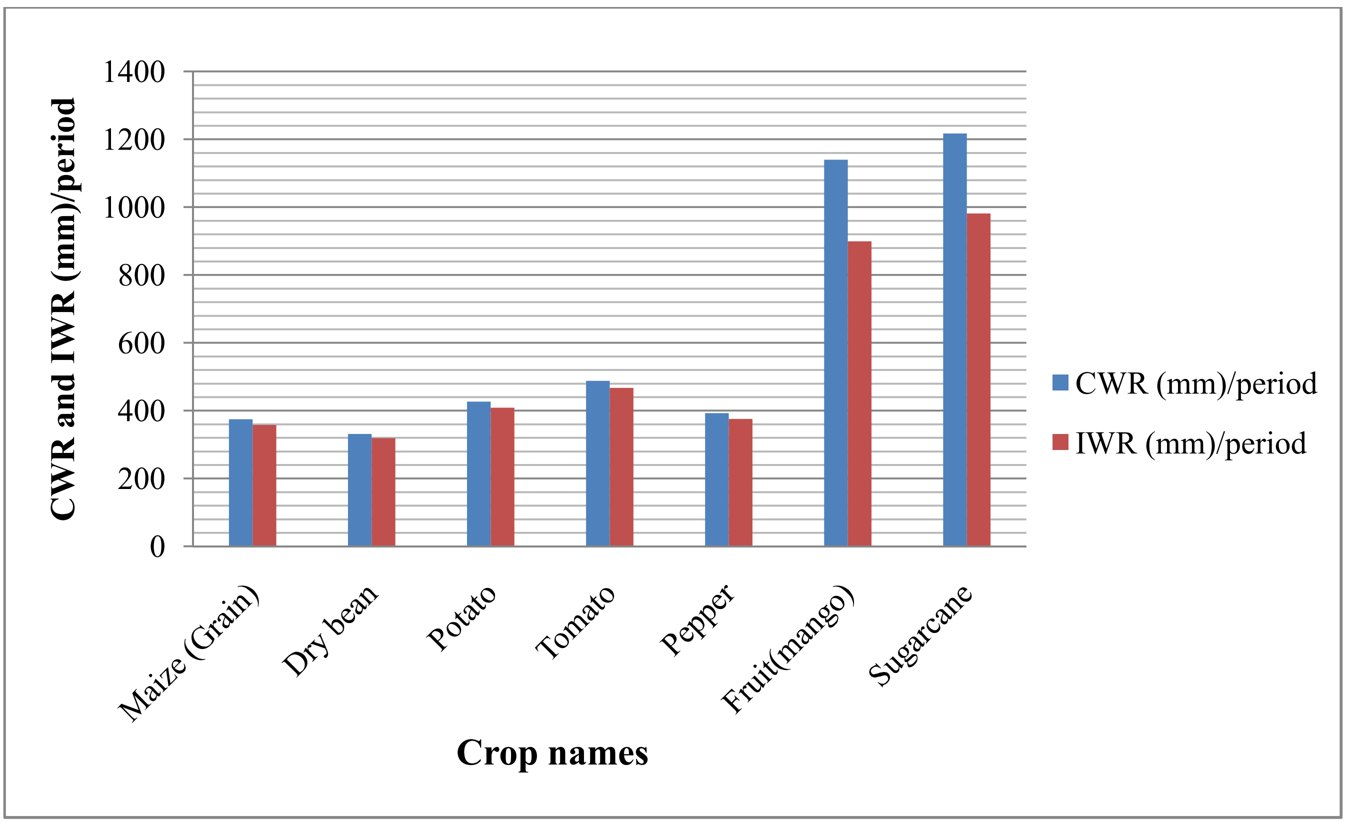

Figure 9: Comparison of CWR and IWR of different crops in the study area

Table 21: CWR and IWR for various Crops in the study area

Crop name	Planting date	Harvesting date	period days	Max, Kc	CWR (mm)/period	IWR (mm)/period
Maize (Grain)	01-Dec	04-Apr	241	1.2	374.2	357.2
Dry bean	02-Dec	21-Mar	256	1.15	331.5	319
Potato	03-Dec	11-Apr	236	1.15	426.4	408.5
Tomato	04-Dec	27-Apr	221	1.15	487.6	467.3
Pepper	05-Dec	08-Apr	241	1.05	392.1	375.1
Fruit(mango)	06-Dec	05-Dec	364	1.1	1139.3	899
Sugarcane	07-Dec	06-Dec	364	1.25	1217	980.7

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The relative water supply (RWS), relative irrigation supply (RIS) and water delivery capacity (WDC) for Wesha small scale irrigation scheme shows that there is a ratio greater than one. This implies that, there were sufficient relative irrigation supply and high relative water supply which was beyond the crop demand. This shows that it could irrigate additional farm land with this delivery amount and available effective rainfall in the study area.

Performance of the Wesha small-scale irrigation scheme was considered as unsatisfactory in terms of water conveyance efficiency of the canals (66.43%) and water application efficiency of the farmers (46.76%). The overall scheme efficiency at the study area was 31.02%, which was very poor; which mean that irrigation water loss was very large indicating need for scheme improvement. This means a lot of water was lost as steady state and transient losses from the canals. Once reached to fields, the water was also lost as deep percolation during application by farmers due to their poor water management practice. Because of the rapid expansion of urbanization and relative water shortage to the tail end farmers, the total area put under irrigation showed sign of declining; meaning that the sustainability of the irrigation scheme is endangered.

However, the irrigators performed well in uniformly spreading water over their fields (average distribution efficiency, DU=91.88%); meaning that more than 91% of the field received equal amount of water to the root zone. The farmers also performed well in terms of water storage efficiency (96.90%). The result of water storage efficiency tells us that about 96% of the moisture depleted below FC by evapotranspiration was refilled by irrigation water. Similarly, the irrigators have appreciable technique to prevent runoff loss by using block-end furrow irrigation practice.

The agriculture production shows that there is satisfactory result compared to previous study results. The Production of all crops was not agreeable in to international market of single crop, for this reason agricultural production performance indicators were not compared with other countries worldwide.

Since the irrigation ratio of Wesha SSIS was found to be 0.28 this elaborates that about 0.72 (72%) of the command area of the irrigation scheme was not under irrigation during the study period. The current irrigated area was under irrigated below the proposed command area due to lack of proper designed irrigation infrastructure.

The computed value of sustainability of irrigated area at the study scheme was found to be 0.35 this is below one, which indicates that the current irrigable area is below the irrigable area at the initial period of the irrigation scheme. Thus the irrigable area in Wesha SSIS showed decreasing trend; about 65% of initial irrigated area has not been irrigated. This indicates that the project is not sustainable, since SIA is much far from 100%. Settlement expansion and shortage of water to the tail end of the command area are the major reasons observed in the field as threats to the sustainability of the project.

The potential evapotranspiration of the study area, calculated using CROPWAT Model, is more than the effective rainfall in most of the months calling for supplemental irrigation. The effective rainfall is more than ETo by 10.96 mm/month during July; meaning that no irrigation is required during this month. Therefore, those farmers who grow crops on July are less likely to apply supplemental irrigation. On the other hand, extensive irrigation is essential for crops planted particularly on October, November, December, January, February, March, April, May (with 84.67, 96.9, 100.16, 82.86, 93.2, 85.15, 88.07 and 53.95 mm of irrigation water requirements, respectively).

5.2. Recommendations

Based on the study results, the following recommendations should be drawn for better performance of the irrigation scheme.

- In order to overcome the poor water management at field level, it is better to give intensive practical training to the farmers about the mitigation of problems related to excess use of irrigation water on their field and in order to practice economical application of water with appropriate inflow rate.
- In order to improve the conveyance efficiency of the system unlined canal should be lined canal.
- Though there were lines of surface drainage system in the estate farms, they are not functioning; it is recommended to rehabilitate the existing drainage networks and construct additional cross drainage structures based on the recent conditions of the cane fields.
- Extensive land leveling and furrow making process should be done with care.
- Since the current water management system of the scheme is not effective and efficient, proper operation and maintenance of irrigation infrastructure has to be done. The Woreda irrigation department should organize the farmers in associations for operation and maintenance of irrigation infrastructure.
- For sustainability of the irrigation scheme periodic maintenance is required to reduce leakage and seepage losses in the division boxes.
- Continuous monitoring and evaluation of the irrigation scheme is necessary to know the performance of the irrigation scheme and it is also important for the future planning and management of the irrigation scheme.
- The water users committee should be strengthened by training and there should be monitoring and evaluation by respected bodies to increase their performance.

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7. APPENDIXES

Appendix 1: Performance indicators computed for 18 irrigation systems in 11 countries (adopted from Molden et al., 1998)

Country	Irrigation System	Year	Output per unit cropped land ($/ha)	Output per unit command area ($/ha)	Output per unit irrigation supply ($/m^3)	Output per unit water consumed ($/m^3)	Gross return investment (%)	Financial self-sufficiency (%)	RWS (Ratio)	RIS (Ratio)	WDC (Ratio)
Burkina Faso	Gorgo	1992/93	1025	1065	0.1	0.91	9	42	1.6	3.5	3.5
	Mogtedo	1992/93	1204	2499	0.09	0.14	21	79	1.4	2.7	2.1
	Savili	1992/93	3085	2652	0.37	0.8	33	-	2.5	2.6	2.9
	Gorgo	199/95	771	679	0.08	0.12	6	35	1.9	2.7	3.5
	Mogtedo	1994/95	1403	2384	0.11	0.15	20	78	1.4	2.5	2.1
	Savili	1994/95	2348	2281	0.28	0.62	29	28	2.5	2.6	2.9
Colombia	Coella	1993	1290	1303	0.14	0.2	24	114	1.8	1.8	2.2
	Saldana	1993	1125	1811	0.12	0.17	33	127	2.2	2.9	3.2
	Samaca	1993	1472	2462	0.63	0.34	36	109	1.2	1.1	1.7
Egypt	Nile Delta	1993/94	1510	2594	0.12	0.11	26	-	1.6	1.6	1.3
India	Mahi Kadana	1991/92	605	515	0.04	0.03	30	-	3.9	3	2.9
	Mahi Kadana	1995/96	916	893	0.07	0.06	52	53	2.7	2.5	2.6
Malaysia	Muda	1994/95	1021	1041	0.38	0.1	59	-	0.8	0.4	-
Mexico	Alto Rio Lerma	1994/95	2227	1464	0.18	0.24	28	80	2.2	3.3	5.1
	Cortazar Module	1994/95	2615	1827	0.22	0.25	33	133	2.1	2.3	1.2
	Salvatierra Module	1994/95	2117	974	0.1	0.27	27	101	4.1	4.8	2.4
Morocco	Triffa Scheme	1994/95	1087	1358	0.27	0.34	47	-	1.3	1.1	-
Niger	Saga	1993/94	1389	2592	0.12	0.13	-	139	2.2	1.8	-
	Kourani Baria I	1994	827	1460	0.05	0.17	-	-	2.9	2.4	-
	Kourani Baria II	1994	1107	1879	0.06	0.11	43	-	2.2	1.7	-
Pakistan	Chishtian	1993/94	384	477	0.04	0.05	-	40	1.3	1.2	0.8
Sri Lanka	Nachchaduwa	1994/95	826	1544	0.04	0.08	34	-	2	2.2	-

Appendix 2: Some performance Indicators computed different irrigation schemes in Ethiopia

Author	Year	Irrigation system	Technical performance indicators				Water related performance indicators		
			Ec (%)	Ea (%)	Es (%)	DU (%)	RWS (Ratio)	RIS (Ratio)	WDC (Ratio)
Mintesnot et al.	1997/98 – 2001/02	May Nigus micro dam irrigation scheme	-	-	-	-	0.8-1.2	3.13-5.96	3.33-6.68
Dessalew et al.	2016	Bedene Alemtena	-	54.9	-	90.2	-	-	-
Abebe	2012/13	Shina Hamusit	-	-	-	-	1.55	1.87	-
	2012/13	Selamko	-	-	-	-	1.31	0.81	-
Yusuf	2004	Batu Degaga		31.5-64.3	80.4-104.7	100	2.32	2.57	0.77
	2004	Doni	-	-	-	-	2.24	2.76	1.83

Appendix 3: Indicative standard values of the conveyance and application efficiency for various canals adopted from (Mati, 2011).

Conveyance efficiency in %					Application efficiency	
Canal length	Earthen canal for different soil type			Lined canal	Irrigation system	Efficiency in %
	Sand	Loam	Clay			
Long > 2000 m	60	70	80	95	Basin	60 - 95
Medium 200 – 2000 m	70	75	85	95	Border	60 - 90
Short < 200 m	80	85	90	95	Furrow	50 - 90

Appendix 4: Range for some soil characteristics parameters

Soil type	FC	PWP	Available water per unit depth of soil (mm/m)
Fine sand	3 - 5	1 - 3	20 - 40
Sandy soil	5 - 15	3 - 8	40 - 110
Soil loam	12 - 18	6 - 10	60 - 130
Clay loam	15 - 30	7 - 16	100 - 180
Clay	25 - 40	12 - 20	160 - 300