COMPARATIVE PERFORMANCE EVALUATION OF IRRIGATION SCHEMES:

A CASE STUDY OF MAI-SHAWSH AND MIDMAR SMALL SCALE IRRIGATION SCHEMES, IN MEREB SUB-BASIN, NORTH ETHIOPIA

M.Sc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE SCHOOL OF

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EXAMINERS' APPROVAL SHEET – 1

(Submission Sheet-1)

We, the undersigned, members of the Board of Examiners of the final open defense by **Guesh Hagos Asresu** have read and evaluated his thesis entitled **"Comparative Performance Evaluation of Irrigation scheme; A case study of Maishawsh and Midmar Small Scale Irrigation Schemes in Mereb Sub Basin, North Ethiopia"** 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 Water Resource Engineering, specialization by **Irrigation and Drainage Engineering**.

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DECLARATIONS

I, the undersigned person, declare that this M.Sc. thesis is my original work and has not been presented for a degree in any other University, and all sources of material used for this thesis have been duly acknowledged.

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Acronyms and Abbreviations

AI – After Irrigation

A.m.s.l - above mean sea level

BI – Before Irrigation

CLIMWAT 2.0- Climate Estimation Model for windows

CROPWAT 8.0 - Crop Water Requirement Estimation Model for Windows 8

DA - Development Agent

ETB – Ethiopian Birr

ETo - Reference evapo-transpiration

ETc – crop evapo-transpiration

FAO - Food and Agricultural Organization

FC – Field Capacity

FSS – Financial Self Sufficiency

GIS - Geographic Information systems

GPS - Global Positioning System

GTP - Growth and Transformation of Plan

GRI – Gross Return Investment

Ha - Hectare

IWMI - International Water Management Institute

Mha - Million Hectares

MoFED - Ministry of Finance and Economic Development

MoA - Ministry of Agriculture

NCWR – Net Crop Water Requirement

NIR – Net Irrigation ratio

NGOs - Non-Governmental Organizations

O & M - Operation and Maintenance

OPUCA - Output per Unit Command Area

OPUIA - Output per Unit Irrigated Area

OPUIS - Output per Unit Irrigation Water Supply

OPUWC - Output per Unit Water Consumed

PWP – Permanent Wilting Point

ReST – Relief Society of Tigray

RIS - Relative Irrigation Supply

RWRB – Regional Water Resource Bureau

RWS - Relative Water Supply

SIA - Sustainability irrigated area

Snnpr – Southern nation nationality and people region

SSI - Small Scale Irrigation

TAW – Total Available Water

WUA – Water Use Association

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ABSTRACT

This study tries to evaluate the performance of small scale irrigation schemes using comparative indicators at Maishawsh and Midmar schemes, Mereb Sub basin, North Ethiopia. This study area has poor water management practice and not evaluated before using *comparative performance indicators. To address the objectives of irrigation water use efficiency and on-field irrigation management performance of this study was field measurements related to canal discharge, moisture content determination of the soils, measurement of depth of water applied to the fields using two inches parshal flume, group discussion and informant interview to establish the cost of production and the price produced. The result of this study revealed that, the conveyance efficiency for Maishawsh scheme was 98.95%, 91.03%, and 75.21%, respectively for main lined, secondary lined and tertiary unlined canals of the scheme, and for Midmar scheme, it was 76.89% which was an earthen canal. The computed application, storage, distribution and overall scheme efficiency values are 60.8, 64.2, 93.40 and 46.7% for Midmar while they are 56.8, 70, 94.2 and 42.7% for Maishawsh schemes, respectively. The comparative indicators of agricultural outputs such as land productivity measured as outputs per unit command area and outputs per unit irrigated area are 3461.58 and 3512.8 US$/ha for Midmar while 3120.91 and 3032.46 US$/ha for Maishawsh respectively. The water indicators such as output per unit irrigation supply and Output per water consumed are 0.36 and 0.61 for Midmar while they are 0.25 and 0.54 US$/$m^3$ for Maishawsh schemes respectively. The water supply indicators measured by, relative water supply and relative irrigation supply gave 1.8 and 1.85 for Midmar while they are 2.29 and 2.37 for Maishawsh schemes respectively. This implied that the amount of water supplied was sufficient for the water demand of both schemes. The original irrigable and command area was declined by 2% from the actual irrigated area in Midmar scheme. However, the actual irrigated area was expanded by 3% and 6% from original irrigable and command area in Maishawsh scheme respectively. The financial indicators measured by gross return on investment and financial self sufficiency for Midmar are 91.5 and 69% while they are 91 and 77% for Maishawsh respectively. Based on this result, Midmar irrigation scheme was slightly better than Maishawsh, the reason might be good water management at field level and Midmar water users pay for what they have consumed.*

KEY WORDS*: *Performance, evaluation irrigation, comparative indicators, efficiency, slightly better, water management

1. Introduction

1.1. Background

Irrigation is expected to play a major role in the realization of Ethiopia food security and poverty alleviation strategy. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops (Awulachew et al., 2010).

The development of irrigation and agricultural water management holds significant potential to improve productivity and reduce vulnerability to climactic volatility in the country. Although Ethiopia has sufficient rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation (Awulachew et al., 2010). At present there are efforts underway to change this situation to reduce dependency on rainfall, through the introduction of various irrigation systems. According to MoFED, (2010), the irrigation sector development program stipulate to develop additional 746,335 ha of land to achieve a total irrigated land of 1.85 Mha at the end of planning period. According to Ministry of Agricultural (MoA, 2015) annual report about 2.4 Mha areas was irrigated up to the end of 2014/15 fiscal year; i.e. the actual achievement is beyond the planned one.

According to Awulachew et al. (2010), the majority of existing traditional and modern irrigation scheme is often community-based and traditional methods, covering less than 200 has. Small scale, modern and traditional irrigations are complemented by rain-fed agriculture, and the crops grown are often horticultural crops and vegetables. Small scale irrigation for food security enhancement and sustainable environment in the rural population is technologically and socio-economically demanding option. The sustainability of small scale irrigation largely depends on the technical, socio-economic, institutional and management planning.

Performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify why the scheme is performing so which in turn imply means of improvement. Of course performance evaluation needs relevant and reliable data which is rarely measured in Ethiopia (Ayana et al., 2011).

In particular Tigray Region, due to its arid climate it was hit by repeated and severe drought. It is not only the total amount of the rains, which is short, but also its spatial and temporal distribution is highly variable. In order to solve this problem construction of dams, ponds and flood diversion schemes are some of the techniques that are being carried out as an immediate solution. The Region has an estimated area of 56,000 km^2 and having a potential of 300,000 ha that is suitable for irrigation. From this only 76,319 ha has irrigated (GTP I, 2010/11). The performance of many irrigation systems is significantly under their potential due to the inefficient irrigation water management and a number of shortcomings, such as poor design and construction in the region.

Hamodo watershed is located within sub-basin of Mereb and the main support for water sources are Mhtsab tegezmati large scale dam and Wedihazo micro dam which are found in the upper catchment area. Maishawsh and Midmar small scale irrigation schemes cover an actual irrigated area of 61.75 and 23.65 ha respectively. .

It used as a bench mark for further irrigation development issues. This study aims to undertake the performance assessment of a small scale irrigation schemes in Mereb Leke Woreda especially in Maishawsh and Midmar schemes for improving the performance of the existing schemes and its sustainable utilization and attractive way for the region.

To provide the information required for design, and mainly for advising irrigators on how to improve their systems and management practices, interventions across different systems and system levels, as well as to compare various irrigation seasons and technologies with one another. And also, these indicators are small, not data-intensive and are cost-effective (Kloezen and Garces-Restrepo, 1998).

Therefore, this study will reveal the seriousness of the problem and to fill the gaps by analyzing the comparative performance indicators and to provide how to improve their irrigation efficiency and water management performance of small-scale irrigation system in Wereda Mereb leke particularly in Midmar and Maishawsh irrigation schemes.

1.2. Statements of the Problem

In Ethiopia; the performance of many irrigation systems are significantly under their potential due to a number of shortcomings, such as poor operations and maintenance (sedimentation impacts and small holders' limited skills) and inadequate structural design and constructions (Awulachew, 2010). The interventions so far made in Tigray region focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes.

Due to poor water management of the project, both at system and farm level in Tigray region has performed low and their sustainability is in question. This is resulted mainly, no reliable data on the area of small-scale irrigation schemes, as well as, a lack of knowhow to evaluate the small-scale irrigation systems. This is true in Wereda Mereb Leke, the actual irrigation management performance at field level has poor and a little/no attention has given to the evaluation of small-scale irrigation systems based on the result of the comparative performance indicators.

Therefore; this study tries to introduce the concept of comparative performance indicator as a tool to evaluate the performance of Midmar and Maishawsh irrigation schemes for better water management that can also be used as a point of entry for better irrigation water management options.

1.3. Objectives

1.3.1. General Objective

The general objective of this study is to undertake comparative performance evaluation on Mai-Shawsh and Midmar small-scale irrigation schemes in Mereb sub basin, North Ethiopia.

1.3.2. Specific objectives

I. To analyze irrigation water use efficiency performance of Midmar and Maishawsh irrigation schemes; using process indicators.

II. To evaluate on-field irrigation management performance of Midmar and Maishawsh irrigation schemes; using comparative indicators.

1.4. Research questions

- What are the main reasons for reduction of irrigation efficiency on the field?
- What are the existing statuses of Maishawsh and Midmar irrigation schemes?
- What are the main out puts and impacts of land and water productivity?

- What are the main restrictions that affect the performance of Maishawsh and Midmar irrigation schemes?

1.5. Scope of the Study

The study particularly focuses in Hamodo catchment area of the two small scale irrigation schemes. This research is done to assess the water application performance (efficiency) of irrigation system to on-field level using performance parameter indicators such as irrigation water use efficiency, water supply, an agricultural output, physical and financial indicators of irrigation management performance.

1.6. Application of this study

Irrigation could apply as a feasible solution to address the problem of food insecurity by improving agricultural production. So many researchers have done in Ethiopia by performance irrigations that set a certain indicators to evaluate irrigation systems. Furthermore, the researcher will allow recognize and characterizing the solutions that applied to manage the problems with the aim of looking for upgrading that potentially. Therefore, this research was important in identifying and understanding the current level of both irrigation schemes using comparative performance indicators and to carry out practically evaluation and provide directions for further research and development schemes that will improve the benefit from irrigation for Maishawsh and Midmar irrigation schemes.

1.7. Organization of the study

This thesis is organized in to five chapters. Chapter one deals with introduction that includes the background, the problem statement, objectives of the research, the research question, scope of the study, application and organization of this study. Chapter two explains the Literature review related to small scale irrigation performance indicators, Chapter three deals with the methods and materials used. Chapter four shows result and discussion about each comparative performance indicators. Chapter five presents with summary, conclusion and recommendations.

2. Literature Review

2.1. Irrigation

Irrigation is the artificial application of water to soil for the point of crop production. Irrigation water is supplied to increase the water available from rainfall and the contribution to soil moisture from ground water. It is a means by which agricultural production can be increased to meet the growing food demands through increasing agricultural yield, increasing the area of arable land and increasing cropping intensity. It is a socio-technical event where farmers have major controlling influence and a means by which agricultural production can be increased to meet the growing food demand through artificial means in the absence or presence of rainfall by reducing water stress on crops, (Gebremeskel, 2013).

Irrigation systems are often designed to maximize efficiencies and minimize labor and capital requirements. The most effective management practices are dependent on the type of irrigation system and its design. A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the region. Many civilizations have been dependent on irrigated agriculture to provide the basis of their society, (FAO, 1989).

2.1.1. Small Scale Irrigation in Ethiopia

Small scale irrigation schemes in Ethiopia are understood to include traditional small scale up to 100 ha and modern communal schemes up to 200 ha. Small scale irrigation is involving irrigation activities on small plots, comprising a small number of farmers, using relatively small reservoirs, river diversion, dams or a cluster of wells controlled by the farmers using technology they can operate and maintain. In highland areas like Ethiopia, where water is delivered through gravity, small scale irrigation schemes concern the upgrading of irrigation works, where the simple diversion structures, check dam ponds constructed by traditional communities with local means such as stone and brushwood (Awulachew et al., 2010).

There are 103 small and medium irrigation schemes developed in Tigray regional state. A total of 4,932.8 ha of irrigated area of which, 3,956.80 ha are from small scale and 976 ha from medium scale. The major organizations involved in irrigation development in Tigray region include: Sustainable Agricultural and Environmental Rehabilitation in Tigray (SAERT), Bureau of Agricultural and Rural Development and ReST (Musie, 2011).

According to Tilahun Amede (2014), based on the assessment of small scale irrigation schemes in case study of Burka Woldya scheme, Zatta scheme and Chelekot scheme; many do not operate at full capacity, due to design failures, too much siltation, poor agronomic and water management practices and weak local institutions have led to a loss of excesses water availability and has reduced the productivity of irrigation schemes. In addition to low returns, there is competition for irrigation water between upstream and downstream users, vegetable grower and between farmers with large irrigable plots and those with small plots.

Gebremeskel (2013), show that there is business potential for private entrepreneur involvement in irrigation. Groups of farmers or water users' associations (WUAs) running parts of irrigation schemes for which responsibility was transferred to them by government, can also be considered as operating private irrigation schemes. Generally, small-scale irrigation schemes are being promoted because of the associated benefits listed below:

- Lower investment costs
- No difficulty to maintenance
- End-users being able to have more control of the water they need
- The chance of remote areas gaining access to controlled water
- Small-scale irrigation requires very little in terms of management capability
- Their potentially less negative environmental impact. Small-scale irrigation (those schemes under the direct management of smallholders).

2.1.2. Performance Evaluation of Irrigation schemes

Evaluation of performance of irrigation schemes have been undertaken mostly from collective water management experienced diverse problems in different type of systems, which determined the strong role of technical criteria in the development of irrigation schemes (Bos et al, 2005). In this context, water balances have been at the core of the evaluation of performances, focusing mainly in the efficiency of water delivery in irrigation and in water productivity. Furthermore, efficiency of water conveyance has been deeply studied, developing indicators to analyze accurately water distribution and field application in order to minimize water losses and optimize its use (Javier R., 2013).

The performance of the schemes varied with the quality of the scheme design, experience of the communities in irrigation agriculture, access to reliable markets, the level of institutional support by government institutions and organizational capacity of the respective communities (Tilahun, 2014).

Ayana and Bekele (2006), in the case study of South, East and Central parts of Ethiopia concluded that, the assessment of irrigation performance in seven irrigation schemes using output of land and water comparative performance indicators resulted that there is a tremendous difference between the schemes in their output performance of sugar cane and cotton. The values were higher and lower outputs per units of land and water respectively. In both researchers were true even for the same cropping and management types, due to the conditions of the irrigation infrastructure, inadequate management capacity and skills, lack of proper operation and on-farm water management practices and procedures, lack of incentives and hence low motivation to improve performance.

According to Ayana and Bekele (2011), to evaluate irrigation efficiencies of small scale schemes 86.5% of the 312 irrigation schemes in Ethiopia were operational during the study period. However, not all functional schemes were operating at full capacity, i.e. serving less than the planned command area. As a result, only 74% of the command area was cultivated with irrigated crops, while 26% of the created irrigation potential was underutilized.

Much of the work in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration and flow rate of water; area irrigated and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of systems management and performance is not adequate, either the process must be changed to reach the target or the target itself must be changed (Molden et al., 1998).

2.1.3. Challenges of Performance Irrigation Management

Small scale irrigation has enormous potential to get better the income of poor rural households in developing countries like Ethiopia. However, the performance and effectiveness of both traditional and formal small scale irrigation schemes are constrained by multidimensional problems ranging from individual farmers' outlook to institutional arrangements (Gebremeskel, 2013).

Gebremedhin (2015), can be explained as technical constraints and knowledge gaps are identified. The main challenges for the development of irrigation in Ethiopia are listed below.

- Inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities,
- Insufficient knowledge on improved and expanded irrigation agronomic practices,
- Shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods
- Scheme based approach rather than area/catchments based approach for the development of SSI schemes,
- Inadequate baseline data and information on the development of water resources,
- Lack of experience in design, construction and supervision of quality irrigation projects,
- Low productivity of existing irrigation schemes,
- Inadequate community involvement and consultation in scheme planning construction and implementation of irrigation development,
- Poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers.

2.1.4. Attributes of Performance Indicators

A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It additional should contain information that enables the manager to determine if the deviation is acceptable. Some of the desirable attributes of performance indicators recommended by (Bos, 1997) are:

Scientific basis: The indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes.

The indicators must be quantifiable: The data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible.

Reference to a target value: This is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values and their margin of deviation should be related to the level of technology and management.

Provide information without bias: Ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments.

Ease of use and cost effectiveness: Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources.

2.1.5. Process Performance Indicators

Process performance indicators are assessed for a variety of reasons: to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints, to better understand determinants of performance and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity. Process measures refer to the processes internal to the system that lead to the ultimate output, where as output measures describe the quality and quantity of the outputs where they become available to the next higher system (Molden et al., 1998).

Kloezen and Garce-Restrep (1998) has summarized the actual performance to system-specific management targets relative to goals established by irrigation managers. The process indicators help system managers to monitor the quality of daily and seasonal operational performance.

Numerous studies focus on the definition of a number of process indicators. Common indicators defined in the literature include:

Reliability and dependability of water distribution: This suggests that at the start of the season, WUAs know how much water will be delivered to them. Establishment of a hydraulic committee at the district level, in which WUAs participate, has given the modules an effective means to monitor the actual supplies against the concessional and assigned volumes.

Equity or spatial uniformity of water distribution: Daily measurements at selected canal and field levels indicate that all farmers receive sufficient water to meet crop requirements. While some variation in spatial distribution exists, there is no bias due to user location (head-middle-tail) within the irrigation network. The reason for this is that farmers closely monitor that they receive the irrigation service they have requested and paid for. At on-farm level, personal interactions between users and ditch tenders play a significant role since this determines both flow size and number of hours that a particular plot may get water.

Adequacy (sufficient) of irrigation delivery: On-field flow measurements point to high adequacy of water at the field level. The way irrigation deliveries are reported by ditch tenders blurs this high adequacy in official reports. Generally, ditch tenders underreport the volumes distributed to farmers. Furthermore, reported volumes are roughly calculated or even calculated using the planned water depth as a reference. As these reported volumes are the basis of the monitoring of water management from the field up to the district level, this practice has considerable consequences for the quality of the performance monitoring done.

Flexibility and timeliness: The hydraulic committee decides on the dates of the opening and closing of the gates. Farmers schedule their irrigation around these days. These irrigation periods are long enough to provide for flexible scheduling within these periods. This is certainly the case under the arranged scheduling arrangement in scheme, in which farmers request and pay for an irrigation service to be provided on a certain day.

Generally, the objective of this assessment improved to be useful as they provide important information about process operational performance processes of the particular systems where the indicators were applied.

2.1.6. Comparative Performance Indicators

Molden et al. (1998), have suggested that, nine comparative performance indicators: agricultural output such as output per unit command area, output per unit irrigated area, output per unit water supply and output per unit water consumed, water supply indicators such as relative water supply, relative irrigation supply and water delivery capacity, and financial indicators of gross return investment and financial self sufficiency. There are also, Eticha (2011), summarized that, the internal performance indicators, such as conveyance, application, storage, distribution and the overall scheme efficiency and those indicators resolved the efficiency which the water is conveyed through the canal, how irrigation is applied to the field, how sufficient the amount is and how the application is uniformly applied to the field.

The comparative indicators depend on the availability of data. Getting complete data to calculate all the external indicators (the agricultural output, water supply, financial and physical indicators) for each small-scale irrigation project was not easy. To compare irrigation schemes, minimum sets of external indicators were applied with the available information and comparative analyses was made within and across the irrigation projects (Yusuf, 2004). However for this study the following indicators have been selected:

2.1.6.1. Irrigation water use efficiencies

I. Conveyance efficiency (Ec)

This is the total amount of water flowing in to a canal system at a point divided by the amount of water reaching a certain distance downstream of the previous point. It measures the efficiency of the canal system to convey water and shows the amount of water loss over a given travel distance. Ec was measured using floating methods in which the water flow velocity in the known cross-sectional areas of the canal system and the discharge computed as the product of velocity and canal cross-sectional area, (Ayana and Bekele, 2011).

The concept of conveyance efficiency viewed as the evaluation of the water balance of the main, lateral and sub-lateral canals and related structures of the irrigation system. It was one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources. The amount lost depends on quality of operation and maintenance and the nature of the soil that affects the seepage rate, (Bos, 1997).

The most important reasons for the failure of schemes are lack of capacity for regularly maintaining the schemes and weak institutional arrangements in planning and transferring schemes to the end users, followed by sedimentation of weirs and canals. Most of the secondary and tertiary canals were not lined and hence there were a higher loss of irrigation water before reaching the fields. This shows there was reduced the conveyance efficiency of the schemes (Ayana and Bekele, 2011).

According to Yewendwosen and Zinabu (2015), the Case Study of Wondogenet, Southern region, Ethiopia, the conveyance efficiency was decreasing in the order of the main canal, secondary and tertiary canals. The lower conveyance efficiency of secondary and tertiary canals could be due to high infiltration rate of the soil. This also shows there is high water loss in the scheme due to excessive percolation.

There are also, Atinkut et al. (2005), the case studies of Haiba; Meala and Mainugus irrigation projects concluded that the conveyance efficiency of Meila is better than the rest two. This is probably related with the quality of the canal works in Meila project. The fact tells that the canals in both Haiba and Ma'nugus are Ponding excessive water. This may be the most probable reason for this large water loss was due to the slope of canal. It is known that great amount of water is lost in unlined canal but it becomes considerable when the canals are not well designed and constructed appropriately.

II. Application efficiency (E_a)

Losses from the field occur as deep percolation and as field tail water or runoff and reduce the application efficiency. To compute application efficiency it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, i.e. the amount of under-irrigation in the soil profile must be determined as well as the losses (FAO, 1989).

According to Yewendwosen and Zinabu (2015), the application efficiency in the command area of Wondogenet, Snnpr, Ethiopia was low. This was due to the amount of water applied during the crop's growing period was more than the crop's requirement, which indicates that much amount of water is being wasted due to poor irrigation water management practice.

According to Roger et al (1997), methods of determining application efficiency of a specific irrigation system is generally time consuming and often difficult because it may vary in time due to changing soil, crop and climatic condition. If the length of run is long, the application efficiency is very low. This will indicate low irrigation efficiency and the water is being wasted as a result of deep percolation.

III. Storage efficiency (E_r)

The storage efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone during irrigation. The value of storage efficiency is important when either the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs and storage efficiency become important when water supplies are limited, (FAO, 1989).

Jibril et al. (2017) suggests that, the storage efficiency is very poor; it was observed that the soil at the project site was mainly sandy loam which has a low water holding capacity, excessive seepage loss form part of the problems. About 1680 mm of water needed by rice 1200 mm (70%) was lost due to the soil at the project site was mainly sandy loam which has a low water holding capacity, excessive seepage loss form part of the problems. However, Yewendwosen and Zinabu (2015), the average water storage efficiency of Wondogenet scheme is 94.96%. It is possible to say that the water applied would successfully meet the root zone moisture content at field capacity.

IV. Distribution Efficiency (D_U)

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a water front will advance at a monotonically decreasing rate until it reaches the end of the field.

D_U which is the minimum depth divided by the average depth. Thus, the evaluator can choose one that fits his/her but it should be clear as to which one is being used (FAO, 1989).

Effective water distribution was obtainable because of good canal layout, each plot in blocks were given adequate time to receive water. Poor management of available water for irrigation both at system and farm levels has led to a range of problems and further aggravated water availability and has reduced the benefit of irrigation investments (Jibril et al., 2017).

2.1.6.2. Agricultural output indicators

According to Lakmali et al. (2015) this gives the information on yield per unit area per season and shows the potential of that land production under set of environmental and other supplementary input services. The relative yield indicator gives the ability of a particular system to produce over the expected yield at optimum conditions. When the water is a scarce resource, agricultural productivity per unit water delivered, as indicated by water productivity, gives a good picture on performance of the system with respect to production.

According to Zeleke et al. (2012), in the case study of Golgota and Wedecha scheme in central Ethiopia, the results of performance with respect to both land and water productivity. In terms of land productivity, Golgota Scheme could be used as a benchmark in the region because farmers invest more on their lands when reliability of water is high and when they get larger landholding and Godino Sub-system of Wedecha Scheme has better water productivity because water is released by government agency and farmers make wise use of it. It is a good example to be benchmarked in the region for water productivity improvement activities.

2.1.6.3. Water Supply Indicators

Water use indicator is a measure of efficiency of water use for a defined user type with specified boundaries, and is expressed without unit (i.e. as a percentage) requiring the formulation of the net and gross amount of water utilized for the activity under study. This explains efficiency of different uses/users in an irrigation system of which there can be many and they may differ in demand of water for the same activity (Magayane et al., 2004).

I. Relative Water Supply (RWS): The RWS is the proportion of total water supplied (irrigation plus rainfall) to the total crop demand. This indicator used both at measurement of adequacy and seasonal timeliness. The value of relative water supply nearest to one but not more than one indicates the total water supply is enough to meet the demand. Higher value of RWS indicates that there is excess water supply. It signifies whether the water supply is in short or in excess of demand (Molden et al., 1998).

II. Relative Irrigation Supply: This is the ratio of total irrigation supply to total irrigation demand. Irrigation water is scarce resource in many irrigation schemes and is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance in relation to irrigation demand. It is given by (Molden et al., 1998).

2.1.6.4. Physical indicators

I. Irrigation Ratio: This is the ratio of currently irrigated area to irrigable command (nominal) area. Expansion or contractions of irrigated areas are attributed to water management responsibilities and reliability of irrigation water supply.

Zeleke et al., (2012), in case study of Golgota and Wedecha irrigation schemes reported that, greater irrigation ratio at Golgota due to, generous water availability, absence of irrigation water fee and better land productivity encouraging farmers to invest on more areas. However, lower irrigation ratio at Wedecha irrigation scheme Godino Sub-system is attributed to lower reliability of irrigation flows during some months of the year, irrigation water fee charged by the regional irrigation authority and relatively lower land productivity compared to Golgota Scheme.

Eticha (2011) in case study of Haleku and Dodicha concluded that, the irrigation ratio for the Haleku irrigation scheme was 1.00, which means that total command area of the scheme was under irrigation during the study period, but the irrigation ratio of Dodicha irrigation scheme was 59% which means about 41% of irrigated area of the scheme was contracted from the command area. The evaluator concluded that, farmers have weak institutional set up of water use association at the scheme.

II. Sustainability of Irrigation Area: The ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the condition of the irrigation systems either contracted or expanded (Bos, 1997)

Solomon (2016) in case study of Jari and Aloma concluded that; sustainability of Jari irrigation scheme is under risk and the irrigable area has been contracting from the original area. The main reason has too much flooding and the cutoff drain was broken. While in Aloma irrigation scheme water shortage, structural failure and farmer's low attitude for irrigation agricultural development were the main cause. This many create social, economical and political problem in both study area.

2.1.6.5. Financial Indicators

I. Gross Return on Investment: The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development. Therefore, this indicator considers the present production and the original total cost of infrastructure for each scheme.

According to Yusuf (2004), the values indicate at Doni has higher rate of return on investment than Batu Degaga. The possible reason for lower GRI value of Batu is that large irrigable area is reduced from the project due to low pump capacity. The water distribution structures of the project are designed and constructed for 140 ha land but the actual irrigable area is only 60 ha.

II. Financial Self Sufficiency: According to Imgle et al. (2015), the revenue from irrigation service fee was taken as irrigation water charges. The financial self sufficiency represents the collection of fees from water users either sufficient or insufficient for operation and maintenance cost. If government supports for operation and maintenance heavily, financial self-sufficiency would be low, whereas if local farmers through their fees pay for most of the O & M expenditures, financial self-sufficiency would be high. Financial self-sufficiency does not tell us the O & M requirement, only the expenditures. A high value of financial self sufficiency does not automatically indicate a sustainable system as the O & M expenditures might be too low to meet the actual maintenance needs (Molden et al., 1998).

3. Materials and Methods

3.1. Description the study area

3.1.1. Location

The project areas are located in the northern part of Ethiopia in the regional state of Tigray, in Mereb sub-basin specifically located in Hamodo catchment at altitude range of 1351 and 1386 m above sea level Maishawsh and Midmar schemes respectively. Maishawsh and Midmar schemes are located at a distance of 3 km north and 3.5 km south from Rama town respectively, having geographic coordinates of 477763 E and 1592894 N for Maishawsh while 478342 and 1590073 N for Midmar scheme and they are accessible through the Adwa - Rama gravel road. The irrigation schemes included in the study were Midmar scheme with actual irrigated area of 23.65 ha while Maishawsh scheme with 61.75 ha irrigated.

Maishawsh scheme used diversion weir and Midmar irrigation scheme used electrical motor pump to draw water from the check dam pond and this river drain into the main river of Maishawsh. Maishawsh and Midmar irrigation schemes are located in the same watershed.

3.1.2. Drainage System

The Hamodo catchment comprises the drainage areas, Maydaro, Adiberak and Ahsea. The size of the Hamodo catchment area was determined by GIS and the size of the drainage area has been estimated to be 315.4 km^2 as indicated Figure 3.1.

Hamodo catchment is sub-basin of Mereb, which drains to River Mereb and a river flowing to Red Sea by crossing Eritrea. Hamodo catchment is surrounded on the south by Aseb and on the north by Mereb river basins. The currently irrigated area of each scheme was determined by delineating the boundary of the command area using Google earth professional and global mapper was taken during digitizing the shape of the catchment area created. Then added to ArcGIS where the boundaries were plotted and the areas determined.

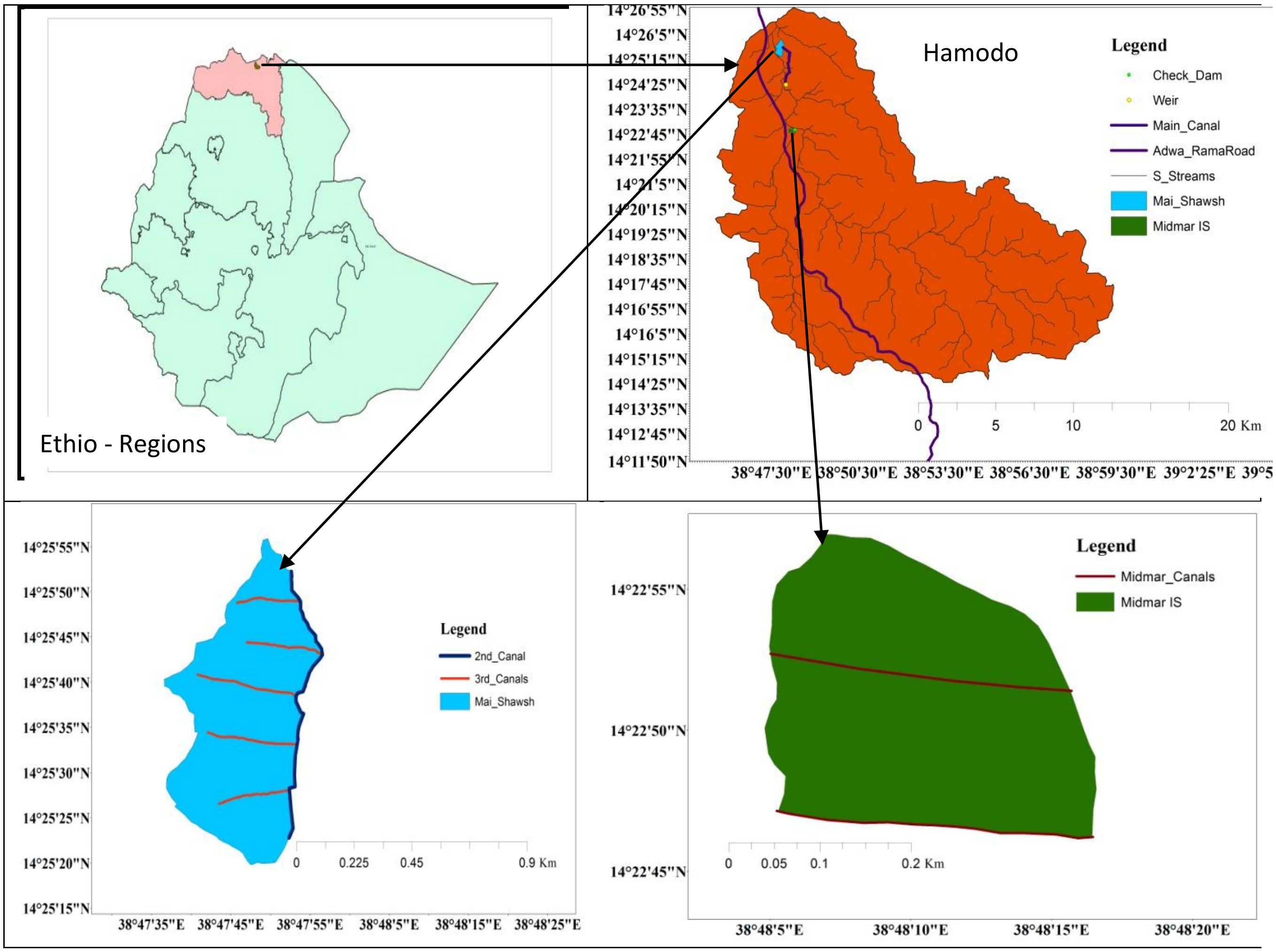


Figure 3.1: Map of the study area, canal net work and drainage system

3.1.3. Climate

The area has a rainy season during summer from June to August, but the remaining months are almost dry. The climate data for rainfall was collected from National meteorological agency Mekele branch Rama station. The maximum and minimum temperature, relative humidity, wind speed and sunshine hours of the climate data were estimated by CLIMWAT 2.0 software, because there was no available climate data in the study area.

The mean maximum monthly temperature of the watershed varies between 23.2 to 30.10 ^{0}C and the mean minimum varies 6.50 to 14.60^{0}C. The average annual rainfall is about 650.13 mm. The monthly relative humidity varies between 60 to 97%. The wind speed varies from 95 km/day in December to 155 km/day in October. The sunshine hours varies between 5.0 hr/day in August to 10.40 hr/day in May. The average annual ETo of the study area was 4.09 mm/day, see Appendix 2, Table 1 and 2.

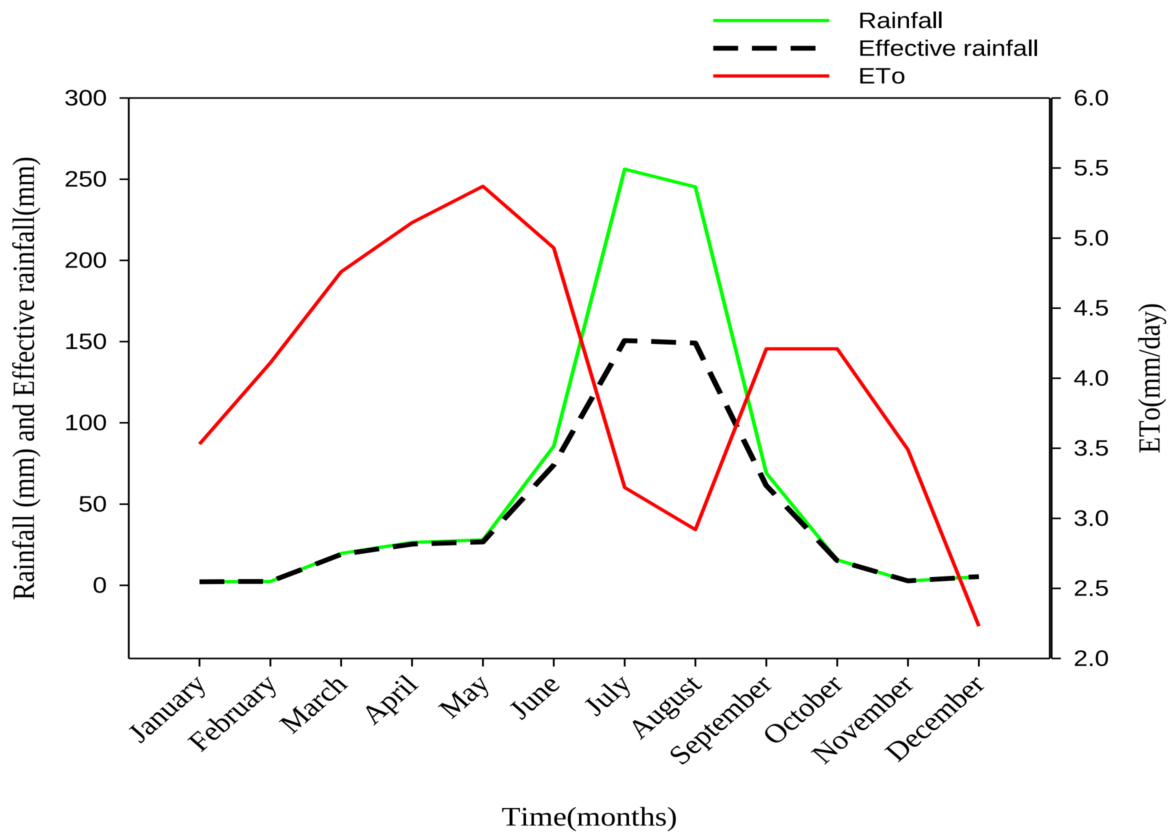


Figure 3.2: Rain fall, Effective rain fall and ET_o for Maishawsh and Midmar schemes

3.1.4. Status of Irrigation Schemes

3.1.4.1. Midmar small scale irrigation scheme

Midmar SSI scheme was constructed in 2013 by Non-Governmental Organization (NGO) called Relief Society of Tigray (ReST) and only gave a service for 4 years. The irrigation scheme has total household beneficiaries of 36 (27 Male and 9 Female). The designed command area of Midmar scheme was 24 ha, however currently 23.65 ha is irrigated, but only 0.35 ha was contracted from the command area, due to the restriction of pump capacity. The actual average discharge of electrical pump and the river were 35.835 & 29.6 liters per second respectively. Since the discharge of pump was greater than the river discharge, therefore; water was stored at night using pond made with Check dam in order to meet crop water demand.

Figure 3.3: Midmar water storage at night time

Table 3.1: Water storage required at night time

	Discharge (lit/sec)					Storage required (V) (m^3)	
	Pump (q_1)	River (q_2)	Difference ($q_i = q_2 - q_1$)	Cumulative ($Q = q_i + q_{i-1}$)	Time (T) (min)	At each interval (V = Q*T)	Max.
Night storage	0	29.6	29.6	29.6	60	106.56	
	0	29.6	29.6	59.2	120	213.12	
	0	29.6	29.6	88.8	180	319.68	
	0	29.6	29.6	118.4	240	426.24	
	0	29.6	29.6	148	300	532.8	
	0	29.6	29.6	177.6	360	639.36	
	0	29.6	29.6	207.2	420	745.92	
	0	29.6	29.6	236.8	480	852.48	
	0	29.6	29.6	266.4	540	959.04	
	0	29.6	29.6	296	600	1065.6	
	0	29.6	29.6	325.6	660	1172.16	
	0	29.6	29.6	355.2	720	1278.7	1278.7
Day time	35.835	29.6	-6.235	348.965	780	1256.27	
	35.835	29.6	-6.235	342.73	840	1233.83	
	35.835	29.6	-6.235	336.495	900	1211.38	
	35.835	29.6	-6.235	330.26	960	1188.94	
	35.835	29.6	-6.235	324.025	1020	1166.49	
	35.835	29.6	-6.235	317.79	1080	1144.04	
	35.835	29.6	-6.235	311.555	1140	1121.60	
	35.835	29.6	-6.235	305.32	1200	1099.15	
	35.835	29.6	-6.235	299.085	1260	1076.71	
	35.835	29.6	-6.235	292.85	1320	1054.26	
	35.835	29.6	-6.235	286.615	1380	1031.81	
	35.835	29.6	-6.235	280.38	1440	1009.37	1009.4

The maximum water storage at night time from river flow was 1,278.72 m^3 as indicated in Table 3.2 and Figure 3.4. But, the capacity of pump at day time was charged 1,548.07 m^3 of water for 12 hours, therefore, at day time the capacity of pump was better than the river flow by 269.35 m^3 and this volume of water could be taken from the water storage at night time. But the remaining 1009.37 m^3 of water was over flow to the downstream beneficiary.

Each beneficiary household charges, 10 birr per hour per 129 m^3 of water during irrigated, 150 birr per season and 120 birr per season, for the electric power consumption, for pump operation and maintenance and for administration of pump respectively. The rotational irrigation schedule has been practiced in the irrigation scheme and most of the time it takes about 5 days for one cycle or rotation.

3.1.5.2. Maishawsh small scale irrigation scheme

Maishawsh SSI was constructed in 2013 by Tigray Regional Water Resource Bureau (RWRB) and it has given only four year service. The irrigation scheme has total household beneficiaries of 87 (72 Male and 15 Female). The designed command area to be irrigated was 60 ha, however, currently 61.75 ha is irrigated, but the actual irrigated area, only 1.75 ha was increased from command area due to the construction of large scale dam in the upper part of the catchment.

The main canal has total length of about 2.5 km and has two secondary canals constructed with lined masonry and each canal has an average length of 550 m. Usual observation made during data collection the main and secondary canals were in good condition; but the tertiary canal was earthen type, and suitable for water loss by percolation. This scheme utilized stone/soil for controlling water at division box. The beneficiary of Maishawsh irrigation scheme was charged, 50 birr per household per season for the operation and maintenance. The same with Midmar scheme, the rotational irrigation schedule has been practiced in this scheme.

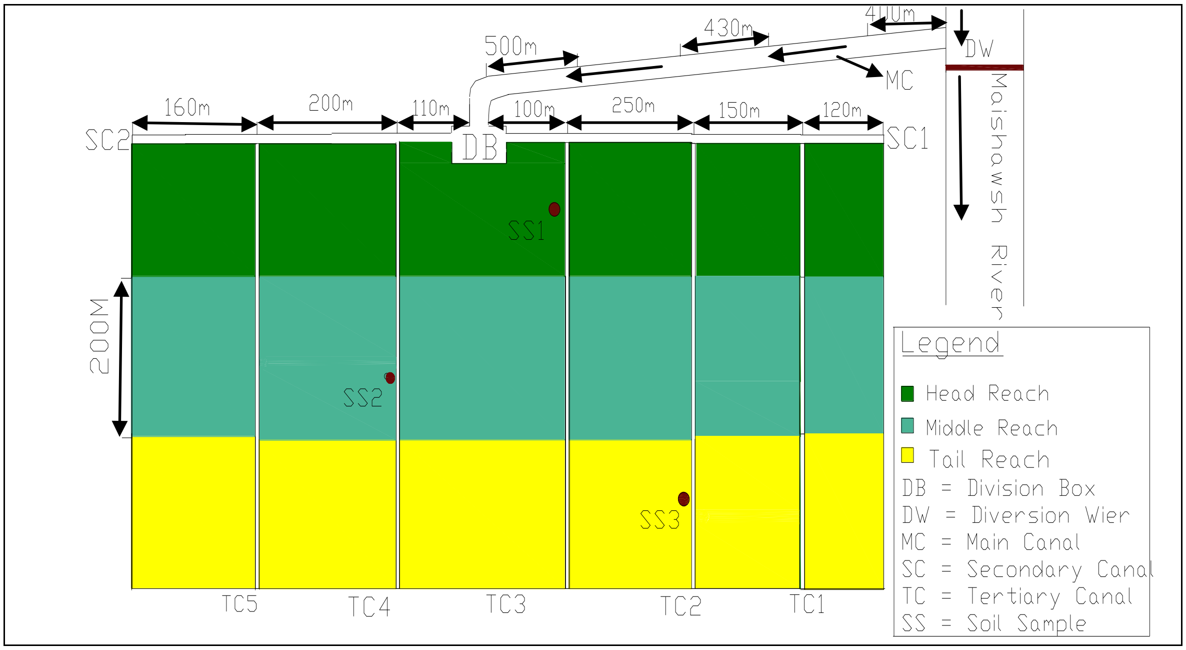
3.3. Field Layout, Crop Selection and Experimental design

In order to evaluate the irrigation water use efficiency of the individual performance indicators at field level and compare it, three farmers' fields were selected at head, middle and tail end of each irrigation schemes. For both schemes, six soil samples were taken before and after irrigation from 0 – 30 cm and 30 – 60 cm depths, but it's difficult by economically more than six soil sample pit was taken. Fields (head, middle and tail), were selected according to crop type, water management practices and willingness of the farmers in both schemes.

Groundnut, tomato and onion are regular crops in both irrigation schemes, but, onion was a major grown crops in both study area, which was growers' farmers were selected. Therefore, onion was the dominant and representative crop in which most farms were covered with it because it has production potential and good market in the area.

The discharge of inflow and outflow in the canal was measuring at specific reaches using floated method to estimate conveyance efficiency and losses from the open ditches. Selection of the representative canals done based on slope, canal type and their shape in the field. Maishawsh irrigation scheme; contains 2.5 km length of main canal, 2 secondary canals an average length of 0.55 km and 5 tertiary canals, whereas in Midmar irrigation scheme has two earthen canals contains 200 meter of length for each was measured, as indicated in Figure 3.5.

A). Maishawsh Irrigation scheme



B). Midmar Irrigation scheme

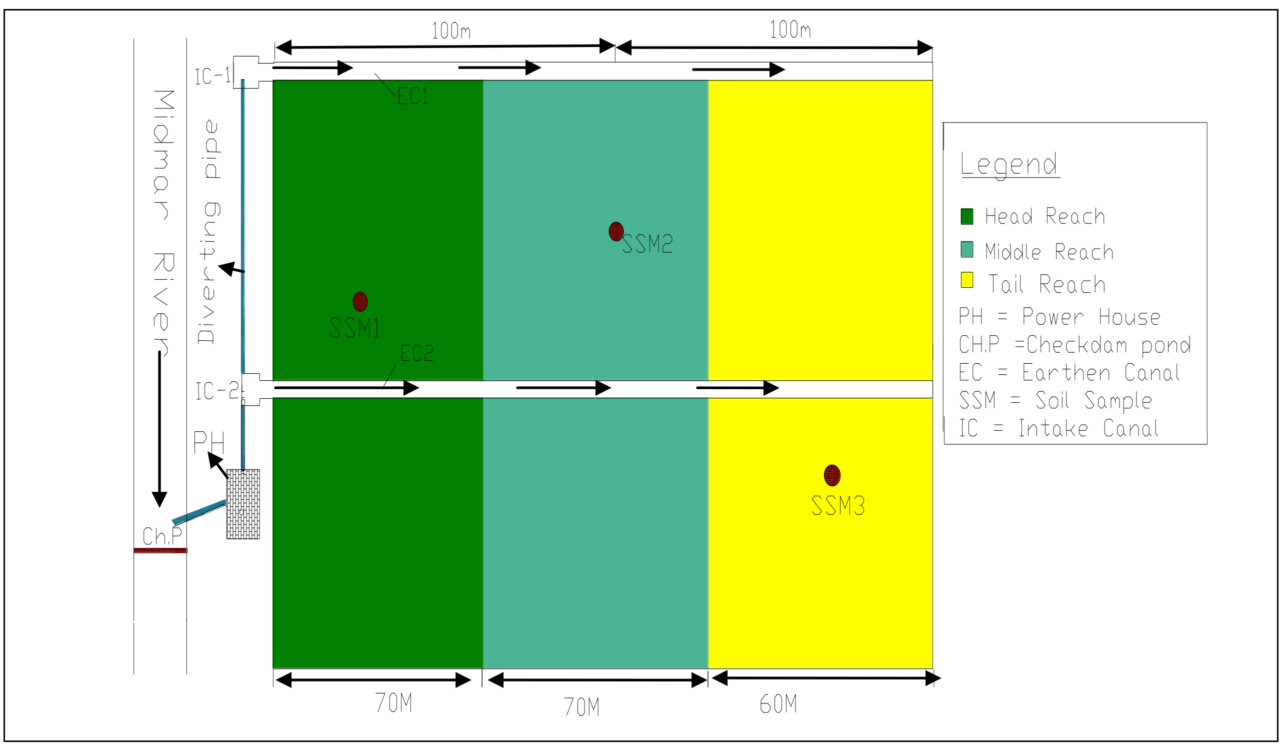


Figure 3.4**: Field layout and water flow rate measurement (not scaled)**

3.4. Data Collection and Analysis

3.4.1. Materials used for data collection

In this study, all the necessary secondary data were collected from the wereda's agricultural office, Tigray regional water resource development bureau and Relief society of Tigray. Moreover, some discussions and interviews also made with farmers and the DA,s of the area to cross check the secondary data obtained. During the field data collection and measurement processes; floated method, double ring infitro-Meter, Auger for soil sampler, Tape Meter, Cutthoat parshal flumes and GPS were used in both schemes.

Data Collection and analysis for Mai-shawsh and Midmar Irrigation schemes

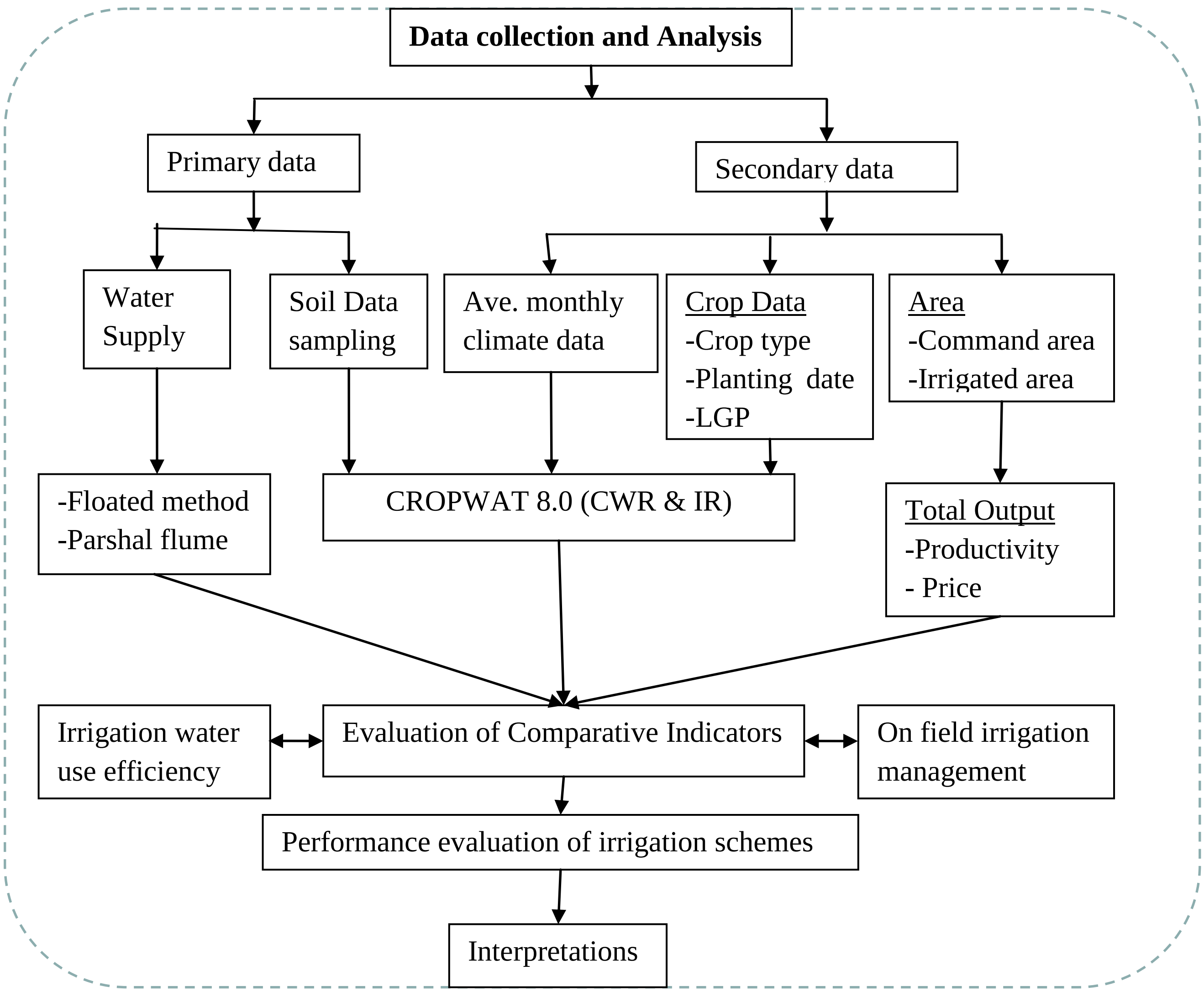


Figure 3.5: Flow chart showing data source, methodology and Interpretations

3.4.1.1. Primary data collection

Primary data was collected through daily field observation approaches, field measurements related to canal water flows, household surveys to establish the cost of production and the price and for cross comparison and analysis.

1. Soil Sampling

To investigate the soil texture, moisture content of before and after irrigation determination, moisture content of the soil at field capacity (FC) and permanent wilting point (PWP) were computed through laboratory analysis.

(i) Texture

Soil texture is the relative proportion of sand, silt, and clay, the texture of soil is analyzed by using hydrometric method and the result cross check with the soil textural classes were determining using USDA soil textural triangle (Bouyoucos, 1951). To determined the soil texture classes, 12 undisturbed soil samples were collected with auger from the profiles pit excavated at three locations (upper, middle, and tail of the scheme) up to a depth of 60 cm based on effective root depth of onion at the 30 cm depth intervals from both schemes, then the values have been computed through laboratory working procedures in Shire research center. The procedures of hydrometric method for determining of each proportion as follows;

Dispersing Solution

Dissolve 40 g sodium hexametaphosphate [$(NaPO_3)_{13}$] (an effective dispersing agent for the soil particles in diluting water and formed a soil suspension), bring in to 1-L volume of diluting water. This solution dissolved with Weigh 50 g of dry soil.

Determination of Silt plus Clay: Mix suspension in the hydrometer jar, using a special paddle carefully, withdraw the paddle and immediately insert the hydrometer. Disperse any froth, if needed, with one drop of amyl alcohol, and take hydrometer reading 40 seconds after withdrawing the paddle. This gives reading silt clay proportion.

Determination of Clay: Mix suspension in the hydrometer jar with paddle; withdraw the paddle, leave the suspension undisturbed and after 4 hour, insert the hydrometer, and take hydrometer reading this give clay proportion.

Determination of Sand: after taking readings required for clay and silt, pour suspension quantitatively through a 50 μm sieve and wash the sieve until the water passing the sieve is clear. Transfer the sand quantitatively from sieve to a 50 mL beaker of known weight, allow the sand in the beaker to settle, and decant excess water. Dry beaker with sand overnight at 105 °C and Cool in a desiccator's then re-weigh the beaker with sand.

Generally the hydrometer method of silt and clay measurement relies in the effect of particle size on the differential settling velocities within a water column. By this method (using Hydrometer with Bouyoucos scale in gram/lit) after 40 second all sand-sized particles (0.05 mm and larger) settle out of the suspension and after 4 hr, particles larger than clay (0.002 mm) settle out of the suspension, (Bouyoucos, 1951).

(ii) Field capacity, permanent wilting point and moisture content determination

The moisture content of the soil at Field capacity (FC) and Permanent Wilting Point (PWP) of 12 disturbed soil samples were collected from both schemes of the selected profiles pit excavated at three locations (head, middle and tail of the scheme) of 0 – 30 cm and 30 – 60 cm depths. The soil samples were taken to the soil laboratory of Addis-Ababa water works design and supervision enterprise for the intended analysis.

Then, the soil samples were saturated all the soil pore spaces filled with water, then enter to the pressure plate of 1/3 bar and 15 bar were applied for Field capacity (FC) and Permanent Wilting Point (PWP), respectively.

The soil moisture content measurements were made by gravimetric method which involves collecting soil samples from both schemes with Auger for each 30 cm depths of interval weighing the wet soil samples, removing the water by drying in an oven at 105 ^{0}C for 24 hours and re-weighing the dry soil samples to determine the amount of water removed. For both schemes, before irrigation and three days after irrigation 24 undisturbed soil samples were taken from 0 - 30 cm and 30 – 60 cm depths, the values have been computed through laboratory working procedures in Shire research center. Soil moisture content in each sample was determined on weight basis using the equation, (George, et al., 2013).

$$\theta_{dw} = \frac{W_{ws} * W_{ds}}{W_{ds}} * 100 \qquad (3.1)$$

Where, θ_{dw} is the soil moisture content on weight basis (%)

W_{ws} is the weight of the wet soil sample (gram),

W_{ds} is the weight of the soil sample after oven drying (gram)

For the determination of total available water (TAW) amount in the soil; field capacity (FC) and Permanent wilting point (PWP) of the soil was determined by taking soil samples from the selected fields. The total available soil moisture for the plant is between FC and PWP. TAW is the total amount of water a crop can extract from its root zone, (FAO, 1989):

TAW (mm) = 1000 * (FC - PWP)*Z_r … ……………………………………………..…..(3.2)

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

FC is moisture content at field capacity (%),

PWP is the moisture content at permanent wilting capacity (%) and

Z_r is the root depth (m).

(iii) Infiltration Rate

The soil intake rate is measured directly by observing the rate at which the water level declined with respect to time. The soil infiltration rate was characterized by using double ring infiltro-meter tools. Infiltration was a process of downward movement of water into the soil through soil surface. This phenomenon has a greater practical importance in irrigation. The volume of water passing through a unit cross sectional area per unit time flowing into the soil profile was termed as infiltration rate (FAO, 1989).

Figure 3.6: Measurement of infiltration rate

Generally, the rate of decrease was rapid initially and the infiltration rate tends to approach a constant value at a certain time. The nearly constant infiltration rate that reaches after some lapsed time from start of irrigation is termed as the basic infiltration rate, as shown in Figure 3.6 and Table 4.4.

3. Flow rate measurement

Flow rate measurement was a computation of conveyance efficiency and water losses of the scheme through floated method and cutthroat flume flow rate measurement equipments were used. For float method straight and regular reach of intake having a certain lengths based on the slope of canal was selected and then dropped the float material and recording the time from float starting to move down stream until it reached the marked length of the canal, as shown in Figure 3.7. The flow rate measurement using float method for the main canal, of the two schemes to compute the lost and amount of diverted.

The discharge amount would be equal to the product of the mean velocity (V_{mean}) and the area of the cross-section (A). The width of the main canal was equal from the intake to the beginning of secondary canal and the flow depth was measured at each division. The mean flow velocity was calculated the average velocity multiplying by 0.85. A coefficient of 0.85 is commonly used to convert surface velocity to mean velocity in each vertical. The discharge (Q), in each section of the canal could be determined by multiplying the area of the section by the mean flow velocity in that section, (Jason, 2011).

The cross-section area in each selected of canals was calculated by;

$$A = b * \left(\frac{d_1 + d_2}{2} \right) \text{--(3.3)}$$

$$V_{mean} = 0.85 * V_{average} \text{--(3.4)}$$

The flow discharge (Q))(m^3/s) in the canal was calculated using the formula below;

$$Q = A * V_{mean} \text{--(3.5)}$$

Where, b = width of canal (m), d = flow depth at inflow and outflow for each section, V_{mean} = mean flow velocity (m/sec) and $V_{average}$ = average flow velocity (m/sec)

The computation was carried out in similar procedure like main canal. For the case of Maishawsh SSI scheme flow rate was measured at 2 Secondary canals and 5 tertiary unlined canals. While in Midmar SSI scheme flow rates was measured at main earthen canal in 100 m length for each.

Measurement of canal reach

Following of floating material

Figure 3.7: Flow rate measurement by floated method,

To determine the depth of water at field inlets measurements were taken by cutthroat Flumes from sampled farmers' plots. Totally six farmers' plots were selected purposively from farmers that has been selected for interview at each canal reaches (head, middle and tail) at both schemes.

The cutthroat flumes used for this study has a maximum capacity of 4.81 lit/sec. The depth of flow in the flumes is measured in meter from its graduated wall and the discharge was calculated based on the following formula, (du, Quebee, 2007).

$Q_f = CH^n$ ……………………………………………………………………………...(3.6)

Where, Q_f is discharge for free flow condition (m^3/sec); C is free flow coefficient; n is exponents for free condition and H is water depth measured in the parshal flume (m). The value of C = 0.1207 and n = 1.55, are used for 2 inch width of Parshall flume set on field to estimate water depth. Figure 3.8 shows installation and reading of the depth of water from parshal flume.

	
Installation of parshal flume	Reading of depth
	
Recording of time during irrigated	Time recording at the end of the field

Figure 3.8: Measurement of Flow rate in field through Parshal flume

3.4.1.2. Secondary data collection

Secondary data were collected from the design documents for each irrigation project from Regional Water resource bureau and ReST. The secondary data included total yield, prices of irrigated crops, area irrigated per crop per season, crop type, production cost per season and cropping pattern for the two schemes. The rainfall data was collected from National meteorological agency Mekele branch Rama station for 14 years and the remains data such as minimum and maximum temperature, relative humidity, wind speed and sunshine hours were estimated from CLIMWAT 2.0 software, due to the absence of available climate data in the study area.

3.4.2. Data Analysis

3.4.2.1. Determination of Crop and Irrigation Water Requirement

CROPWAT 8.0 computer program; is a practical tool to carry out standard calculations for reference evapotranspiration, effective rain fall, crop water requirement and irrigation requirements (Joss, 2010).

Reference Crop Evapotranspiration (ETo); values measured or calculated using CROPWAT 8.0 model based on monthly climatic data: minimum and maximum air temperature, relative humidity, sunshine hours and wind speed;

Effective Rainfall (E_{ff} .R); computed based on monthly rain fall and effective rainfall refers to that portion of rainfall that can effectively be used by plants. This is to say that not all rain is available to the crops as some is lost through runoff and deep percolation. How much water actually infiltrates the soil depends on soil type, slope, crop canopy and the initial soils water content.

Crop water requirements (CWR); include the total amount of water used in evapotranspiration. CWR defined as ‘the depth of water needed to meet the water loss through evapotranspiration of a crop. The model needs climatic, crop type, infiltration rate and soil data for the determination of crop water requirement. The values of ETc and CWR (Crop Water Requirements) are identical, where by ETc refers to the amount of water lost through evapotranspiration and CWR refers to the amount of water that is needed to compensate for the loss, (Harare, 2002). The program estimates (ETc) based on equation, (FAO, 1989):

$ETc = ETo * Kc$ ……………………………………………………………………………...[3.7]

Where, ETc is a crop evapotranspiration (mm/day), Kc = crop coefficients (dimensionless) and ETo is a reference evapotranspiration (mm/day). The value of Kc for the initial, middle and end growth stages, Kc-init, Kc-mid and Kc-end, respectively, for many crops taken from (FAO-56, 1998) and the value indicated in Table 4.1.

Irrigation requirements (IR); refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. If irrigation is the only source of water supply for the plant, the irrigation requirement will always be greater than the crop water requirement to allow for inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water.

The determination of irrigation requirement was made after estimation of effective rainfall. In order to compute the irrigation water requirement, CROPWAT 8.0 computes a daily water balance of the root zone (Harare, 2002) and is computed as;

$IWR = ET_c - E_{ff}.R$……………………………………………………………………[3.8]

3.4.2.2. Comparative Performance Indicators

Performance analysis was conducted using comparative indicators. The evaluations were made for the following indicators; irrigation water use efficiency, agricultural productivity, financial and physical indicators have been used in this study to assess and compare the performance of the two small scale irrigation schemes.

I. Irrigation water use efficiency

1. Estimation of Conveyance Efficiency (Ec)

The conveyance of water from the source to the irrigated field can be through constructed earthen or lined canals. As water flows from the system to the irrigation field, some amount of water was lost in different ways such as evaporation from the water surface, deep percolation to soil layer below the canals, seepage through the bunds of the earthen canals, overtopping the bunds and runoff in the drain. Efficient irrigation system transports water with minimum losses and hence has high conveyance efficiency.

The method of discharge measurement was called floating method as floating materials being used for velocity measurement. The discharge measurement was started from the upper position of the main canal. Floating material was drop on the upper of the canal section and the time it took to reach the marked section of the same canal was registered. This test was measured at three or more selected lengths based on the slope of the canal and the time it took was taken to calculate the discharge. In order to determine the rate of flow (discharge) were calculated by equation (3.5). Water use efficiency from the source to the field was measured by conveyance and can be expressed by equation (3.9), (Rogers et al., 1997);

$$E_C = \frac{Q_{out}}{Q_{in}} \quad \text{[3.9]}$$

$$L = Q_{in} - Q_{out} \quad \text{[3.10]}$$

Where; L is conveyance loss (l/s),

E_C is conveyance efficiency (%),

Q_{in} and Q_{out} are the inflow and outflow in specified canal reach length respectively.

2. Estimation of application efficiency (E_a)

Application efficiency is a comparison between the amounts of water applied and the amount retained in the root zone. Losses from the field occur as deep percolation and runoff and reduce the application efficiency. Water applied to the field was measured by installing parshall flumes at entrance of selected farmer's field during irrigating time. The parshall flume was putting at a straight section of flow, before proceeding to the measurement. To determine the amount of water applied to the field, water depth passing through the flume to field and its respective time intervals were recorded with the size of the field being irrigated. Since it is free flow, only upstream measurement point was used. The discharge in each field was calculated using equations (3.6) and the depth of water applied is computed as ratio of discharge times elapsed time to area irrigated. The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

The depth of water stored in the root zone of selected field was determined from the soil moisture content before and three days after irrigation by gravimetric method. The depth of water applied to the field was estimated as follows (FAO, 1989):

$$Z_r = \sum_{i=0}^{n} \frac{\theta_{AI} - \theta_{BI}}{100} i * D_i \quad \text{[3.11]}$$

where,

Z_r = depth of water retained into root zone of the soil (mm),

θ_{AI} and θ_{BI} are moisture content of the ith soil layers after and before irrigation on oven dry volume basis (%), respectively,

D_i is thickness of ith soil layers of the root zone (mm).

n = number of layers in the root zone

The application efficiency of each field was calculated as

$$E_a = \frac{depth of\ water retained in root zone (mm)}{depth water applied on the\ field (mm)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. [3.12]$$

3. Estimation of water storage efficiency

The depth of water stored in the root zone can be estimated based on the soil water content before and three days after irrigated by taken the soil sample from the selected field (farmers') was computed by using equation (3.11), and the water needed in the root zone prior to irrigation is estimated by the equation (3.13) given by (Abebe et al, 2013).

$$W_n = \sum_{i=0}^{n} \frac{\theta_{FC} - \theta_{BI}}{100} i * D_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.13$$

where, W_n = the depth of water needed in the root zone prior to irrigation (mm), θ_{FC} and θ_{BI} = soil moisture content at field capacity and moisture content of the soil before irrigation in volume percent, respectively in the ith soil layers and

D_i = the depth of soil profile in root zone (mm)

Storage efficiency was measured using equation (3.11) and (3.13)

$$E_r = \frac{Z_r}{W_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3.14)$$

Where, E_r = Storage efficiency, Z_r = depth of water retained in to root zone and

W_n = depth of water needed in the root zone prior to irrigation

4. Estimation of distribution uniformity (Du)

Distribution efficiency refers to the on-field system used to store and distribute water to the fields. A common ratio used to calculate distribution efficiency was the volume of water applied to selected fields and the factor that considered evaporative and seepage losses from storage need to be qualified to measure distribution efficiency.

Distribution uniformity is the ratio of the average of the lowest depth of measurements of irrigation water infiltrated to the average depth of irrigation water infiltrated. And the soil moisture contents of the soils at the selected points were analyzed to determine the depth of water penetration. To determine the distribution uniformity of irrigation water in the field, soil moisture samples were taken from the selected farmer's field at three locations of the scheme, starting from the head to the end of the fields. At each selected points of the fields, soil samples were collected at depths of 0 – 30 cm and 30 – 60 cm and the moisture contents of the soil were computed to determine the depth of water penetration as;

$$D_U = \frac{Minimum\ \ Depth\ of\ \ water}{\text{Average Depth of water}} \quad \ldots\ldots(3.15)$$

Finally the overall scheme efficiency was calculated as the product of conveyance and application efficiency. It was computed using the following formula (FAO, 1989):

$$E = \frac{(E_C * E_a)}{100} \quad \ldots\ldots(3.16)$$

E = scheme irrigation efficiency (%)

E_C = conveyance efficiency (%)

E_a = field application efficiency (%)

The overall scheme irrigation efficiency for surface (furrow) irrigation methods of 50-60% is good; 40% is reasonable, while 20-30% is poor, (FAO, 1989).

II. Agricultural output indicators (water and land productivity)

According to Beshir and Bekele (2004), the four basic comparative performance indicators are output per unit command area, output per unit irrigated area, output per unit irrigation water supply and output per unit water consumed. These indicators provide the basis for comparison of irrigated agriculture performance. Water and land are the main inputs for output of crop production. It is computed as the total value of production per harvested area in the irrigation seasons.

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

It is computed as the total value of production per harvested area in the irrigation season. In addition to water availability, soil type and fertility, land suitability, crop variety and agricultural inputs do have significant impact on land productivity. It was 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 irrigated seasons.

$$\text{OPUIA} = \frac{Value\ \ of\ production}{\text{Irrigated cropped area}} \qquad (3.17)$$

Where, OPUIA = output per unit irrigated area

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

This is the value of agricultural production per unit of nominal area which can be irrigated. 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.

$$OPUCA = \frac{\text{Value of production}}{\text{Production command (nominal) area}} \qquad (3.18)$$

Where, OPUCA = Output per unit command area

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

This tells on how well the total seasonal diverted irrigation water from a source is productive. Irrigation water supply includes conveyance losses in canals. Water management is aiming to increase the output per drop of irrigation water diverted to the command area:

$$OPUIS = \frac{\text{Value of production}}{\text{Diverted Irrigation Water}} \qquad (3.19)$$

Where, OPUIS = Output per unit irrigation water supply

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

The value of production per unit delivered irrigation water to the head of farm inlets in the irrigation seasons. It is the net irrigation water delivered to the farm and it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. A lower value of this indicator indicates there is inefficient water use in the irrigation system or specifically at farm level

$$OPUIC = \frac{\text{Value of production}}{\text{Delivered Irrigation Water}} \qquad (3.20)$$

Where, OPUIC = Output per unit irrigation water consumed

III. Water Supply Indicators

Water supply performance two types of indicators, relative water supply (RWS) and relative irrigation supply (RIS) were used for evaluation of water use performance, (Abebe, 2015).

1. Relative Water Supply (RWS): The ratio of total water supplied (irrigation plus rainfall) to the amount of crop water demand (i.e. actual crop evapotranspiration (ETc). It signifies whether the water supply is in short or in excess of demand:

$$RWS = \frac{\text{Total Water Supply}}{\text{Crop demand}} \qquad [3.21]$$

Where; Total water supply = surface diversion plus effective rainfall (mm), Crop water demand = potential ET, or the ET under well- water conditions for each crop (m^3).

2. Relative Irrigation Supply (RIS): RIS indicators described as the ratio of irrigation supply to irrigation demand. Irrigation water is a limited resource in many irrigation schemes and it is a major constraint for production. This indicator is useful to assess the degree of irrigation water use less or more in relation to irrigation demand, (Molden et al., 1998.

$$\text{RIS} = \frac{\text{Irrigation Supply}}{\text{Irrigation demand}} \quad [3.22]$$

Where; Irrigation supply = only the surface diversion for irrigation, Irrigation demand = the crop ET less effective rainfall. RIS relates irrigation supply to irrigation demand of the irrigation schemes in the production season. The computed value shows some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched .

IV. Physical Performance Indicators

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

1. Irrigation Ratio

Zeleke et al. (2012) reported that; the relation between currently irrigated areas to irrigable command (nominal) area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. To compute the indicator information's of irrigated areas in the irrigation season designed irrigable areas of both schemes were obtained from Agricultural and Rural development, Water resources Offices and from water users.

$$\text{IR} = \frac{\text{Irrigated area}}{\text{Command (nominal) Irrigable area}} \quad (3.23)$$

Where, Irrigation area = irrigated area in the irrigation season (ha)

Command area = the designed (nominal) irrigable area (ha)

2. Sustainability of Irrigated area

According to Bos, (1997), sustainability of irrigation measured by the ratio of currently irrigated area to initially irrigated area. It is a useful indicator for assessing the sustainability of irrigated agriculture. This mainly used to observe either contracted or expanded from the initially irrigated area. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time may be showed due to different reasons, i.e. water shortage or their own low interest of the farmers.

On the other hand, values higher than 1 indicate expansion of irrigated area and would imply more sustainable irrigation.

$$SIA = \frac{\text{Currently Irrigable area}}{\text{Initially Irrigated area}} \quad \text{.....(3.24)}$$

Where, Currently irrigable area = the area currently can be irrigated (ha),

Initially irrigated area = the designed/nominal/ irrigable area (ha)

V. Financial Indicators

The two financial indicators are; gross return on investment (GRI) and financial self sufficiency (FSS) indicators were engaged, (Molden et al., 1998).

$$GRI(\%) = \frac{\text{Gross value of Production}}{\text{Cost of Irrigation Infrastructure}} \quad \text{...(3.25)}$$

Where: Gross value of production is the output production value of the irrigation projects (ETB/ha) Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the production in ETB/ha.

$$FSS(\%) = \frac{\text{Revenue from Irrigation}}{\text{Total O \& M expenditure}} \quad \text{....(3.26)}$$

Where: Revenue from irrigation, is the revenue generated, either from fees, or other locally generated income, and Total O & M expenditure is the amount expended locally through operation and management.

4. Result and Discussions

4.1. Analysis of Soil Physical Properties

4.1.1. Particle size distribution and texture class

Based on laboratory analysis of particle size distribution, the textural classes of both irrigation schemes were determined. As indicated in Table 4.1 the soil texture distribution was slightly varied at Midmar irrigation scheme. Sandy loam is found in the head and middle of the scheme; whereas in the tail end of soil is loam while at Maishawsh irrigation scheme the dominant soil is clay loam.

Table 4.1: Soil physical characteristics of Midmar and Maishawsh irrigation schemes

Midmar Scheme					
Field Code	Soil depth(cm)	Particle size distribution (%)			Textural Class
		Sand	Silt	Clay	
Head	0 – 30	58	22	20	Sandy loam
	30 – 60	52	28	20	Sandy loam
Average	0 – 60	55	25	20	Sandy loam
Middle	0 – 30	52	31	17	Sandy loam
	30 – 60	53	29	18	Sandy loam
Average	0 – 60	52.5	30	17.5	Sandy loam
Tail	0 – 30	32	44	24	Loam
	30 – 60	36	38	26	Loam
Average	0 – 60	34	41	25	Loam
Maishawsh Scheme					
Head	0 – 30	34	30	36	Clay loam
	30 – 60	36	26	38	Clay loam
Average	0 – 60	35	28	37	Clay loam
Middle	0 – 30	28	32	40	Clay loam
	30 – 60	32	34	34	Clay loam
Average	0 – 60	30	33	37	Clay loam
Tail	0 – 30	32	28	40	Clay loam
	30 – 60	36	32	32	Clay loam
Total average	0 – 60	34	30	36	Clay loam

4.1.2. Soil field capacity and permanent wilting point

The values of field capacity (FC), permanent wilting point (PWP) and total available water content (TAW) are indicated in Table 4.2. The total available moisture content at Midmar irrigation scheme ranges from 29.76 to 36.18 mm for sandy loam and loam soils while at Maishawsh irrigation scheme it ranges from 31.95 to 38.43 mm for clay loam soils.

Table 4.2: Soil FC, PWP and TAM of water content

Midmar irrigation scheme						
Field Code	Soil depth (cm)	Textural Class	FC (%)	PWP (%)	TAW (%)	TAW (mm)
Head	0 – 30	Sandy loam	22.30	12.34	9.96	29.88
	30 – 60	Sandy loam	24.19	12.97	11.22	33.66
Average	0 – 60	Sandy loam	23.245	12.655	10.59	31.77
Middle	0 – 30	Sandy loam	19.68	9.59	10.07	30.21
	30 – 60	Sandy loam	20.84	10.92	9.92	29.76
Average	0 – 60	Sandy loam	20.26	10.255	9.995	29.985
Tail	0 – 30	Loam	20.27	8.39	11.88	35.64
	30 – 60	Loam	19.10	7.04	12.06	36.18
Average	0 – 60	Loam	19.685	7.715	11.97	35.91
Maishawsh irrigation Scheme						
Head	0 – 30	Clay loam	29.28	16.56	12.72	38.16
	30 – 60	Clay loam	30.50	17.69	12.81	38.43
Average	0 – 60	Clay loam	29.89	17.125	12.765	38.295
Middle	0 – 30	Clay Loam	30.40	19.37	11.03	33.09
	30 – 60	Clay Loam	32.08	21.43	10.65	31.95
Average	0 – 60	Clay loam	31.24	20.40	10.84	32.52
Tail	0 – 30	Clay loam	29.78	18.6	11.18	33.54
	30 – 60	Clay loam	29.23	18.03	11.20	33.6
Average	0 – 60	Clay loam	29.50	18.315	11.19	33.57

4.1.3. Soil infiltration rate

The constant infiltration rates of 2.85 cm/hr and 1.8 cm/hr after 6:15 and 4:50 hours for sandy loam and loam soil types were tested at field condition, respectively in Midmar irrigation scheme as indicated in Table 4.3, while in Maishawsh scheme, the type of soil is clay loam and the constant infiltration rate is 1.2 cm/hr after 4:50 hour, as shown in Table 4.3.

According to FAO (1990), the recommended infiltration value for the basic soil types were given in Table 4.4. Based the above infiltration rate, clay loam soil was out of the recommended ranges. This is due to some exaggerated infiltration rate recorded during the test as indicated in Table 4.3.

Table 4.3 : Infiltration measurement at Midmar and Maishawsh schemes

Time elapsed (min)	Cumulative time (min)			Difference depth (cm)			Cumulative depth (cm)			Infiltration rate (cm/hr)		
	Clay loam	Loam	Sandy loam	Clay loam	Loam	Sandy loam	Clay loam	Loam	Sandy loam	Clay loam	Loam	Sandy loam
0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	3	3	1.5	1.4	2.1	1.5	1.4	2.8	30	28	42
3	6	6	6	1.1	1.1	1.6	2.6	2.5	5.2	22	22	32
3	9	9	9	0.8	0.8	1.4	3.4	3.3	7	16	16	28
5	14	14	14	1.2	1.2	1.8	4.6	4.5	9.5	14.4	14.4	21.6
5	19	19	19	1	0.9	2	5.6	5.4	11.7	12	10.8	24
5	24	24	24	0.8	0.7	1.7	6.4	6.1	13.7	9.6	8.4	20.4
5	29	29	29	0.6	0.6	1.5	7	6.7	15.2	7.2	7.2	18
10	39	39	39	1	1	1.9	8	7.7	17.8	6	6	11.4
10	49	49	49	1.3	0.8	1.6	9.3	8.5	20.6	7.8	4.8	9.6
10	59	59	59	1.1	0.8	1.3	10.4	9.3	23.1	6.6	4.8	7.8
10	69	69	69	0.8	0.9	1.1	11.2	10.2	25.3	4.8	5.4	6.6
20	89	89	89	1.5	1.4	2.2	12.7	11.6	28.2	4.5	4.2	6.6
20	109	109	109	1.3	1.2	1.9	14	12.8	31.3	3.9	3.6	5.7
20	129	129	129	1.4	0.9	1.7	15.4	13.7	33.6	4.2	2.7	5.1
20	149	149	-	0.7	1	-	16.1	14.7	-	2.1	2.2	-
30	179	179	159	0.8	1.1	2	16.9	15.8	36.2	1.6	2.2	4.4
30	209	209	189	0.6	0.9	2.1	17.5	16.7	38.8	1.2	1.8	4.6
30	239	239	219	0.6	0.9	1.8	18.1	17.6	41.3	1.2	1.8	3.8
30	269	269	249	0.6	0.9	1.6	18.7	18.5	43.7	1.2	1.8	3.2
40	-	-	289	-	-	1.9	-	-	46.2	-	-	2.85
40	-	-	329	-	-	1.9	-	-	48.7	-	-	2.85
40	-	-	369	-	-	1.9	-	-	51.2	-	-	2.85

For Midmar scheme= sandy loam and loam soil, and for Maishawsh scheme = clay loam soil

Table 4.4: Basic infiltration rates for various soil types

Soil type	Basic infiltration rate (cm/hr)
Sand	Less than 3
Sandy loam	2 – 3
Loam	1 – 2
Clay loam	0.5 – 1
Clay	0.1 – 0.5

The possible reasons for this record may come from soil crack by burrowing animal. The infiltration rate used for input of CROPWAT 8.0 is 1cm/hr and this rate is from Table 4.4.

4.3. Cropping Pattern

Cropping pattern consisting of the availability of water, planting date, crop coefficient (Kc), length of growth period, root depth, irrigated area and type of soil were provided during the study period. In both irrigation schemes a combination of cropping system cultivated between November to April. Onion, tomato, cabbage and groundnut were the main crops cultivated in the irrigation seasons in Maishawsh while in Midmar, Onion, tomato, maize and groundnut are the main crops cultivated during the study period. Crop characteristics; such as planting date and length of growing period (LGP) were collected from water users as indicated in Table 4.5. Crop coefficient (Kc), was taken from, (FAO, No.56, 1989).

Table 4.5: Input data for CROPWAT 8.0 at both irrigation schemes.

Type of Crop	Midmar irrigated area (ha)	Maishawsh irrigated area (ha)	Root depth (cm)	Plating date	LGP (days)					Kc value for each stage		
					Ini	Dev	Mid	Late	Total	Ini	Mid	Late
Cabbage	1.75	-	50-80	18/12	20	25	60	15	120	0.7	1.05	0.95
G/nut	1.25	2.25	50-100	16/12	25	35	45	25	130	0.4	1.15	0.6
Maize	-	12.25	80-120	02/12	20	35	40	30	125	0.3	1.20	0.6
Onion	13.15	29.75	30-60	02/11	15	25	70	40	150	0.7	1.05	0.75
Tomato	7.5	17.5	70-150	18/12	30	40	40	25	135	0.6	1.15	0.8
Total	23.65	61.75										

LGP = Length of Growth Period

4.4. Crop and Irrigation Water Requirements

Crop water requirements were computed based on equation (3.7) and irrigation water requirements were determined after the effective rain fall was computed using equation (3.8). CRW and IR were determined for the main crops grown in both irrigation schemes. The main crops grown in the irrigation seasons have been identified for both schemes. Using input from Table 4.5 the total crop and irrigation water requirements were computed for the estimation of total water demands at the two schemes for the growing seasons using equation (3.7) and the total demand per season of the schemes for growth period is indicated in Table 4.6. The scheme net irrigation requirement (NIR) in the growing season, in monthly bases was also determined for a given cropping pattern of the irrigation schemes were indicated in Figure 4.1 and the detail can be seen in Appendix 3 & 4.

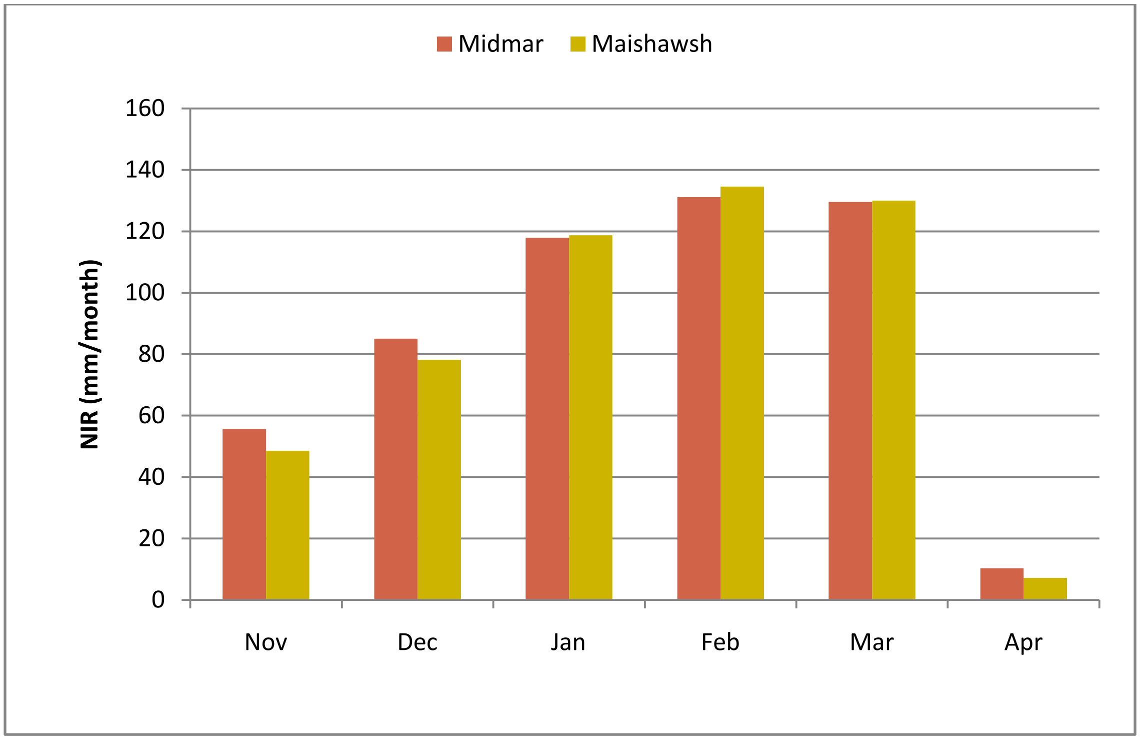


Figure 4.1: Monthly net irrigation requirement at both irrigation schemes

Table 4.6: Crop and Irrigation Water Requirement both Schemes

Scheme	Irrigated Crops	Area (ha)	CWR(mm /season)	R.eff(mm /season)	IR(mm /season)	Total NCWR (mm/season)	Total NIR (mm/season)
Midmar	Cabbage	1.75	520.0	38.9	481.10	38.48	35.60
	Groundnut	1.25	519.90	46.2	473.70	27.48	25.04
	Onion	13.15	592.30	31.4	580.9	329.33	311.87
	Tomato	7.5	529.90	30.4	499.5	168.04	158.40
Total		23.65				563.33	530.91
Maishawsh	Groundnut	2.25	519.5	46.2	473.30	18.93	17.25
	Maize	12.25	478.10	32.70	445.40	94.85	88.36
	Onion	29.75	591.70	31.4	560.3	285.07	269.94
	Tomato	17.50	529.4	30.4	499	150.03	141.42
Total		61.75				548.88	516.97

The total water consumption of the total net crop water requirement and the total net irrigation requirements of Midmar and Maishawsh irrigation schemes were determined Table 4.7.

❖ Total net crop water requirement (demand) at Midmar irrigation scheme computed as;

$$NCWR = CWRcabbage * \frac{AREAcabbage}{TOTAL\ \ AREA} + CWRgroundnut * \frac{AREAgroundnut}{TOTAL\ \ AREA} + CWRonion * \frac{AREAonion}{TOTAL\ \ AREA} + CWRtomato * \frac{AREAtomato}{TOTAL\ \ AREA}$$

$$NCWR = 520.0 * \frac{1.75}{23.65} + 519.90 * \frac{1.25}{23.65} + 592.30 * \frac{13.15}{23.65} + 529.90 * \frac{7.5}{23.65} = 38.48 + 27.48 + 329.33 + 168.04 = 563.33\ mm/season$$

❖ Total net Irrigation requirement (demand) at Midmar irrigation scheme

$$NIR = IRcabbage * \frac{AREAcabbage}{TOTAL\ \ AREA} + IRgroundnut * \frac{AREAgroundnut}{TOTAL\ \ AREA} + IRonion * \frac{AREA\ onion}{TOTAL\ \ AREA} + IRtomato * \frac{AREAtomato}{TOTAL\ \ AREA}$$

$$NIR = 481.10 * \frac{1.75}{23.65} + 473.70 * \frac{1.25}{23.65} + 580.90 * \frac{13.15}{23.65} + 499.5 * \frac{7.5}{23.65} = 35.60 + 25.04 + 311.87 + 158.40 = 530.91\ mm/season.$$

- And the net crop and irrigation water requirements of Maishawsh irrigation scheme was calculated with the same procedure of Midmar scheme.

Table 4.7: Summarize of Water Consumption for Midmar and Maishawsh Schemes

Scheme	Area (ha)	NCWR (mm/season)	NIR (mm/season)	R.eff (m^3/season)	NCWR (m^3/season)	NIR (m^3/season)
Midmar	23.65	563.33	530.91	7,667.33	133,227.54	125,560.21
Maishawsh	61.75	548.88	516.97	19,704.43	338,933.4	319,228.97

4.5. Flow Rate Measurement

In both schemes, it was so difficult to measure water flow rates especially at tertiary canals; because there were covered by weeds and flow fluctuations due to irregular shape of canal. The farmer’s uses rotational scheduling systems, but sometimes there were illegal water users in the upstream, and absence of reliable and functional flow control systems at each division boxes. The water supply system from the main canal to the field was based on rotation. Farmers practiced diverting and closing irrigation water to fields using traditional system. This traditional diverting system has damaged the main canal and creates over flooding especially during night time and increasing the water loss along main and secondary canals. They have also observed illegal abstraction of water from main and secondary canal during field survey. For sample points of average in-flow rate nine measurement at Maishawsh for main canal and seven for secondary canals were taken and accordingly the average rate of in-flow and out-flow at main and secondary canals were 62.85 lit/sec and 28.59 lit/sec respectively, as shown in Table 4.8 and the details can be seen in Appendix 6 Table 1 and 2. The irrigation scheme of Maishawsh has five tertiary canals and has two earthen canals for Midmar irrigation scheme. Average in-flow rates at Maishawsh and Midmar schemes were 12.065 lit/sec and 27.925 lit/sec respectively as shown Table 4.8 and Appendix 6 Tables 3 and 4. All at field canals of Maishawsh and Midmar irrigation schemes were constructed traditionally (earthen canal).

Table 4.8: Average flow rate, Ec and losses at Maishawsh and Midmar irrigation schemes

Scheme	Canal Location	Average length(m)	Q_{in} (lit/sec)	Q_{out} (l/sec)	Ec (%)	Water loss (lit/sec/m)
Maishawsh	Main canal	148	63.18	62.52	98.95	0.005
	Secondary canal	156	29.925	27.25	91.03	0.017
	Tertiary canal	166	13.73	10.40	75.21	0.020
Midmar	Earthen canal	100	31.53	24.32	76.9	0.072

Where; Ec = conveyance efficiency, Q_{in} = in flow discharge, Q_{out} = out flow discharge

4.6. Comparison of the two Irrigation Schemes

4.6.1 Irrigation water use efficiency performance

4.6.1.1. Conveyance Efficiency

1. Lined canal at Maishawsh irrigation scheme

The mean conveyance efficiency value was indicating that; the amount of water lost during conveyance of water from the source to the field canal. The conveyance efficiency and water losses were calculated based on equation (3.9) and (3.10) respectively.

In Maishawsh SSI scheme, the conveyance efficiency of the main canal was decreasing from the head to the tail end of the scheme. The average conveyance efficiency ranges from 99.53 – 98.34%, as indicated in Appendix 6 Table 1, the minimum one occurred at the intake of secondary canal. The overall average conveyance efficiency and losses of the main canal was 98.95% and 0.005 lit/sec/m respectively as shown in Table 4.8.

The minimum and maximum conveyance efficiencies of Maishawsh secondary canal was 89.16% and 92.50% and the overall average conveyance efficiency was 91.035%. This indicates that, an average conveyance loss of 0.017 lit/sec/156m was computed from 7 observations in the secondary canal. This result was, due to absence of controlling system and illegal abstraction of water was made in secondary canal that leads for water losses or low conveyance efficiencies as compared to main canal, as indicated in Figure 4.2 and Appendix 6 Table 2.

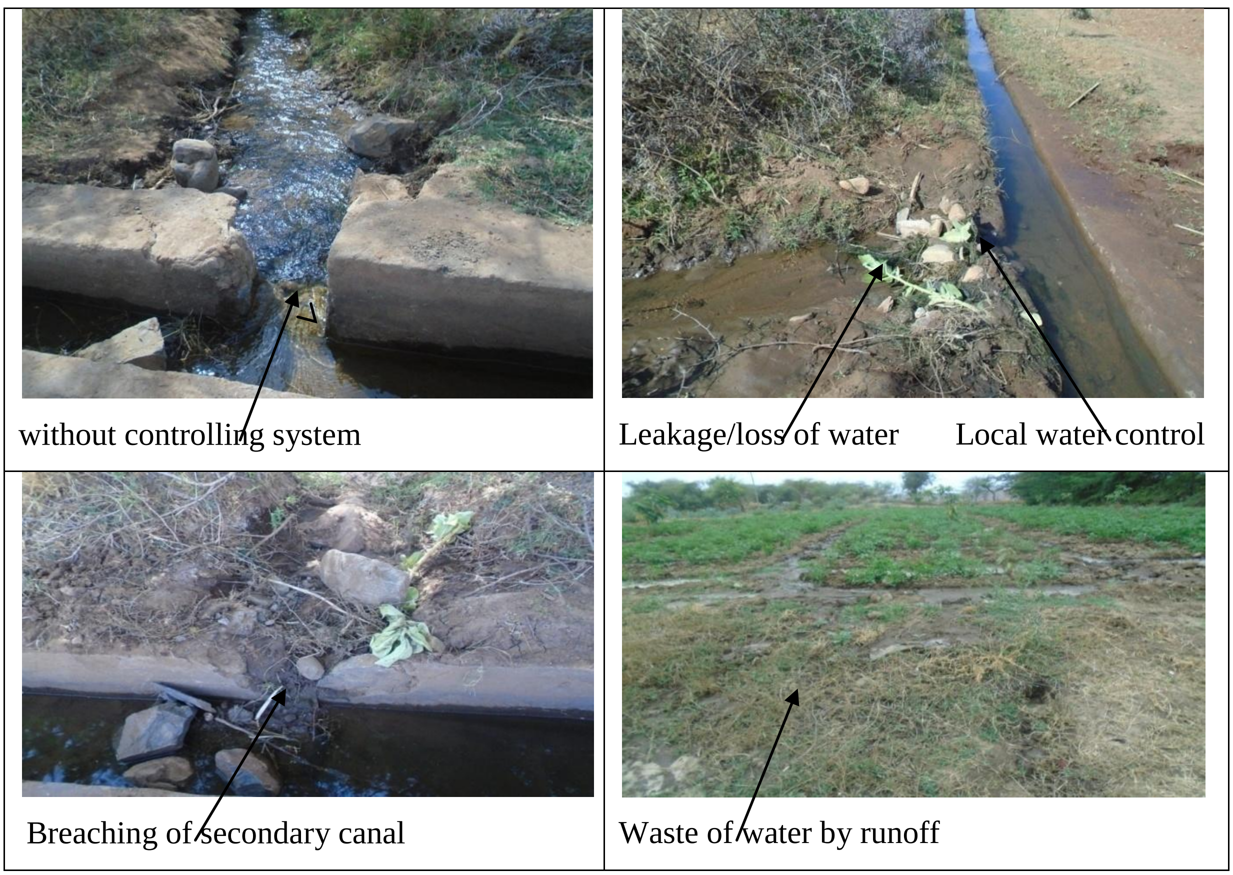


Figure 4.2: Local water control, breaching of canal and losses of water

The minimum and maximum amount of lose in the canal were 0.012 and 0.026 lit/sec/m respectively (Appendix 6 table 2). The largest amount water of loss occurred at Secondary canal 1 relative to secondary canal 2. Secondary canal 1 was broken, which has been contributed for leakage through off take points (from local controlling system), overflow losses and has maximum length of canal as compared to secondary canal 2.

2. Earthen canal at Midmar and Maishawsh irrigation schemes

Since, main and secondary canals were lined and the conveyance efficiency and losses problems mainly observed on tertiary (earthen) canals. Therefore, in both irrigation schemes conveyance efficiency and loss evaluation have done only for earthen type canals. Therefore, during evaluation each canals were shown different conveyance efficiencies. This was due to some management activities, leakage in intakes, overtopping due to low embankments, seepage through porous unlined canal, and increased efficiency as a result of canals maintenances and cleaned vegetated grasses. From both irrigation schemes, earthen canals of the conveyance efficiencies were lower than the required amounts, but the problem was similar in both SSI schemes. As a result the earthen canals of the two irrigation schemes have been found under poor performance conditions; couldn't deliver the amount of inflow rate to the required fields.

As shown in Appendix 6 Table 4, from 4 observations, the minimum and maximum conveyance efficiencies of 74.2% and 79% were calculated in earthen canals of Midmar irrigation scheme respectively and the overall average reached to 76.9%. And the minimum and maximum conveyance loss of 0.067 and 0.076 lit/sec/100m were lost respectively, with average losses of 0.072 lit/sec/100m. The average conveyance efficiency of earthen canal 2 was better than canal 1. But, the largest amount of losses were occurred at both earthen canals, relatively, canal 1 was better than canal 2, due to siltation problems decreasing flow depth and widening of canal widths and weeds inside the canal which can reduce the flow velocity and conveyance efficiency.

In case of Maishawsh tertiary unlined canal, the overall delivered water as indicated on Appendix 6 Table 3, the average conveyance efficiency and losses were 75.21% and 0.02 lit/sec/166m respectively. From the results evaluation, the average conveyance efficiency of tertiary canal-1 has relatively better as compared to others; due to canal cleaning and maintenances. But, the mean conveyance efficiencies of tertiary canal 1, 3 and 4 were almost equal and have good conveyance losses as compared to tertiary canal 2 and 5. The main reasons for low conveyance losses have, the flows in canal network was not uniform, vegetation in the unlined waterways, weak banks, lack of maintenance, not well compacted and Seepage from canal side walls along the canal length.

According to FAO (1990), the conveyance efficiency (E_c) mainly depends on the length of the canals, the soil type and the condition of the canals. Furthermore, the conveyance efficiency of Midmar and Maishawsh irrigation schemes were relatively good comparable with the result obtained in Meila of 74.48% (Atinkut, 2013) and in the case study of Haleku and Dodicha irrigation schemes (Eticha, 2011), the values of conveyance efficiency for both schemes were below the recommended value i.e. 70% for unlined poorly managed main canals.

Finally, from the overall conveyance efficiency of earthen canals; an average 76.9 and 75.21% from the diverted amount of water were delivered to field inlets at Midmar and Maishawsh SSI schemes, respectively. However, the overall mean conveyance loss, in Midmar 0.072 lit/sec/100m was higher than Maishawsh 0.02 lit/sec/166m, due to high flow rate 31.53 lit/sec at Midmar was better than 13.73 lit/sec at Maishawsh earthen canals. Even though, the conveyance efficiency at Midmar was relatively higher than Maishawsh; both schemes have low conveyance efficiencies and high conveyance losses compare with lined masonry canal. Generally 23.10% and 24.79% of the delivered water at Midmar and Maishawsh irrigation schemes was lost before it reaches to the fields, respectively.

4.6.1.2. Application Efficiency

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop and also tells us whether the irrigation water is stored in the intended soil profile or lost as deep percolation and by evaporation. The average application efficiency of selected fields at Midmar irrigation scheme is 60.8% and for Maishawsh is 56.8%, using equation 3.12. The details of application efficiencies for the selected fields in both schemes are shown in Table 4.9 and 4.10.

Table 4.9: Soil moisture content measured BI and AI of Midmar and Maishawsh schemes

Midmar irrigation scheme					
Location	Soil depth (cm)	Moisture BI (%)	Moisture AI (%)	Moisture Stored (%)	Z_r (mm)
Field-1	0 – 30	10.09	17.64	7.56	22.67
	30 – 60	11.12	14.31	3.18	9.55
Field-2	0 – 30	10.22	17.96	7.73	23.20
	30 – 60	13.48	16.28	2.81	8.42
Field-3	0 – 30	16.04	24.89	8.89	26.57
	30 – 60	14.12	16.81	2.68	8.05
Maishawsh irrigation scheme					
Field-1	0 – 30	22.61	28.33	5.72	17.16
	30 – 60	21.50	23.43	1.93	5.79
Field-2	0 – 30	24.45	30.84	6.39	19.16
	30 – 60	26.84	28.72	1.88	5.65
Field-3	0 – 30	23.66	29.51	5.85	17.56
	30 – 60	26.00	27.71	1.71	5.13

BI and AI = before and after irrigation respectively, Z_r = water stored in the root zone

Table 4.10: Applied irrigation water measured by parshal flume for both schemes for estimating of Application efficiency

Midmar irrigation scheme								
Field code	Water depth (cm)	Area of Fields (m^2)	Time elapsed (sec)	Discharge (Q_f) (lit/sec)	Total volume (lit)	Depth applied (mm)	Water Stored at Z_r (mm)	E_a (%)
Field-1	9.25	100	1722.5	3.0146	5192.62	51.93	32.22	62.04
Field-2	12.5	160	1885	4.8075	9062.11	56.64	31.62	55.83
Field-3	9.75	200	3286.82	3.2709	10750.79	53.75	34.62	64.41
Average of application efficiency (%)								60.76
Maishawsh irrigation scheme								
Field-1	8.75	180	2924.82	2.7658	8089.45	44.94	22.95	57.74
Field-2	9.5	140	1955	3.1418	6142.22	43.87	24.81	56.55
Field-3	8.5	120	1832.5	2.6443	4845.63	40.38	22.69	56.19
Average of application efficiency (%)								56.83

Z_r = root zone, and Ea = application efficiency,

As indicated in Table 4.10, the application efficiency of Midmar irrigation scheme was in the range between 55.83 – 64.41% and an average value of 60.76%, while for Maishawsh application efficiency is in the range between 56.19 – 57.74% and an average value of 56.83%. According to FAO (1990) the field application efficiency (Ea) mainly depends on the irrigation method and the level of farmer know how. A good indicative values of the average field application efficiency of surface irrigation method is 60% and above. Based on this, the application efficiency of Midmar irrigation scheme, from the three selected field 1 and 3 were efficient, but field 2 was inefficient. As indicated in Table 4.10 and Figure 4.3 those farmers working on field two applied more water but has less water stored in the root zone comparable to field 1 & 3 and this may show water management problem at field two. But the overall E_a of Midmar is found to be efficient.

But for Maishawsh scheme as indicated in Table 4.10 and Figure 4.3, the application efficiency of three selected field were below the standard set by FAO (1990). The reason for less efficiency in Maishawsh irrigation scheme has more water lost at the tertiary canal before entering to the field. Generally, the application efficiency of Midmar irrigation scheme was more efficiently than Maishawsh irrigation scheme but the moisture content before irrigation of the soil was the reverse.

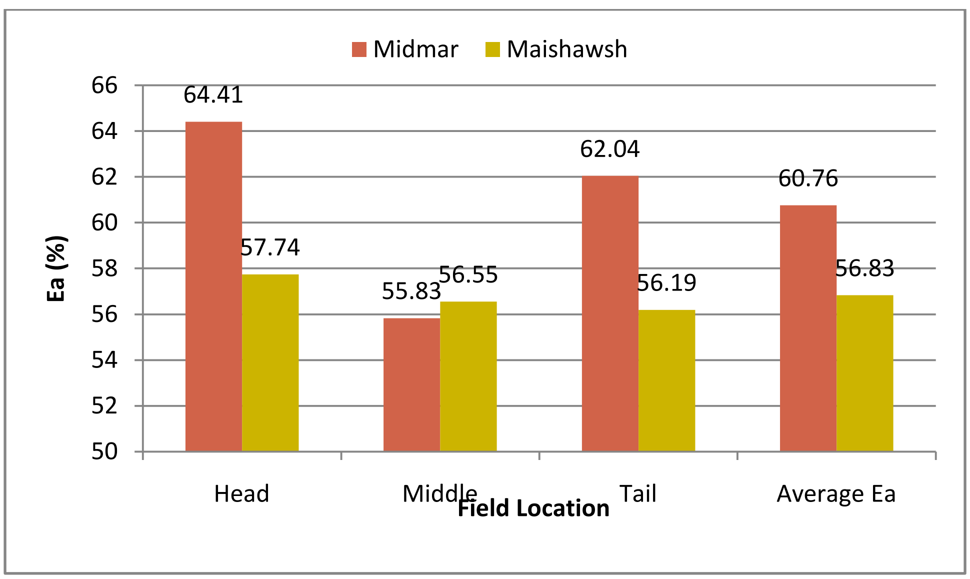


Figure 4.3: Application efficiency at each location for both schemes

4.6.1.3. Storage Efficiency-

The water storage efficiency (E_r) was computed from data such as soil moisture before and three day after irrigations using equation (3.14). The result of storage efficiency of selected fields from Midmar irrigation scheme as indicated Table 4.11 was found to vary from 59.1 to 70.7% with an average storage efficiency of 64.2% and that of selected fields from Maishawsh varied from 48.82 to 80.9% with an average storage efficiency of 67.9%. According to Alfred (1890), the common values of storage efficiency of on farm level ranges from 50 – 85%, based on this, the storage efficiency for selected fields and the average storage efficiency for both schemes are within ranges as indicated in Appendix 5 Table 1, 2 & 3.

Table 4.11: Soil moisture content of BI and AI of Midmar and Maishawsh schemes

Field Code	Soil depth (cm)	BI (%)	AI (%)	FC (%)	Water Stored in Z_r (mm)	W_n (mm)	Er (%)
Midmar irrigation scheme							
Field-1	0 – 30	16.04	24.89	22.30	34.62	48.99	70.67
	30 – 60	14.12	16.81	24.19			
Field-2	0 – 30	10.22	17.96	19.68	31.62	50.46	62.66
	30 – 60	13.48	16.28	20.84			
Field-3	0 – 30	10.09	17.64	20.27	32.22	54.48	59.14
	30 – 60	11.12	14.31	19.10			
Average	0 – 60				32.82	51.31	64.16
Maishawsh irrigation scheme							
Field-1	0 – 30	22.61	28.33	29.28	22.95	47.01	48.82
	30 – 60	21.50	23.43	30.50			
Field-2	0 – 30	24.45	30.84	30.40	24.81	33.57	73.90
	30 – 60	26.84	28.72	32.08			
Field-3	0 – 30	23.66	29.51	29.78	22.69	28.05	80.89
	30 – 60	26.00	27.71	29.23			
Average	0 – 60				23.48	36.21	67.87

Z_r = root zone, W_n = the depth of water needed in the root zone prior to irrigation, E_r = storage efficiency

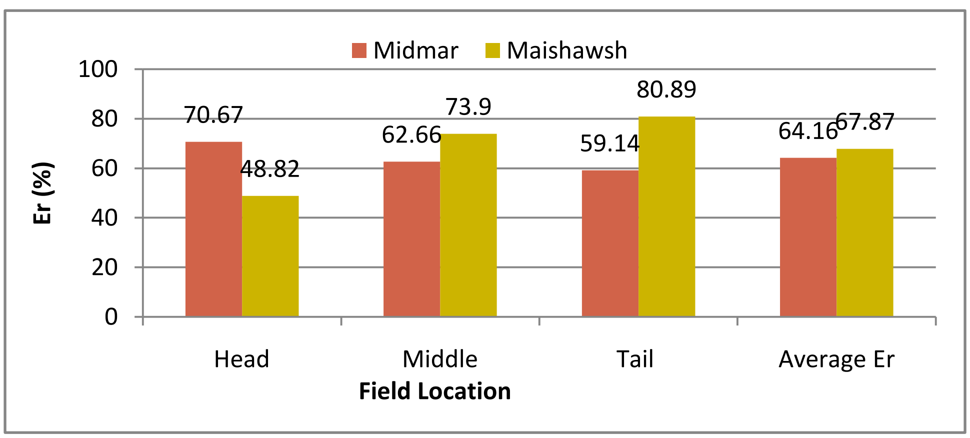


Figure 4.4: Storage efficiency at each location for both schemes

As shown in Table 4.11 and Figure 4.4 the storage efficiency at Maishawsh was greater than Midmar irrigation scheme the reason might to be due to the soil type of in Maishawsh is clay loam more water hold than sandy loam and loam in Midmar irrigation scheme. Relatively both irrigation schemes have good water storage efficiency but Maishawsh scheme is better.

4.6.1.4 Distribution uniformity

Distribution uniformity (D_U) of the scheme was evaluated by the depth of water infiltrated into the root zone depth using equation (3.15). According to Alfred (1890), the common accepted value of distribution uniformity for furrow irrigation is in the ranges between 50 and 60%. In this study the irrigation uniformity for Midmar irrigation scheme gave an average value of 93.40% and in the field of Maishawsh irrigation scheme gave an average of 94.21%. As indicated in Table 4.12 the distribution uniformities of both schemes are accepted, but Maishawsh scheme is better than Midmar irrigation scheme.

Table 4.12: Distribution uniformity for Midmar and Maishawsh schemes.

Location	**Midmar Scheme**						**Maishawsh Scheme**					
	Soil depth (cm) (0 – 30)			Soil depth (cm) (30 – 60)			Soil depth (cm) (0 – 30)			Soil depth (cm) (30 – 60)		
	AI (%)	BI (%)	Water depth (mm)	AI (%)	BI (%)	Water depth (mm)	AI (%)	BI (%)	Water depth (mm)	AI (%)	BI (%)	Water depth (mm)
Field-1	24.89	16.04	26.55	16.81	14.12	8.07	28.33	22.61	17.16	23.4	21.5	5.79
Field-2	17.96	10.22	23.22	16.28	13.48	8.4	30.84	24.45	19.17	28.7	26.8	5.64
Field-3	17.64	10.09	22.65	14.31	11.12	9.57	29.51	23.66	17.55	27.7	26	5.13
Average (mm)			24.14			8.68			17.96			5.52
D_U (%) for each layer			93.83			92.97			95.55			92.93
Average D_U (%)			93.4						94.21			

Where, D_U = distribution uniformity, BI and AI = before and after irrigation respectively

4.6.1.5. Overall Scheme Efficiency

The overall efficiency of the scheme is the product of conveyance efficiency and application efficiency and estimated using equation (3.16). The overall efficiencies of Midmar and Maishawsh were found to be 46.72 and 42.74%, respectively. The average overall irrigation efficiencies of both schemes are tabulated in Table 4.13. Moreover, the overall scheme efficiency of Midmar and Maishawsh irrigation schemes were comparable with result obtained in Haleku irrigation schemes was found to be 47.34% (Eticha, 2011). The result indicated that Midmar and Maishawsh irrigation schemes were lower compared with the Haleku irrigation scheme. According to (FAO, 1989) a scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20-30% is poor and according to this guide line.

Table 4.13: Overall field efficiencies of Midmar and Maishawsh schemes

Schemes	Efficiencies, %		
	Application	Conveyance (in field)	Overall scheme efficiency
Midmar	60.76	76.89	46.72
Maishawsh	56.83	75.21	42.74

According to guide line by FAO (1989), the performance of both irrigation schemes were relatively fair. But, the overall scheme efficiency of Midmar irrigation scheme was better than Maishawsh. Due to the higher value of application and conveyance efficiency at Midmar irrigation scheme.

4.6.2. Agricultural Output Indicators

According to the collected data of planting and harvesting of each crop for the season, the agricultural practice of the farm was analyzed. Based on the average discharge of 35.8 lit/sec for 12 hr/days, the total volume of water diverted to the Midmar irrigation project for 23.65 ha during the irrigation season (2ndNov– 1stApr), was 232,210.80 m^3 as indicated in Appendix 1.

The total volume of water diverted to the Maishawsh irrigation project during the same season with average discharge of 62.52 lit / sec was 756,241.92 m^3. As indicated in Table 4.14, the crop production per season for Midmar was about 2094.8 quintal from the local market price, the gross incomes of 83,077.825 US$. Due to malfunction of pump, the total command area of Midmar cultivated was reduced by 0.35 ha. At Maishawsh irrigation scheme, the total production of 5325 quintal from the local price, the gross income was 187,254.35 US$ for a total command area of 61.75 ha.

Table 4.14: From the experimental field, the output production value for Midmar and Maishawsh schemes for year 2016/17

Scheme	Irrigated Crops	Area (ha)	Production in Qui/ha	Production in Qui	Av. Price in birr/Qui	Gross Income (birr)	Gross income (US $)
		(1)	(2)	(3)= (1)*(2)	(4)	(5) = (3)*(4)	(6)=(5)/(23birr)
Midmar	Cabbage	1.75	38	66.5	1100	73150	3,180.435
	Groundnut	1.25	40	50	2400	120000	5,217.39
	Onion	13.15	82	1078.3	800	862640	37,506.09
	Tomato	7.5	120	900	950	855000	37,173.91
Total		23.65		2094.8		1,910,790	83,077.825
Maishawsh	Groundnut	2.25	38	85.5	2400	205200	8,921.74
	Maize	12.25	62	759.5	700	531650	23,115.22
	Onion	29.75	80	2380	750	1785000	77,608.70
	Tomato	17.50	120	2100	850	1785000	77,608.70
Total		61.75		5325		4,306,850	187,254.35

Where; Qui = Quintal = 100 kg, and US$ = 23ETH birr, average exchange rate for 2016/17

Table 4.15: Irrigated area, water supply and production of Midmar and Maishawsh Schemes

Scheme	Command area (ha)	Irrigated area (ha)	Water consumed (m^3/season)	Irrigation supply (m^3/season)	Production (US$)
Midmar	24	23.65	133,227.54	232,210.80	83,077.825
Maishawsh	60	61.75	338,933.40	756,241.92	187,254.35

For land productivity parameters such as output per unit irrigated area and output per unit command area and for water productivity performance indicators such as output per unit irrigation supply and output per unit water consumed were used to evaluate both irrigation schemes. The four comparative indicators were determined for both schemes as indicated in Table 4.16 and Figure 4.5 using equation 3.16, 3.17, 3.18 and 3.19 respectively.

Table 4.16: Summarize the Output of land and water for Midmar and Maishawsh schemes

Scheme	OPUCA (US$/ha)	OPUIA (US$/ha)	OPUIS (US$/$m^3$)	OPUWC (US$/$m^3$)
Midmar	3,461.58	3,512.80	0.36	0.62
Maishawsh	3,120.91	3,032.46	0.25	0.55

Comparing the land productivity of the two schemes as indicated Table 4.16; output per unit irrigated area computed are 3,512.8 US$/ha and 3,032.46 US$/ha and the output per unit command area are 3461.6 US$/ha and 3120.9 US$/ha for Midmar and Maishawsh schemes, respectively. According to the above output per unit irrigated area and command area the result of, Midmar was greater than Maishawsh irrigation scheme. This is due to road accessibility, the unit price per quintal of Maishawsh lower than Midmar scheme. More over OPUIA value of Midmar and Maishawsh irrigation schemes was better comparable with result obtained in Jari and Aloma irrigation schemes of 2198 and 1356 US$/ha respectively, (Solomon, 2016). There are also 2500 & 1650 US$/ha were obtained in Wedecha irrigation scheme sub-system of Godino and Gohaworki respectively, (Zeleke et al., 2012).

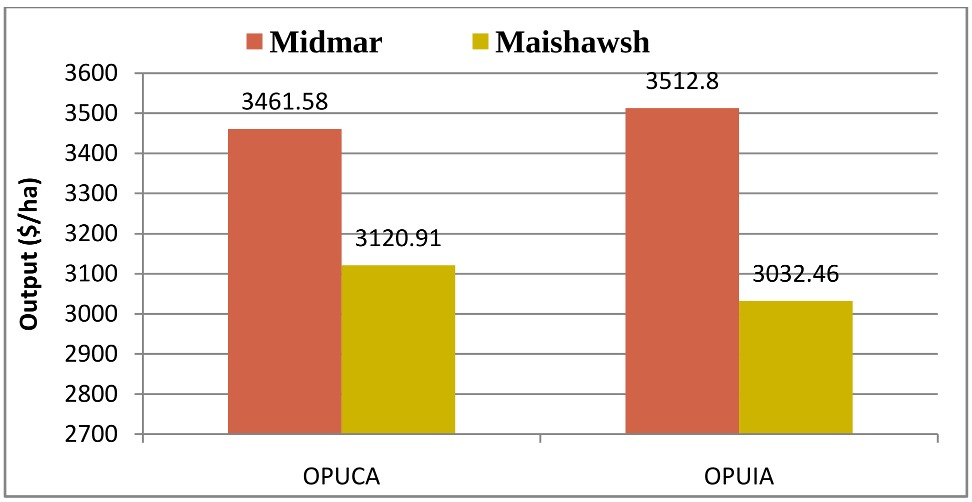


Figure 4.5: Land productivity indicators for both schemes

Performances of water productivity were evaluated with output per unit irrigation water supplied and output per unit water consumed. As indicated in Table 4.16 and Figure 4.6, the output per unit irrigation water supply and output per unit water consumed of Midmar scheme was higher than Maishawsh scheme. As well as the output per unit water consumed of Midmar irrigation scheme was higher than Maishawsh irrigation scheme. Particularly in Midmar scheme the OPUWC of 0.62 US$/$m^3$ with OPUIS of 0.36 US$/$m^3$ indicating that 38% of the irrigation water supply to the field was unproductive. In case of Maishawsh scheme the OPUWC of 0.55 US$/$m^3$ with OPUIS of 0.25 US$/$m^3$ implying that 45% of the water supply to the field was unproductive. Furthermore, the OPUWC value of Midmar and Maishawsh irrigation schemes were higher comparable with the result obtained in Jari and Aloma irrigation schemes of 0.49 and 0.30 US$/m^3 respectively, (Solomon W., 2016). Figure 4.5 & 4.6 indicated that the values of land and water productivity indicators computed from Midmar SSI have shown higher performance than Maishawsh scheme. This implied that better water management brings better water productivity for Midmar scheme.

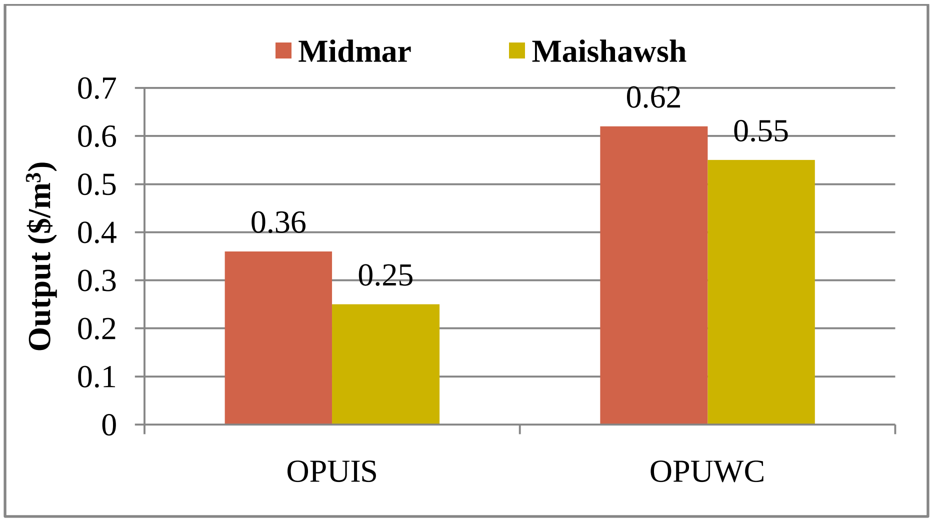


Figure 4.6: Water productivity indicators in both schemes

4.6.3. Water Supply Performance Indicators

Two indicators, such as relative water supply (RWS) and relative irrigation supply (RIS) were used in the evaluation of water use performance for both schemes. The amount of total net crop water requirement and net crop irrigation requirement were determined by using equation (3.7) & (3.8) for a given cropping pattern and irrigation seasons as indicated Table 4.5. For the two schemes, the comparative indicators such as RWS and RIS were computed using equation (3.21) and (3.22) respectively and are given in Table 4.17.

Table 4.17: net crop and irrigation water requirement and water supply indicators

Scheme	NCWR (mm/season)	NIR (mm/season)	RWS	RIS
Midmar	563.33	530.91	1.8	1.85
Maishawsh	548.88	516.97	2.29	2.37

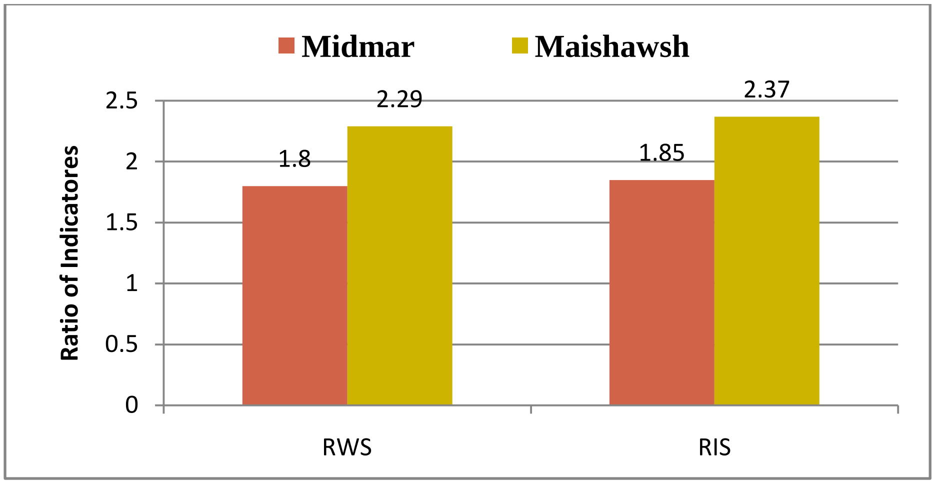


Figure 4.7: Water Supply indicators at Midmar and Maishawsh schemes

4.6.3.1. Relative water supply

This implied that, whether there is enough irrigation water supplied to the field or not. Based on equation 3.20, this indicator was determined for both schemes. The relative water supply value below one normally indicates that the water applied is less than the crop demands and values above one indicate extra water is added to the root zone beyond plant demands (Molden et al., 1998). As indicated in Table 4.17 and Figure 4.7 the relative water supply of Midmar irrigation scheme was found to be 1.8 and that of Maishawsh scheme was 2.29. This result indicated that, more water is supplied beyond the crop demand in both schemes, especially in Maishawsh irrigation scheme.

4.6.3.2. Relative irrigation supply

Relative Irrigation Supply (RIS) and relative water supply were almost similar, because the rainfalls in the study area were low at both schemes. As indicated in Table 4.17 and Figure 4.7 for both irrigation schemes the computed values of RIS were greater than one; which showed excess irrigation water supplied for crop demand. The relative irrigation supply of Midmar irrigation scheme was found to be 1.85 and Maishawsh irrigation scheme was 2.37 using equation 3.22. Molden et al. (1998) indicated that, it is better to have a relative irrigation supply near one than a higher value. Therefore at both schemes, RIS values should be minimized by adjusting the irrigation release from the source to effectively use of the water supply.

4.6.4. Physical sustainability indicators

The physical indicators of the two schemes such as, command area, initially irrigated area and currently irrigated area were collected to evaluate the physical performance indicators. The currently irrigated area of each scheme was determined by delineating the boundary of the command area using Google earth professional. Then added to ArcGIS where the boundaries were plotted and the areas determined. The command areas were taken from the design project of RWR bureau and ReST. The initial irrigated areas for both schemes were taken from water users association and DA's reports as indicated in Table 4.18.

Table 4.18: Computed value of irrigation ratio and sustainability of irrigation area

Scheme	Command area (ha)	Initial Irrigated area (ha)	Currently irrigated area (ha)	Indicators	
				IR (%)	SIA (%)
Midmar	24	24	23.65	98	98
Maishawsh	60	58.50	61.75	103	106

Where; IR = irrigation ratio, and SIA = sustainability of irrigation area

4.6.4.1. Irrigation ratio

Irrigation ratio is an indicator for the degree of utilization of a given irrigable area in the specific production season estimated by equation 3.23. Irrigation ratio as indicated in Table 4.19 is higher for Maishawsh Scheme with a value of 1.03 implying 103% of the irrigable command area is currently irrigated, which means the currently irrigated area from the irrigable command area was increased by 3%. High irrigation ratio at Maishawsh could be due to construction of relatively large dam at upper catchment and farmers get water free charges. Relatively lower irrigation ratio at Midmar irrigation scheme was due to the restriction of pump capacity. These ratios were compared with other ratios reported in Ethiopia. Abebe, (2015) a case study of Shina-Hamusit and Selamko irrigation schemes, reported that the values of irrigation ratios as 96 and 94% respectively. And these values indicated that the schemes tested in this study show better performance.

4.6.4.2. Sustainability of irrigated area

Sustainability of irrigated area is indicative of whether the area under irrigation is contracting or expanding with reference to the nominal area initially developed and is estimated by equation (3.24). As indicated in Figure 4.8 Maishawsh scheme was expanded by 6% from the initial irrigated area but Midmar irrigation scheme was contracted by 2% from the initial irrigated area. The same reasons given for irrigation ratio, namely, restriction due to pump capacity was the main reduction for Midmar irrigation ratio. The sustainability of irrigated areas in Maishawsh and Midmar schemes shows better performances comparing with other result reported in Ethiopia by Zeleke et al., (2012) showed maximum irrigated area reduction of 20% for Wedecha irrigation scheme in Godino and Gohaworki sub system but expansion of 22% for Golgota irrigation scheme was better than from Maishawsh and Midmar irrigation schemes.

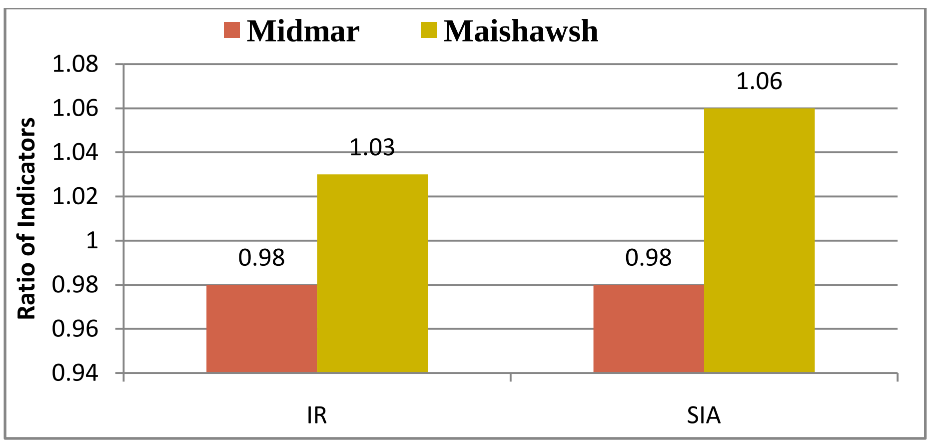


Figure 4.8: Irrigation Ratio and Sustainability Irrigated Area indicators of both schemes

4.6.5. Financial indicator

4.6.5.1. Gross return on investment

To estimate the gross return costs of irrigation structures were obtained from original costs of design documents. The documents of Maishawsh scheme included the cost of weir and cost of canals and for Midmar, cost of Check dam pond, Pump, transformer and power house were included. The cost of irrigation structures were estimated as Present Value of Worth, through the average interest rate of the service years. The base year taken to estimate the Net Present Worth is the year 2016/17, with a service years of 4 for both schemes. The values of GIR were computed using equation (3.25) and summarized in Table 4.19 and Figure 4.9. Gross return on investment estimated as 91.50% and 91% for Midmar and Maishawsh schemes respectively.

Table 4.19: Gross Investment cost of the irrigation systems

Scheme	Irrigated area (ha)	Service year	Structure cost (birr)	Structure cost (birr/ha)	Cost in PNW (birr/ha)	Production (birr/ha)	GIR (%)
Midmar	23.65	4	1718596.9	72667.94	88328.34	80794.50	91.50
Maishawsh	61.75	4	3881812.62	62863.36	76410.81	69746.56	91.00

PNW = Present Net Worth value, $F=P(1+r)^n$, r = interest rate (%), n= number of service year, p=initial structure cost, F= present net cost, GRI-gross return on investments.

The results indicated that Midmar has slightly higher gross return on investment than Maishawsh, due to high initial cost at Maishawsh scheme. These results were lower compared with other country results such as, 108% in Turky by Molden et al., (1998) but these irrigation schemes almost the same compared to other schemes in Ethiopia 91% for Nuraera by Beshir and Bekele (2004).

4.6.5.2. Financial self sufficiency

Financial self sufficiency indicates that the revenue from irrigation over the expenditure for operation and maintenance. Each members of beneficiary at Midmar scheme charged 10 birr per hour (10 birr per 129 m^3 water) during irrigation season for electric power consumption, 120 birr per household per season for administration of the motor pump and 150 birr per season for pump operation and maintenance. And the beneficiary of Maishawsh scheme charged 50 birr per household per season for the operation and maintenance. But in both schemes, there was no financial support from the government or other donors for operation and maintenance. As indicated in Table 4.20 at Midmar irrigation scheme large amount of money has been charged by the beneficiaries for operation and maintenance. This expenditure was spent to cover electric consumption and daily management of Pump while in Maishawsh irrigation scheme small value spent for main canal maintenance.

Table 4.20: Financial self sufficiency Indicator

No	Parameter	Midmar	Maishawsh
1	Revenue from irrigation service fee (birr)	5,400	1900
2	Total operation and maintenance expenditures	7,864	2450
3	Financial Self sufficient (FSS) (%)	69	77

Where, Revenue from irrigation is the revenue generated fees, or other locally generated income after operation and maintenance fee, and total operation & maintenance expenditures are the amount expended locally through operation & maintenance plus outside subsidies from the government. But all costs were collected from the water users/farmers for both schemes.

As indicated in Table 4.20 and Figure 4.9 financial self sufficiency of Maishawsh scheme was 77% while Midmar scheme was 69% using equation (3.26). Therefore, financial self sufficiency Maishawsh scheme was higher than Midmar irrigation scheme. These results were better compared with other results of 51% in Tono irrigation scheme (Thomas et al., 2016).

The diversion weir is 4 years old and until now there was no failure on the system and the secondary canals were maintained by water users. Therefore, the total income collected from the beneficiaries at Midmar was much larger than Maishawsh & total running cost was also higher at Midmar.

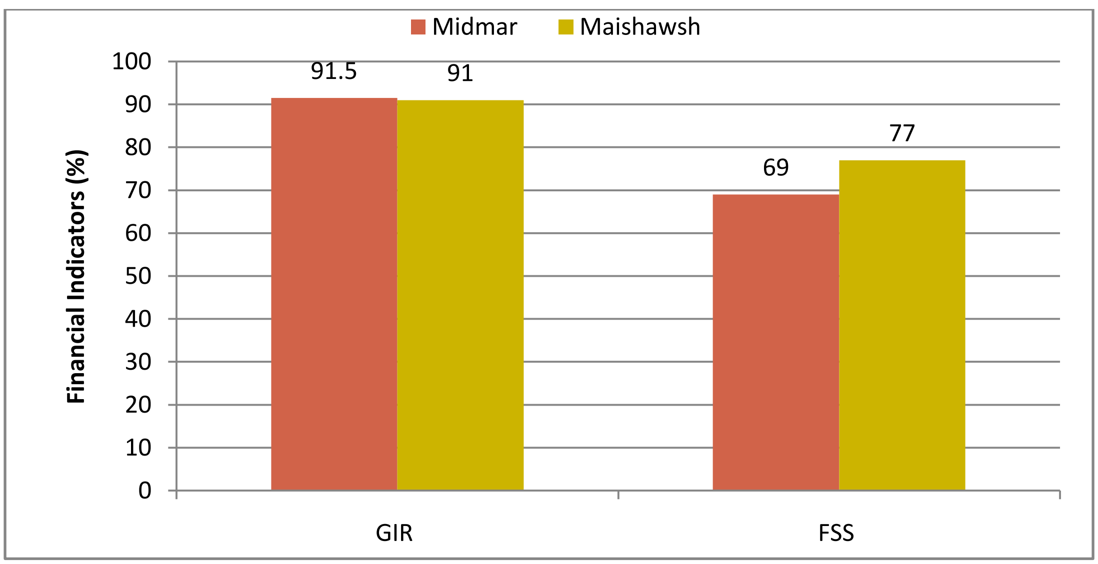


Figure 4.9: Gross investment return and financial self sufficiency indicators for both schemes

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

This study carry out to evaluate the comparative performance indicators, such as irrigation water use efficiency, agricultural output, water supply performance, physical and financial indicators as a tool to assess the performance of small-scale irrigations selected in the Mereb sub basin.

Primary data collections prepared and incorporated through field observations, measurements of flow rate in canal and at field level, determination of moisture content of the soils at selected irrigation fields before and three day after irrigations using 2 inch parshal flume to measure the depth of water applied to the specified areas of both schemes were determined.

The parameters used to compare the efficiencies at field level were application, storage, distribution and the overall scheme efficiencies with an average result of 76, 64.16, 93.40 and 46.72% for Midmar while 56.83, 70, 94.24 and 42.74% for Maishawsh scheme computed respectively. In both irrigated areas onion was a dominant crop during the irrigation season (56%) for Midmar and (48%) for Maishawsh irrigation schemes was covered then it was taken as representative in measurement irrigation efficiencies. The conveyance efficiencies were also estimated by measuring the dimension of average length and flow rate of main, secondary and tertiary canals using floated method. In Maishawsh irrigation scheme, the average results of main, secondary and tertiary canals were obtained 98.95%, 91.03%, and 75.21% respectively whereas in Midmar irrigation scheme has an average conveyance efficiency of 76.89%.

Secondary data collection has been performed through group discussions and interviews with water users, DA and government officials. The secondary data include total yields, prices of irrigated crops, area irrigated per crop per season, crop types, crop pattern and design documents of both irrigation schemes were collected.

The agricultural productions are; output per unit command area, outputs per unit cropped area, outputs per unit water consumed and outputs per unit irrigation supply of the two irrigation schemes were evaluated and the values were in the order of 3461.58 $/ha, 3512.8 $/ha, 0.61

$/m^3 and 0.36 $/m^3 for Midmar whereas 3120.91 $/ha, 3032.46 $/ha, 0.54 $/m^3 and 0.25 $/m^3 for Maishawsh irrigation schemes respectively. The values of RWS and RIS were 1.8 and 1.85 for Midmar while, they were 2.29 and 2.37 for Maishawsh schemes respectively.

According to the result of physical indicators, the ratio of IR and SIA were the values of 0.98 and 0.98 in Midmar while 1.03 and 1.06 in Maishawsh scheme respectively. The values of GRI and FSS were in order of 91.50 and 69% for Midmar where as 91 and 77% for Maishawsh irrigation schemes respectively.

5.2. Conclusions

- As observed to the field during irrigated, on-farm irrigation water management were generally poor and significant losses of water especially from Maishawsh irrigation scheme due to the absence of flow controlling systems.
- The relative water supply and relative irrigation supply for both schemes shows that there was a maximum value, this implies that the amount of water diverted during irrigation was high, but does not mean that the amount of water applied to the field during irrigation was much higher than the required water by crops, because the application efficiency of Maishawsh was poor, due to loss of water at tertiary canal (almost 58% of water irrigation was lost).
- Based on the land and water productivity, Midmar irrigation scheme was better than Maishwsh scheme, but for the water supply performance indicators of Maishwsh was better than Midmar scheme.
- The financial self sufficiency of Maishawsh was better than Midmar irrigation scheme, therefore, the income generated from the farms to the purpose of operation and maintenance was little money for the main canal and the beneficiary participated in the secondary canal clearing by their own good feeling without any expenditure. In Midmar scheme, spent large money for operation and maintenance costs. But Midmar irrigation scheme has better experience in collecting fee for water
- Irrigation ratio was showed that expansions or contractions of irrigated areas are attributed to water management responsibilities and reliability of irrigation water supply. This was confirmed by a contraction of area at Midmar Scheme by about 2% and expansion of area by about 3% at Maishwsh Scheme. The reasons for expansion at Maishwsh scheme is due

to construction of large scale dam at the upper catchment results excess availability of water through a season.

- In general, based on the performance indicators, Midmar irrigation scheme was slightly better than Maishawsh, especially by water management at field level and agricultural output. And, this study result will used to identify the performance gaps and can be used further evaluation has to be carried out in the surrounded area.

5.3. Recommendations

- In order to improve the conveyance efficiency of the system unlined canal should be lined canal.
- For Midmar irrigation scheme additional pump to be needed as a reserve and will be substitute if it is necessary or during technical problem.
- Strengthen water use association that can manage illegal breaching of canals and have good control.
- Introduce high value crops such as groundnut to other areas,

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LIST OF APPENDIX TABLES

Appendix 1: Comparative performance indicators

Indicators of Irrigated Agricultural Output and water supply

- **Midmar Irrigation Scheme**

Total rainfall at Midmar irrigation scheme = NCWR – NIR = 563.33 – 530.91 = 32.42 mm. The capacity of motor pump is 35.835 lit/sec and 12 hrs pumped in a day (2nd Nov – 1st Apr = 150 days) = 0.035835 m^3/sec*150*12*60*60 = 232,210.80 m^3/season and

Diverted Irrigation = $\frac{\text{Total diverted water}}{\text{Irrigated cropped area}} = \frac{232{,}210.80\ m3}{23.65*10000\, m2}$ = 981.86 mm

Land productivity

- Output per unit cropped area = $\frac{\text{Production}}{\text{Irrigated cropped area}} = \frac{1910790}{23.65} = 80{,}794.50\,\frac{\text{birr}}{\text{ha}}$
- Output per unit command area = $\frac{\text{Production}}{\text{Command cropped area}} = \frac{1910790}{24} = 79616.25\,\frac{\text{birr}}{\text{ha}}$

Water productivity

- Output per Irrigation supply = $\frac{\text{Production}}{\text{Diverted Irrigation supply}} = \frac{1910790}{232{,}210.80} = 8.23\,\frac{\text{birr}}{m3}$
- Output per unit water Consumed = $\frac{\text{Production}}{\text{Volume of Water Consumed by ET}} = \frac{1910790}{133{,}227.54}$ = 14.34 birr/m^3

Water Supply Indicators

- Relative Water Supply = $\frac{\text{Total Water Supply}}{\text{NCWR}} = \frac{(\text{Irrigation Diverted} + \text{Total Precipitation})}{\text{NCWR}}$

  RWS = $\frac{981.86\ mm + 32.42\,mm}{563.33}$ = 1.8
- Relative Irrigation Supply = $\frac{\text{Irrigation applied}}{\text{Irrigation requirement}} = \frac{981.86}{530.91}$ = 1.85

- The total agricultural output and water supply of Maishawsh irrigation scheme was calculated with the same procedure of Midmar scheme.

Appendix 2: Climate data for Maishawsh and Midmar Irrigation Schemes

Table 1: Average monthly climate data estimated from CLIMWAT 2.0 Software

Month	Min. Temp (°C)	Max. Temp (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine hour (hr)	ETo (mm/day)
January	7.4	26.20	69	104	9.60	3.53
February	8.00	27.5	65	112	10.0	4.11
March	11.50	29.2	61	130	9.60	4.76
April	13.30	30.10	69	131	10.10	5.11
May	13.80	29.7	63	147	10.40	5.37
June	13.60	26.7	60	147	9.50	4.93
July	13.3	23.3	96	138	6.30	3.22
August	14.60	23.2	97	138	5.0	2.92
September	12.10	25.2	74	130	9.10	4.21
October	9.80	27.2	79	155	10.10	4.21
November	8.10	28.2	92	104	9.10	3.49
December	6.50	26.7	83	95	9.10	2.23
Average	11	26.93	76	128	9.00	4.09

Table 2: Average monthly Rainfall and Effective Rainfall of both schemes from 2003 to 2016

Month	Rainfall (mm)	Effective Rainfall (mm)
Jan	2.2	2.2
Feb	2.4	2.4
Mar	19.6	19
Apr	26.4	25.3
May	28	26.7
Jun	85.7	73.9
Jul	256.2	150.6
Aug	245.2	149
Sep	69.1	61.5
Oct	15.7	15.3
Nov	2.7	2.7
Dec	5.2	5.3
Average	758.50	533.9

Effective rainfall calculated using the USDA.SCS formulas;

Eff. R. = ((125 – 0.2*Total Rainfall)*Total Rainfall)/125……If total rainfall < 250 mm/month)

Eff. R. = 0.1*Total Rainfall + 125 ………If total rainfall > 250 mm/month

Appendix 3: CWR and IR for Maishawsh Scheme from CROPWAT 8

Table 1: Crop and irrigation water requirements for onion

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.92	26.3	1.6	24.5
Nov	2	Deve	0.71	2.82	28.2	0.2	28.0
Nov	3	Deve	0.84	3.17	31.7	0.7	31.0
Dec	1	Deve	0.99	3.56	35.6	1.6	34.0
Dec	2	Mid	1.07	3.68	36.8	2.0	34.8
Dec	3	Mid	1.07	3.80	41.8	1.6	40.2
Jan	1	Mid	1.07	3.93	39.3	1.0	38.3
Jan	2	Mid	1.07	4.05	40.5	0.6	39.9
Jan	3	Mid	1.07	4.25	46.8	0.7	46.1
Feb	1	Mid	1.07	4.45	44.5	0.3	44.2
Feb	2	Late	1.07	4.64	46.4	0.0	46.4
Feb	3	Late	1.03	4.70	37.6	2.1	35.5
Mar	1	Late	0.96	4.61	46.1	4.8	41.3
Mar	2	Late	0.88	4.44	44.4	6.8	37.7
Mar	3	Late	0.80	4.15	45.7	7.3	38.4
Total					591.7	31.4	560.1

Table 2: Crop and irrigation water requirements for tomato

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	2	Init	0.60	2.37	7.1	0.1	7.1
Nov	3	Init	0.60	2.27	22.7	0.7	21.9
Dec	1	Init	0.60	2.17	21.7	1.6	20.0
Dec	2	Deve	0.61	2.09	20.9	2.0	18.9
Dec	3	Deve	0.73	2.59	28.5	1.6	26.9
Jan	1	Deve	0.88	3.23	32.3	1.0	31.3
Jan	2	Deve	1.02	3.88	38.8	0.6	38.1
Jan	3	Mid	1.15	4.59	50.4	0.7	49.8
Feb	1	Mid	1.17	4.88	48.8	0.3	48.5
Feb	2	Mid	1.17	5.10	51.0	0.0	50.9
Feb	3	Mid	1.17	5.36	42.9	2.1	40.8
Mar	1	Late	1.16	5.59	55.9	4.8	51.1
Mar	2	Late	1.05	5.29	52.9	6.8	46.1
Mar	3	Late	0.90	4.66	51.2	7.3	43.9
Apr	1	Late	0.82	4.33	4.3	0.8	4.3
Total					529.4	30.4	499.8

Table 3: Crop and irrigation water requirements for groundnut

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	2	Init	0.40	1.38	6.9	1.0	5.9
Dec	3	Init	0.40	1.42	15.7	1.6	14.1
Jan	1	Deve	0.40	1.48	14.8	1.0	13.8
Jan	2	Deve	0.54	2.06	20.6	0.6	19.9
Jan	3	Deve	0.77	3.07	33.8	0.7	33.1
Feb	1	Deve	1.00	4.17	41.7	0.3	41.5
Feb	2	Mid	1.16	5.05	50.5	0.0	50.4
Feb	3	Mid	1.17	5.34	42.7	2.1	40.6
Mar	1	Mid	1.17	5.61	56.1	4.8	51.3
Mar	2	Mid	1.17	5.87	58.7	6.8	51.9
Mar	3	Late	1.16	6.02	66.2	7.3	58.9
Apr	1	Late	1.02	5.42	54.2	7.9	46.3
Apr	2	Late	0.80	4.35	43.5	8.6	34.9
Apr	3	Late	0.64	3.57	14.3	3.5	9.9
Total					519.5	46.2	472.4

Table 4: Crop and irrigation water requirements for maize

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	1	Init	0.30	1.08	9.7	1.5	8.1
Dec	2	Init	0.30	1.03	10.3	2.0	8.3
Dec	3	Deve	0.43	1.54	17.0	1.6	15.4
Jan	1	Deve	0.71	2.62	26.2	1.0	25.2
Jan	2	Deve	0.98	3.71	37.1	0.6	36.5
Jan	3	Mid	1.21	4.80	52.8	0.7	52.2
Feb	1	Mid	1.23	5.13	51.3	0.3	51.0
Feb	2	Mid	1.23	5.36	53.6	0.0	53.5
Feb	3	Mid	1.23	5.64	45.1	2.1	43.0
Mar	1	Late	1.21	5.82	58.2	4.8	53.4
Mar	2	Late	1.04	5.23	52.3	6.8	45.5
Mar	3	Late	0.83	4.27	46.9	7.3	39.6
Apr	1	Late	0.66	3.51	17.6	3.9	13.6
Total					478.1	32.7	445.3

Appendix 4: Crop and irrigation water requirements for Midmar Scheme

Table 1: Crop and irrigation water requirements for Onion

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.93	26.3	1.6	24.5
Nov	2	Deve	0.71	2.82	28.2	0.2	28.0
Nov	3	Deve	0.84	3.18	31.8	0.7	31.0
Dec	1	Deve	0.99	3.57	35.7	1.6	34.0
Dec	2	Mid	1.07	3.68	36.8	2.0	34.8
Dec	3	Mid	1.07	3.81	41.9	1.6	40.3
Jan	1	Mid	1.07	3.93	39.3	1.0	38.3
Jan	2	Mid	1.07	4.06	40.6	0.6	39.9
Jan	3	Mid	1.07	4.25	46.8	0.7	46.1
Feb	1	Mid	1.07	4.45	44.5	0.3	44.3
Feb	2	Late	1.07	4.65	46.5	0.0	46.4
Feb	3	Late	1.03	4.70	37.6	2.1	35.5
Mar	1	Late	0.96	4.61	46.1	4.8	41.3
Mar	2	Late	0.88	4.45	44.5	6.8	37.7
Mar	3	Late	0.80	4.15	45.7	7.3	38.4
					592.3	31.4	560.6

Table 2: Crop and irrigation water requirements for Tomato

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	2	Init	0.60	2.37	7.1	0.1	7.1
Nov	3	Init	0.60	2.27	22.7	0.7	22.0
Dec	1	Init	0.60	2.17	21.7	1.6	20.0
Dec	2	Deve	0.61	2.10	21.0	2.0	19.0
Dec	3	Deve	0.73	2.60	28.6	1.6	27.0
Jan	1	Deve	0.88	3.23	32.3	1.0	31.3
Jan	2	Deve	1.02	3.88	38.8	0.6	38.2
Jan	3	Mid	1.15	4.59	50.5	0.7	49.8
Feb	1	Mid	1.17	4.88	48.8	0.3	48.6
Feb	2	Mid	1.17	5.10	51.0	0.0	51.0
Feb	3	Mid	1.17	5.37	42.9	2.1	40.8
Mar	1	Late	1.16	5.59	55.9	4.8	51.2
Mar	2	Late	1.05	5.29	52.9	6.8	46.1
Mar	3	Late	0.90	4.66	51.3	7.3	43.9
Apr	1	Late	0.82	4.33	4.3	0.8	4.3
Total					529.9	30.4	500.3

Table 3: Crop and irrigation water requirements for cabbage

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	2	Init	0.70	2.41	7.2	0.6	7.2
Dec	3	Init	0.70	2.49	27.4	1.6	25.9
Jan	1	Deve	0.71	2.63	26.3	1.0	25.3
Jan	2	Deve	0.84	3.19	31.9	0.6	31.3
Jan	3	Deve	1.00	3.97	43.6	0.7	42.9
Feb	1	Mid	1.07	4.46	44.6	0.3	44.3
Feb	2	Mid	1.07	4.66	46.6	0.0	46.5
Feb	3	Mid	1.07	4.90	39.2	2.1	37.1
Mar	1	Mid	1.07	5.14	51.4	4.8	46.6
Mar	2	Mid	1.07	5.39	53.9	6.8	47.1
Mar	3	Mid	1.07	5.53	60.8	7.3	53.5
Apr	1	Late	1.04	5.50	55.0	7.9	47.2
Apr	2	Late	0.98	5.33	32.0	5.2	27.7
Total					520.0	38.9	482.6

Table 4: Crop and irrigation water requirements for Groundnut

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	2	Init	0.40	1.38	6.9	1.0	5.9
Dec	3	Init	0.40	1.43	15.7	1.6	14.1
Jan	1	Deve	0.40	1.48	14.8	1.0	13.8
Jan	2	Deve	0.54	2.06	20.6	0.6	20.0
Jan	3	Deve	0.77	3.08	33.8	0.7	33.1
Feb	1	Deve	1.00	4.18	41.8	0.3	41.5
Feb	2	Mid	1.16	5.05	50.5	0.0	50.5
Feb	3	Mid	1.17	5.34	42.7	2.1	40.6
Mar	1	Mid	1.17	5.61	56.1	4.8	51.3
Mar	2	Mid	1.17	5.87	58.7	6.8	52.0
Mar	3	Late	1.16	6.02	66.2	7.3	58.9
Apr	1	Late	1.02	5.42	54.2	7.9	46.4
Apr	2	Late	0.80	4.35	43.5	8.6	34.9
Apr	3	Late	0.64	3.57	14.3	3.5	9.9
Total					519.9	46.2	472.8

Appendix 5: soil moisture content

Table 1: Soil moisture content of before and after irrigated for Midmar scheme

Field code	Soil depth (cm)	Before Irrigation		After Irrigation		Moisture Before Irrigation (%)	Moisture After Irrigation (%)	Moisture Stored (%)	Water Stored in root zone (mm)
		Before oven dry (gram)	After oven dry (gram)	Before oven dry (gram)	after oven dry (gram)				
Field-1	0 – 30	168.81	145.48	175.4	140.44	16.04	24.89	8.89	26.57
	30 – 60	175.68	153.94	170.77	146.2	14.12	16.81	2.68	8.05
Field-2	0 – 30	165.82	150.44	182.88	155.04	10.22	17.96	7.73	23.20
	30 – 60	171.62	151.24	174.34	149.93	13.48	16.28	2.81	8.42
Field-3	0 – 30	167.82	152.44	188.29	160.05	10.09	17.64	7.56	22.67
	30 – 60	176.26	158.62	176.43	154.35	11.12	14.31	3.18	9.55

Table 2: Soil moisture content of before and after irrigated for **Maishawsh** scheme

Field code	Soil depth (cm)	Before Irrigation		After Irrigation		Moisture Before Irrigation (%)	Moisture After Irrigation (%)	Moisture Stored (%)	Water Stored in root zone (mm)
		Before oven dry (gram)	after oven dry (gram)	Before oven dry (gram)	After oven dry (gram)				
Field-1	0 – 30	169.56	148.98	188.44	160.64	22.61	28.33	5.72	17.15
	30 – 60	180.89	159.04	176.54	153.55	21.50	23.43	1.93	5.79
Field-2	0 – 30	178.30	155.36	192.75	162.49	24.45	30.84	6.39	19.16
	30 – 60	189.05	161.34	181.50	153.32	26.84	28.72	1.88	5.65
Field-3	0 – 30	183.36	160.95	195.70	166.74	23.66	29.51	5.85	17.56
	30 – 60	189.34	162.99	184.99	157.8	26.00	27.71	1.71	5.13

Table 3: Soil physical characteristics of Midmar and Maishawsh schemes

Field Code	Soil depth (cm)	Particle size distribution (%)			Textural Class	FC (%)	PWP (%)	TAW (%)	TAW (mm)
Midmar Scheme									
		Sand	Silt	Clay					
Head	0 – 30	58	22	20	Sandy loam	22.30	12.34	9.96	29.88
	30 – 60	52	28	20	Sandy loam	24.19	12.97	11.22	33.66
Middle	0 – 30	52	31	17	Sandy loam	19.68	9.59	10.07	30.21
	30 – 60	53	29	18	Sandy loam	20.84	10.92	9.92	29.76
Tail	0 – 30	32	44	24	Loam	20.27	8.39	11.88	35.64
	30 – 60	36	38	26	Loam	19.10	7.04	12.06	36.18
Maishawsh Scheme									
Head	0 – 30	34	30	36	Clay loam	29.28	16.56	12.72	38.16
	30 – 60	36	26	38	Clay loam	30.50	17.69	12.81	38.43
Middle	0 – 30	28	32	40	Clay Loam	30.40	19.37	11.03	33.09
	30 – 60	32	34	34	Clay Loam	32.08	21.43	10.65	31.95
Tail	0 – 30	32	28	40	Clay loam	29.78	18.6	11.18	33.54
	30 – 60	36	32	32	Clay loam	29.23	18.03	11.20	33.60

Appendix 6: Conveyance Efficiency and Losses at Maishawsh & Midmar schemes

Table 1: Main canal of Maishawsh

Canal Reach	Observation	Length each segment (m)	Q_{in} (lit/sec)	Q_{out} (lit/sec)	E_c (%)	Water loss (lit/sec/m)	Remark
Head reach	1	100	66.05	66.05	100	0.0	Lined Canal
	2	150	65.79	65.41	99.43	0.004	
	3	150	65.78	65.22	99.14	0.004	
Average		133.33	65.87	65.56	99.53	0.0013	
Middle reach	1	120	65.97	65.18	98.81	0.007	Lined Canal
	2	160	65.06	64.47	99.09	0.004	
	3	150	62.28	61.71	99.09	0.004	
Average		143.33	64.44	63.79	98.99	0.005	
Tail reach	1	200	60.93	60.18	98.77	0.004	Lined Canal
	2	100	59.13	58.58	99.06	0.0055	
	3	200	59.75	58.05	97.16	0.0085	
Average		166.67	59.94	58.94	98.34	0.006	
Total Average		148	63.42	62.52	98.95	0.005	

Table 2: Secondary canal of Maishawsh

Canal Reach	Observation	Length each segment (m)	Q_{in} (lit/sec)	Q_{out} (lit/sec)	E_c (%)	Water loss (lit/sec/m)	Remark
Secondary canal-1	1	250	36.97	33.94	91.82	0.012	Lined Canal
	2	150	31.89	29.37	92.08	0.017	
	3	100	30.03	26.80	89.25	0.012	
	4	120	28.69	25.58	89.16	0.026	
Average		155	31.89	28.925	90.58	0.017	
Secondary canal-2	1	110	30.33	28.05	92.50	0.021	Lined Canal
	2	160	26.59	24.15	90.81	0.015	
	3	200	26.96	24.55	91.07	0.012	
Average		156.67	27.96	25.58	91.49	0.016	
Total Average		156	29.925	27.25	91.035	0.017	

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Table 3: Tertiary canal of Maishawsh

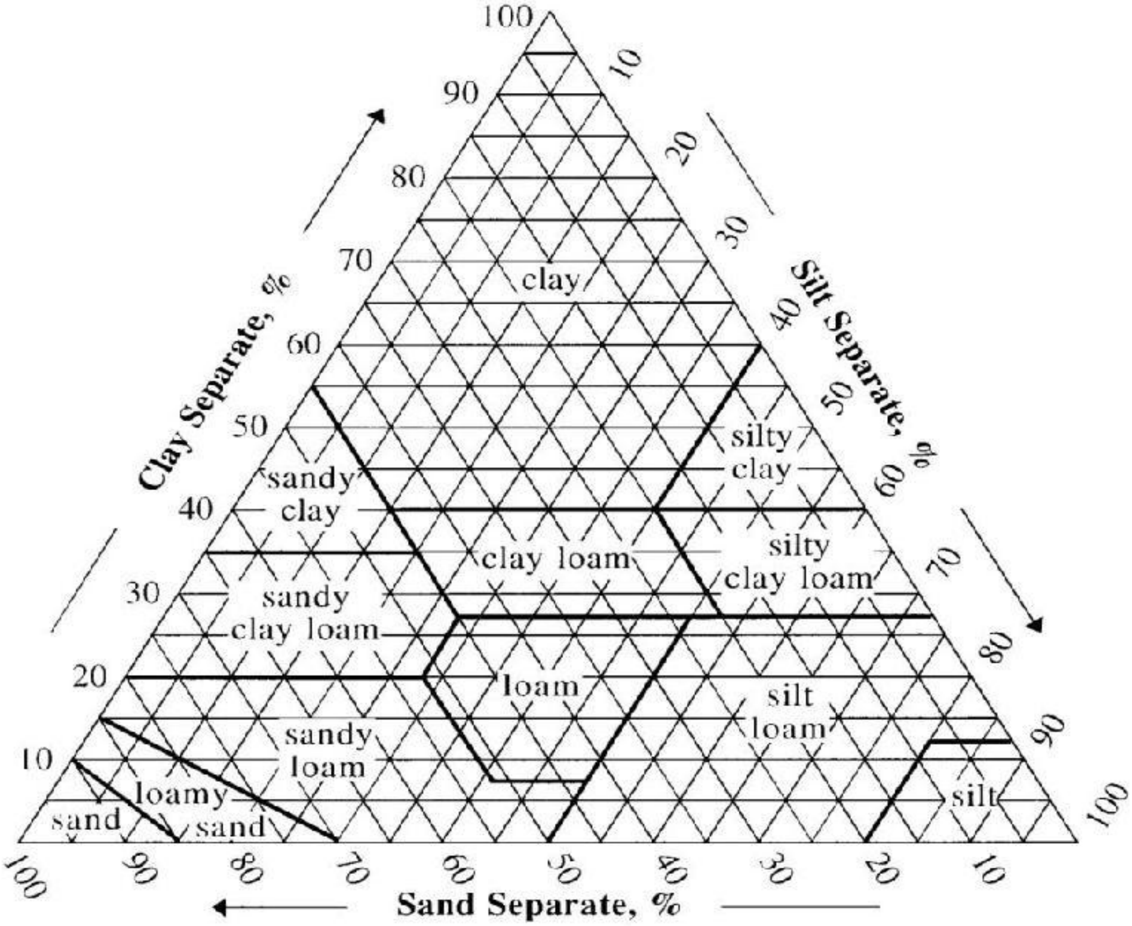
Canal reach	Observation	Length each segment (m)	Q_{in} (lit/sec)	Q_{out} (lit/sec)	E_c (%)	Water loss (lit/sec/m)	Remark
Tertiary canal-1	1	120	20.84	16.53	79.33	0.036	unlined canal
	2	160	16.85	12.90	76.53	0.025	
	3	200	15.24	11.76	77.16	0.017	
	4	150	9.45	7.20	76.17	0.015	
Average		157.5	15.59	12.10	77.30	0.023	
Tertiary canal-2	1	200	18.99	14.85	78.20	0.021	unlined canal
	2	150	13.25	10.15	76.58	0.021	
	3	200	12.69	9.46	74.54	0.016	
	4	150	8.32	6.16	74.07	0.014	
	Average	175	13.31	10.155	75.85	0.018	
Tertiary canal-3	1	180	24.98	19.08	76.36	0.033	unlined canal
	2	265	19.49	14.69	75.35	0.018	
	3	140	12.20	9.19	75.31	0.022	
	4	125	8.95	6.64	74.20	0.019	
Average		177.5	16.40	12.40	75.305	0.023	
Tertiary canal-4	1	160	19.32	14.66	75.89	0.03	unlined canal
	2	220	14.47	10.98	75.88	0.016	
	3	130	9.58	6.90	72.00	0.021	
Average		170	14.46	10.85	74.59	0.022	
Tertiary canal-5	1	150	12.16	9.12	75.00	0.0203	unlined canal
	2	200	8.46	5.94	70.22	0.013	
	3	100	6.0	4.43	73.84	0.016	
Average		150	8.87	6.5	73.02	0.016	
Total Average		166	13.73	10.40	75.21	0.020	

Table 4: Earthen canal at Midmar scheme

Canal reach	Observation	Length each segment (m)	Q_{in} (lit/sec)	Q_{out} (lit/sec)	E_c (%)	Water loss (lit/sec/100m)	Remark
Canal-1	1	100	35.56	27.96	78.63	0.076	Earthen canal
	2	100	26.98	20.01	74.18	0.07	
Average		100	31.27	23.985	76.41	0.073	
Canal-2	1	100	36.11	28.52	78.97	0.076	Earthen canal
	2	100	27.46	20.80	75.76	0.067	
Average		100	31.785	24.66	77.37	0.072	
Total Average		100	31.53	24.32	76.89	0.0725	

LIST OF APPENDIX FIGURE

Appendix figure 1: Output data collection from beneficiary



Appendix figure 2: USDA soil texture triangular method