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MASTER OF THESIS ON:

ASSESSMENT OF BOJI TIKA SMALL-SCALE IRRIGATION WATER CONVEYANCE PERFORMANCE IN AMBO DISTRICT

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BY

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JIMMA, ETHIOPIA

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DECLARATION

I, the undersigned, declare that this entitled assessment of Boji Tika small-scale irrigation water conveyance performance in Ambo District is my original work, has not been presented for a degree in this or any other university and that all sources of materials used for the thesis have been fully acknowledged.

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ABBREVIATIONS

ACC	Actual Canal Capacity
AGP	Agriculture Growth Program
a.s.l	above sea level
CRS	Catholic Relief Service
CCSA	Central Statistics Authority
DIDA	District Irrigation Development Authority
DU	Distribution Uniformity
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FC	Field canal
FMIS	Farmer Managed Irrigation System
Gr.Irr	Gross Irrigation
IDD	Irrigation Development Division
IWR	Irrigation Water Requirement
LRMC	Lined Rectangular Main Canal
MoA	Ministry of Agriculture
MoWR	Ministry of Water Resource
Net Irr	Net Irrigation
O and M	Operation and maintenance
PPIR	Peak Irrigation Requirement
RAM	Readily Available Moisture
RPIP	Research Program on Irrigation Performance
SC	Secondary canal
SSI	Small-Sale Irrigation
TAM	Total Available Moisture
TC	Tertiary Canal
WDC	Water Delivery Capacity
WUA	Water Users Association

Table of Contents

List of Tables

List of Figures

ABSTRACT

The level of performance of irrigation system is one of the most important issues that need to be addressed in Ethiopia. This study was carried out at Boji Tika small-scale irrigation to characterize and identify existing irrigation practices in terms of assessment of performance indices and water productivity for future improvements. The farmers in Boji Tika irrigation scheme have long experiences in irrigation, attained from traditional knowledge. The irrigation scheme has 60 ha of irrigable area. The criteria for selection were its nearness to Ambo Research Center, availability of secondary data and organizational set up. Collecting primary and secondary data of each irrigation scheme has been carried out by the study. Primary data collection included canal water flow measurement and physical structure status. The secondary data collection has been carried out in collaboration with government officials, of irrigated crops, area irrigated per crop per season or per year, crop types, maintenance and operation cost. Conveyance efficiency and delivery capacity efficiency were the selected performance indicators for evaluation. Main canal conveyance efficiencies for 30 m canal reaches at two locations for lined canal and 200 m at various location for unlined canal were 92.05 % and 77.8 % respectively. The corresponding canal losses were in the order of 0.092 and 0.019 l/s per unit meter length.

For future improvement of efficiencies and overall water productivity of the scheme proper design and layout of appurtenant structures, guidance and support farmers in arresting serious threat of gulley on water control, operate training farmers and improvement of physical structures of the scheme are essential.

Performance assessment of small scale irrigation is the systematic observation, documentation and interpretation of the management of an irrigation system, with the objective of ensuring that the input of resources, operational schedules, intended outputs and required actions proceed as planned.

Keywords: Cropwat8.0; small-scale irrigation; conveyance efficiency; conveyance loss; Boji Tika

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

With steady increase of the global population, the contribution of irrigation towards increasing agricultural production is enormous. Particularly, in some emerging and least developed countries irrigation development and use is a backbone to the extent that it is responsible for the nations' welfare and feeding the vast majority of their population. Agriculture depending on rainfall has failed to produce enough food, with increasing rainfall variability, productivity of rain fed agriculture is expected to diminish. The expected global agricultural water abstraction by 2050 would be about 14% higher than the abstraction in 2000 (FAO, 2006). Irrigation plays the key role in the performance of agriculture, which increases income growth. Income growth is essential for economic growth (Hussain I and Biltonen, 2001).

The World Bank, other development banks and numerous countries have invested in large irrigation projects, but there have been conflicting opinions about the wisdom of investing further in new irrigation projects as the performance of those developed has not been satisfactory. For instance, many large-scale irrigation systems have been constructed in the sub-Saharan Africa ccountries in the past, but their performance record indicated a failure against anticipated benefits. As a result of shortcomings of these large-scale irrigation systems, and with the expected continued growth of irrigation development, there is increasing tendency to promote small-scale irrigation instead.

The estimated irrigation potential of Ethiopia is 4.3 million hectares of which only 247,470 ha is currently developed. This breaks into 138,339 ha (55.9%) traditional irrigation schemes, 48,074 ha (19.4%) modern small-scale irrigation and 61,057 ha (24.67%) covered by modern medium and large-scale irrigation schemes (Tilahun Haile and Paulos Dubale, 2004). This shows that 75% of the irrigated area is under small-scale traditional and modern schemes.

It can be generalized that, even though the country has a substantial potential for irrigated agriculture assessed both from available land and water resource view point, the bulk of this potential is still untouched. Concerted effort is underway by the government of Ethiopia to expand irrigation of all categories including rain-water harvesting with the prime purpose of overcoming the problem of food insecurity, extreme rural poverty, and to promote economic dynamism.

Ethiopia has considerable development potential. Its endowment of land and water resource is adequate relative to its population. Much of Ethiopia is suitable for crop and livestock production. However, Ethiopian agriculture has been characterized by small scale subsistence production system where crop and livestock yields are very low (Berhanu, 2006).
The research aimed to evaluate the hydraulic and water delivery performance in the small-scale irrigation scheme with the objectives of evaluating the existing operation rules and proposing alternative options for more effective operation and water saving. In this scheme, the research made special emphasis on the hydraulic (water distribution) aspects of the performance. Moreover, the research also carried out irrigation performance assessment and irrigation service evaluation in the community managed scheme. External comparative performance and irrigation service delivery to farmers were the major concerns of this research on these schemes.

1.2. Problem Statement

The need for optimum development of water resources has become more urgent than ever due to the rapid growth in population and constraint of not to utilizing all the available resource to the required extent. Irrigation is productivity enhancing, growth promoting, and poverty reducing. The majority of existing traditional and modern irrigation schemes are micro level in size, usually serving households not more than 300 in number. Many of these schemes use diverted stream or river water and fewer schemes use small dams or perennial springs as their water source. These traditional and modern small scale irrigation systems may be described as forms of farms' cooperatives. Each beneficiary has access to water on equal basis, and however, equity in the water distribution needs a strong attention. In sub Saharan Africa more land is going out of irrigation each year than can be developed for irrigation because of the difficulty of planning and conducting sustainable schemes.

In Ethiopia, inadequate attention to factors other than engineering and projected economic implication of small scale irrigation schemes has led to difficulties on sustainable irrigation development (CRS, 1999). Decision to construct dam or upgrade traditional irrigation systems have often been made in the absence of sound objective assessment of their environmental and social implication (CRS,1999). SSI has a potential to meet the demand for food security, agricultural diversity and productivity. There is a considerable experience with small scale irrigation but the extent and potential has not been quantified and documentation is sparse (CRS, 1999). Information on water requirement of crops, the input, and the environmental effect are hardly available. Even if much data may be available they may not be accurate and reliable (CRS,1999). The government of Ethiopia plans to expand irrigation of all categories including rain-water harvesting with the prime purpose of overcoming the problem of food insecurity, extreme rural poverty, and to promote economic dynamism (FDRE, 2010). In line with the development objective of the country, the regional government of Oromia is also promoting SSI development, so as to increase and stabilize food production in the region. It is with this aim that Boji Tika small scale irrigation was developed from traditional water use to modern scheme in Kiba Kube Kebele (village), Ambo District,West Showa zone of Oromia Region with the budget from Agriculture Growth Program (AGP) in 2012.

The analysis of project design papers reported that, improving farmer welfare can be achieved, if schemes are designed properly, constructed properly and managed according to specific set of key management objectives, which must be achieved within the context of effective organizational coordination and farmer participation (Elias, 2011).

One of the pressing challenges of the intervention in SSI development made in Ethiopia in general and in Oromia in particular, focused only on improving and expansion of the physical structure of existing traditional small-scale irrigation schemes. That is why sustainability of existing small scale irrigation schemes is not as anticipated as the planning and appraisal stages (Leliso, 2008).This is a problem for professionals in the water sector that the country's limited resources are allocated to reduce the chronic food security problem, but could not result in the desired change.

Hence, it is clear that there is a lot to be done in search for some set of institutional, social, environmental and practices under which we feel confident that, the system will continue to exist and function, at least for the time intended during the planning stage of the project by understanding the past and current situation of the scheme. Therefore, this specific research is designed to generate location specific data on water conveyance performance of SSI scheme in the area and this is the driving force for this research.

1.3 Objective of the study

The general objective of this research is to study the performance of water conveyance of Boji

Tika small scale irrigation scheme in Ambo District, Oromia Regional State, Ethiopia.

Specific Objective of the Study

- To characterize the irrigation scheme
- To investigate the performance of canal systems.
- To assess the problems on existing irrigation water management practices and technical capabilities of the operational staffs on the scheme.

Research Questions

1. How to characterize the irrigation scheme?
2. What the performance problem of canal system?
3. What are the existing irrigation water management and operation problem?

1.4 Significance of the Study

One of the present day issues of the Government of Ethiopia is, to increase the national economy through Agriculture lead Industrialization. To this end, the irrigable land farms in the country are contributing at large on providing the industrial crops to the growing agro-industries of the country. Therefore, the wide application of small scale & large-scale irrigation development is one of considerable solutions. Furthermore, the increasing computation among the limited land and water resources leads to the development, monitoring and evaluation of irrigated agricultures. This particular research make a bit contribution to existing stock of knowledge and practice on water conveyance performance of SSI schemes in Kiba Kube Area. It is also essential to analyze the past nature of the performance of irrigation schemes, besides new developments, so that these schemes are considered as a reference tool in the current program of agricultural production scaling.

1.5 Scope and limitation of the study

The study specifically focuses on assessing water conveyance performance condition of Boji Tika small scale irrigation schemes in Ambo District. It is delimited to Boji Tika small scale irrigation schemes. Hence, the results and finding on the problem and improved situation are the reflection of the study area which may be difficult to replicate to other areas of the regions. In addition, performance of irrigation scheme is a multidimensional and dynamic concept, which is the result of interaction of various factors over a long period of time; it was difficult to carry in-depth investigation. Despite these limitations, the study is expected to generate valuable information which may be of great use to different stakeholders.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Irrigation

Irrigation is defined as the ministering of land through the artificial application of water to ensure double cropping as well as steady supply of water in areas where rainfall is unreliable (Mutsvangwa, 2006). Irrigation is assumed to be a major contributor to the increase in food production that changed countries like Bangladesh and India from famine-prone regions to food-surplus regions (Hassain I. and Hanjra, 2003). Apart from producing crops, irrigation systems in developing countries are vital to rural livelihoods, providing water for livestock and fish production, domestic use and many small enterprises. The primary reason for irrigation was to improve agricultural productivity in areas where surface soils are naturally drier.

Irrigation is a process that uses more than two-thirds of the Earth's renewable water resources and feeds one-third of the Earth's population. According to the same source 2.4 billion people depend directly on irrigated agriculture for food and employment. Irrigated agriculture thus plays an essential role in meeting the basic needs of billions of people in developing countries. Although water resources are still ample on a global scale, serious water shortages are developing in the arid and semi-arid regions (Hall, 1999).

There is a need to focus attention on the growing problem of water scarcity in relation to food production. The World Food Summit drew attention to the importance of water as a vital resource for future development. A major part of the developed global water resources is used for food production. The estimated minimum water requirement per capita is 1200 m^3 annually (50 m^3 for domestic use and 1150 m^3 for food production) (FAO, 1996).

Sustainable food production depends on judicious use of water resources as fresh water for human consumption and agriculture become increasingly scarce. To meet future food demands and growing competition for clean water, a more effective use of water in both irrigated and rain fed agriculture will be essential. Options to increase water-use efficiency include harvesting rainfall, reducing irrigation water losses, and adopting cultural practices that increase production per unit of water.

Irrigation is an obvious option to increase and stabilize crop production. Major investments have been made in irrigation over the past 30 years by diverting surface water and extracting groundwater. The irrigated areas in the world have, over a period of 30 years, increased by 25 % (mainly during a period of accelerated growth in the 1970s and early 1980s (FAO, 1993).

2.1.1 Small-Scale Irrigation

Small-Scale irrigation can be defined as irrigation, usually on small plots, in which small farmers have the controlling influence, using a level of technology which they can operate and maintain effectively. Small-Scale irrigation is, therefore farmer managed: farmers must be involved in the design process and, in particular, with decisions about boundaries, the layout of the canals, and the positions of outlets and bridges. Although Some SSI systems serve an individual farm household, most serve a group of farmers, typically comprising between 5 and 50 households (Stern, 1979). Many development organizations believe small-scale irrigation methods are an effective way to increase food production.

According to (FAO, 2003), smallholder irrigation development has shown throughout the developing world that it can be used as a key drought mitigation measure and as a vehicle for the long-term agricultural and macroeconomic development of a country. Successful smallholder irrigation schemes can result in increased productivity, improved income and nutrition, employment creation and food security.

2.2 Water resources and irrigation development of Ethiopia

It is believed that Ethiopia has a total volume of 123 billion cubic meters of surface water and about 2.6 billion cubic meters of groundwater. The distribution is not, however, uniform. The western half of the country receives sustainable amounts of precipitation and has many perennial rivers and streams while the precipitation is marginal in the eastern half of the country. The Ethiopian plateau is the source of the Abay, Awash, Tekeze, Mereb, Baro-Akobo and Omo rivers that flow to the west and southwest (Appendix table).

The Baro-Akobo basin is potentially the largest possible irrigable area (about 483 thousand hectares) though only a negligible portion of it has been developed probably because of the large investment cost required and its distance from the central market, which makes it less favorable for commercial agriculture. Awash River is the only river extensively used for commercial plantations of industrial and horticultural. Out of the total irrigated area of about 161,125 ha, over 43% is found in the Awash River basin. The remaining potential of the Awash River for irrigated agriculture is in the order of 136,220 ha (McCornick et al., 2003).

2.2.1 Irrigation Development in Ethiopia

The Ethiopian government has committed itself to irrigation development several years ago. Before concentrating on the history and policies of irrigation development in Ethiopia, a look on the African water resource development is taken. Since the 1960s many of Africa's river systems were dammed for irrigation, hydropower or flood control purposes. River basin development planning and large-scale water projects dominated the water resource development. Authoritarian interventionist states, supported by international donors, adopted mainly technological top-down approaches in order to satisfy the food, energy and water needs of their populations.

The need of developing irrigation for crop production is acquiring more and more attention in Ethiopia in response to the growing demand for agricultural produce. In general, Ethiopia receives an annual rainfall apparently adequate for food crop and pasture production. However, the distribution of rain varies from region to region. Much of the eastern part of the country receives very little rain while the western areas receive adequate rainfall. Production of sustainable and reliable food supply is almost impossible due to the temporal and spatial imbalance in the distribution of rainfall and the consequential non- availability of water at the required period. Sometimes, even the western highlands of the country suffer from food shortage owing to the discrepancies in the rainfall distribution (MoWR, 2002).

Attempts have been made by the government to address the food security problems through preparation of relevant agricultural development policies and programs. However, low level of water use efficiencies are among the major constraints for development as well as operation of all water sectors including irrigation (MoWR, 2002). Prior to 1974, private investment in agriculture had increased due to the government's policy of encouraging the development of commercial farming in sparsely populated lowland areas of the country. Irrigated commercial farms made a start in the Awash Valley through either, land acquisition, agreement made with the local leaders, or government concessionaire arrangements.

From 1974 to 1991, no large scale private capital investment was committed as a result of the prohibition of private land ownership or rental of land on commercial scale by the land reform proclamation of 1975 as per the then socialist policy adopted by the Government. During this period public capital expenditure concentrated on the development of state farms and producer cooperatives which contributed for less than 10 percent of the total production during that period (Fekadu et al., 2000)

The Military Government nationalized the rural lands and commercial farms, and changed the existing commercial farms together with newly established farms (mainly rain fed farms), into state owned enterprises. It was considered as a way out to address the problem of food self-insufficiency and to earn foreign currency.

Consequently, commercial farm development during this regime was practically nonexistent. On the other hand, development of small scale irrigation was encouraged to be effected by the local farmers to cope with recurrent droughts (Fekadu et al., 2000)

The attempt by the government to enhance the participation of individual peasants in small scale irrigation development had been considered earlier throughout the 1970s and 1980s; but the results were below expectations. Though the Government has been providing irrigation infrastructure free of charge and the infrastructure development progressed well, but putting the schemes into production at optimum level was very disappointing, and in some instances only 10 % of the developed areas were put into production (Fekadu et al., 2000).

Under the current agriculture led economic development plan of the country, focus is being made on irrigation development by harnessing the natural resources. According to the estimates made in the year 1991, the areas under small scale comprised of 6400 ha while the areas under medium and large scale were 112,105 ha. These areas account only 3.4 percent of the total food crop production of the country. If the country is to curtail the recurrent food deficit caused by draught and persisting population pressure, relevant measures have to be taken to improve the productivity of rain fed as well as irrigated agriculture (MoWR, 2002).

The current development has been focusing on the development of small scale irrigation. To address the problem of food security, and to meet the demands of food and fiber requirement, the country has prepared a fifteen year plan to develop additional 273,829 ha of land, which is an increase of 135 percent of the currently irrigated land. A country wide total area of 1,057 small scale schemes having a combined area of 80,667 ha have been planned for development by various stakeholders during the short and medium planning horizons.

Based on the command area it serves irrigation in Ethiopia is classified in to three classes: small, medium, and large scale irrigation schemes. The small, medium and large scale possesses command area of below 200 hectares, between 200 and 3000, and above 3000 hectares, respectively (MoWR, 2001).

2.3 Performance Assessment of small-scale Irrigation System

Irrigation system performance assessment needs a framework to adequately guide the work and for the stakeholders to effectively use the outcomes from performance assessment. The purpose of the framework is to form a link between repeated actions in such a way as to provide a learning experience for the manager that allows things to be done better in each successive iteration (Bos et al., 2004). The framework defines why the performance assessment is needed, what data are required, what methods of analysis will be used, who is the performance assessment for, etc. (BOS et al., 2005). Performance assessment is based on collection, analysis and interpretation of data related to irrigation management and irrigation service delivery. Performance assessment of irrigation management can be operation performance and strategic performance.

The principal objective of evaluating surface irrigation systems is to identify management practices and systems that can be effectively implemented to improve the irrigation efficiency. Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year (FAO, 1989). The performance of any irrigation system is the degree to which it achieves desired objectives. As many farmer managed irrigation scheme do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge,1993). The evaluation of surface irrigation at field level is an important aspect of both management and design of the system.

Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989). Public agencies in many developing countries want to assist farmer-managed irrigation systems improve their performance through better management. And, better management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives (Oad R. and R. K. Sampath, 1995). Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions. The development potential for small-scale irrigation seems attractive in view of cost effectiveness, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and setbacks that hinder the introduction of small-scale irrigation.

2.3.1 Irrigation Performance Indicators

Identification of irrigation performance essentially has to incorporate all aspects of the irrigated agricultural system including institutional setups, resources used, services delivered and agricultural outputs. Performance indicators can be broadly categorized into internal and external indicators to describe the above mentioned aspects. Internal indicators are used to assess the performance of the internal processes and irrigation services. They are concerned with operational procedures of the systems, institutional setups for management, irrigation infrastructure and water delivery services. Internal indicators enable comprehensive understanding of the processes that influence water delivery service and the overall performance of a system (Renault and Wahaj, 2007). Hence, they are useful to show what would have to be done to improve the internal and hence the external performance. External indicators on the other hand evaluate inputs and outputs to and from irrigation schemes. They are generally meant to evaluate the efficiency of resource use (land, water, finance) in irrigated agriculture. External indicators can be best used as part of a strategic performance assessment and benchmarking performance of schemes (Burt and Style, 2004). An irrigation system, consisting of a water delivery and a water use subsystems, can be conceptualized to have two sets of objectives. One set relates to the outputs from its irrigated area, and the second set relates to the performance characteristics of its water delivery system summarizes the performance indicators currently used in the Research Program on Irrigation Performance (RPIP) (Oad and Sampath, 1995). Within this program field data are measured and collected to quantify and test about 40 multidisciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance and sustainability of irrigation, environmental aspects, socio-economic and management. He also noted that it is not recommended to use all described indicators under all circumstances. The number of indicators that should be used depends on the level of detail with which one needs to quantify (e.g., research, management, information to the public) performance and on the number of disciplines with which one needs to look at irrigation and drainage (water balance, economics, environment, management).

2.3.1.1. Water use performance indicators

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

2.3.1.2. Physical performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Among those reason water scarcity and input availability are the main reason why lands in command area are not fully under irrigation in a particular season. From physical performance irrigation ratio and water delivery ratio are the two main indicators.

2.3.2 Comparative Irrigation Performance Evaluation

Comparative performance indicators enable to see how well irrigated agriculture is performing at different scales, i.e. at the scheme, basin, national or international scales. Comparative performance has a set of advantages for stakeholders in the irrigation and drainage sector, including policy makers, irrigation managers, researchers, farmers and donors. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year (FAO, 1989).

The performance of any irrigation system is the degree to which it achieves desired objectives. As many FMIS do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993). The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989)

2.4 Irrigation Efficiency

Irrigation efficiencies can be measured in many ways and also vary in time and management (Roger et al., 1997). Very "efficient" system by some definitions can be very poor performers by other definition. (Lesley W, 2002) supplemented this idea and explained it as the public's perception of irrigation efficiency is focused mostly on water use, whereas farmer's perception relates more to production. For this reason, it is unrealistic to use one all-encompassing definition. For instance, where water is very short, efficiency may be measured as crop yield per cubic meter of water used, or profit per millimeter of irrigation. It depends what you want to know. (Michael, 1997) stated that the primary performance indicators are: storage efficiency, application efficiency and distribution uniformity. According to (James, 1988), the performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm. (Mishra and Ahmed, 1990) also said that irrigation efficiency indicates how efficiently the available water supply is being used, based on different methods of evaluation. The objective of these efficiency concepts is to show where improvements can be made, which will result in more efficient irrigation.

2.4.1. Conveyance efficiency

Significant volume of water is lost by the networks of the conveyance canals due to seepage and evaporation depending on the nature of the soil and agro-climatic zone in which the canals are located. Conveyance efficiency is defined as the ratio of the amount of water that reaches the field to the total amount of water diverted into the irrigation system.

The concept can also be viewed as the evaluation of the water balance of the main, lateral and sub-lateral canals and related structures of the irrigation system (Rust and Snellen, 1993). It is 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 (Bos, 1997). 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 where the main canals are long and unlined. The amount lost depends on quality of operation, and maintenance, and the nature of the soil that affects the seepage rate.

In general, (Kamara and McCornick, 2003) states that all small-scale systems may have advantages over large-scale systems. These advantages include that small-scale technology can be based on farmers existing knowledge; local technical, managerial and entrepreneurial skills can be used; migration or resettlement of labor is not usually required; planning can be more flexible; social infrastructure requirements are reduced; and external input requirements are lower.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location, Topography and Climate

Boji Tika irrigation scheme is found in Kiba Kube Peasant Association, Ambo District, Oromia Regional state at a distance of 140 km from Addis Ababa and 20 km to south of Ambo town. The source of Irrigation water for the land farm is Boji Tika River by diversion weir. The scheme head work is located at 0373302 E longitude and 0984662 N latitude, and an altitude of 2384 m a. s.l. The annual average rainfall from 15 years (2001-2015) near the study site recorded at Ethiopian Agricultural Research Institute (EARI), Ambo Plant Protection Center station was 1461.5 mm. The mean annual minimum and maximum temperature are 8.62^{o}c and 27.89^{o}c respectively. The Boji Tika irrigation scheme was established by a Non-governmental organization called Agricultural Growth Program (AGP). The irrigation scheme was developed in 2012 with total investment cost of 593,488.53 ETB funded by AGP . Then, in 2015 a maintenance work, with additional cost of 171,233 ETB, was undertaken. The scheme was intended to provide food and jobs to the local people. It covers 60 hectares and with 103 household beneficiaries. The canal system is both lined and unlined. The lined canal width of 0.6 m and a depth of 0.6 m was designed to convey water to the field.

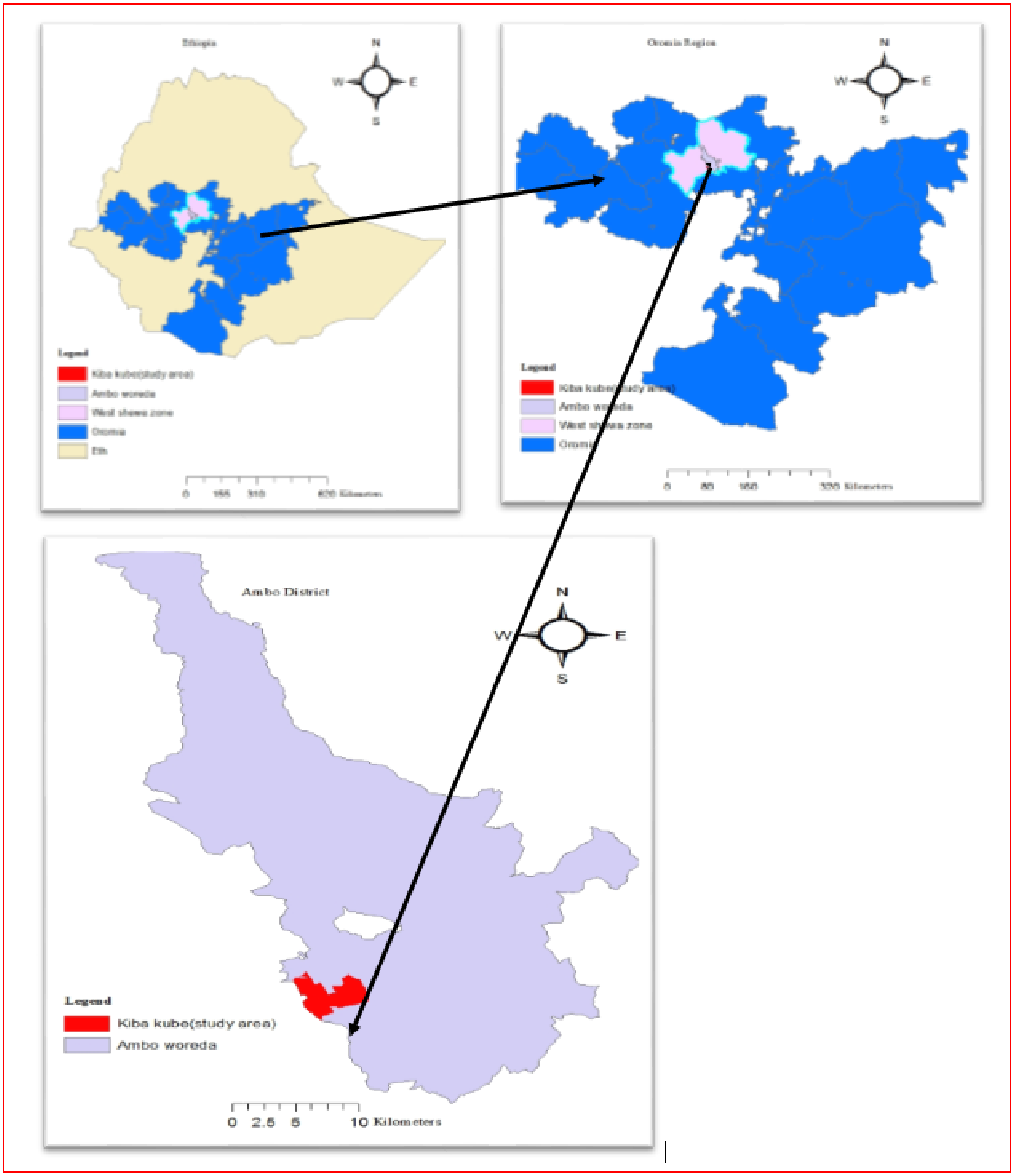

Figure 3.1 Location of study area

Table 3. 1 meteorological data (2001-2015)

Month	**Rainfall (mm)**	**Min Tem (^{0}C)**	**Max Tem (^{0}C)**	**Sunshine (hours/day)**	**R.hum.(%)**	**Wind speed(km/hr**
Jan.	14.5	8.9	26.2	6	55	1.5
Fab.	13.2	10.1	28.6	7.2	47	1.5
Mar.	67.2	11.2	29.2	5.1	51	1.8
Apr.	53.4	11.6	28.2	4.1	53	1.6
May.	99.5	11.2	28.4	7.8	62	11.2
Jun.	169.8	11.5	12.8	3.4	62	0.6
Jul.	230.2	10.9	24.6	2.9	73	11.8
Aug.	216.2	10.3	23.8	3.8	75	0.6
Sep.	100.9	10.2	24.6	0.7	69	0.7
Oct.	27.6	9	25.9	6.4	57	1.1
Nov.	304.7	8.2	26.2	5.1	54	17.3
Dec.	164.3	8.5	26.1	4.7	57	1.3

The research methodology followed at the Boji Tika irrigation scheme is as follows:

- Flow measurement with floating method and stage-discharge in the main supply canals to assist in evaluation of water supply indicator;
- Interview water users and technical experts of the scheme office on the level of irrigation service;
- Evaluation of performance with selected performance criteria;
- Development an adequate water management set up for the irrigation scheme that would enhance irrigation service. Figure 2.1 shows a simplified conceptual framework of this research.

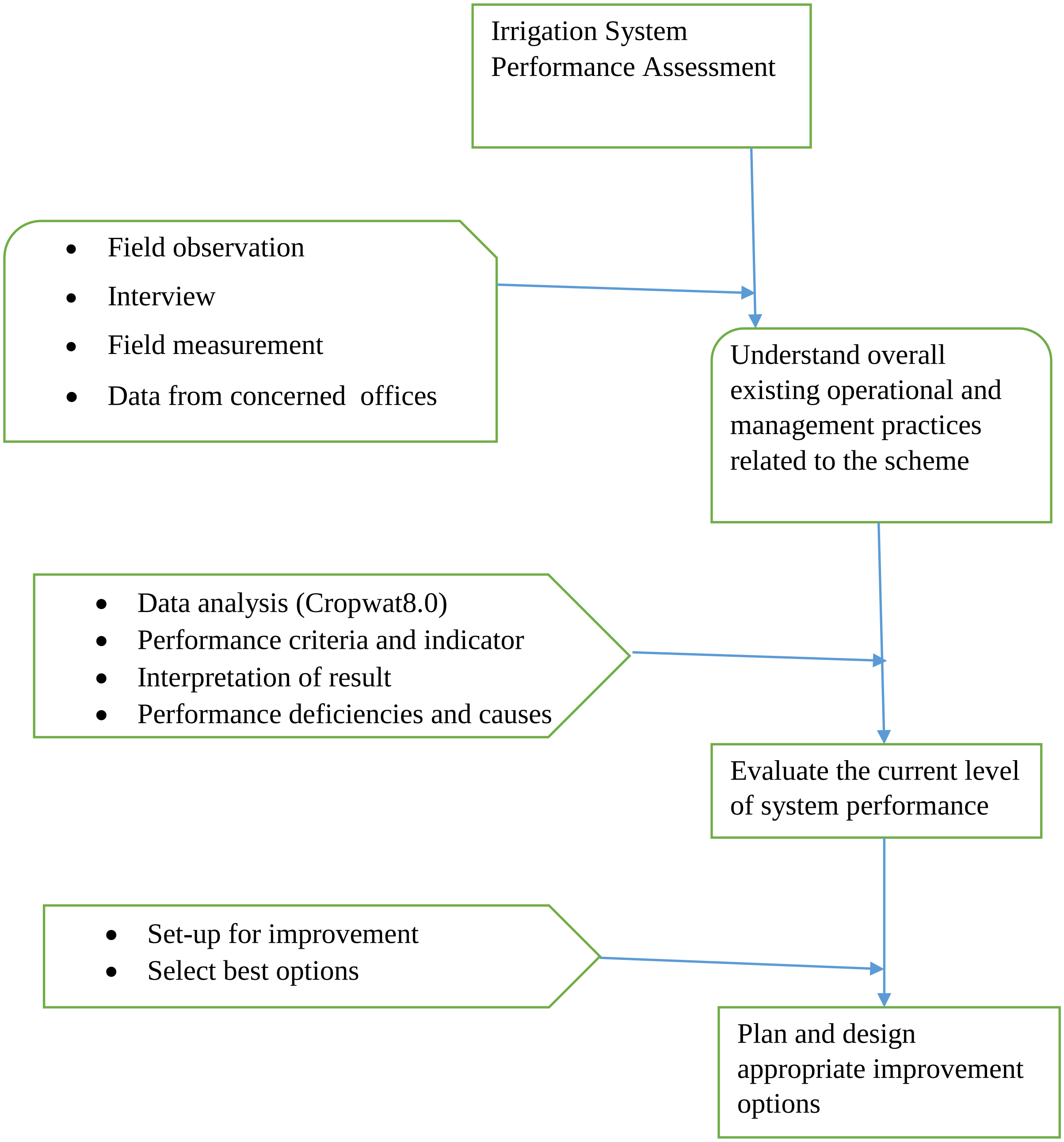

Figure 3.2 Simplified conceptual framework of the research

Figure 3.3 Lined Canal of the Scheme

3.2 Research Design

A case study research design was used in this study. It is designed to bring out the details from the viewpoint of the participants by using multiple sources of data. The most important with case studies according to (Yin, 2003) is to explain the causal links in real life intervention, describe the real life context in which an intervention has occurred and evaluate the intervention itself.

3.3. Primary and Secondary Data Collection

During the study period, regular visits and observations were made to assess the method of water applications and practices related to water management at the study sites. A structured interview schedule supported by personal observations of physical features was used to collect primary data.

3.3.1 Primary Data Collection

Primary data collection tools were used by the researcher to collect data from the field whereby interviews and observations were employed.

3.3.1.1 Interview

The researcher used interview to extension officers in order to solicit information regarding the contribution of small scale farmers' irrigation schemes in enhancing rural livelihood. According to the interview tool is very important source of getting information and it is helpful in handling case study related matters as the research design indicates.

3.3.1.2 Observation

The researcher used direct observation method to prove the information obtained from interview. It is stated that through structured observation, rich information and awareness about a phenomenon can be obtained. The eye witness in real situation assists the researcher to justify what to be revealed from the interview while observing the behaviors of respondents when performing their activities. The reason for using this method was its ability to obtain faithful answers from the respondents exactly when performing their jobs and making sure that what was observed is what is reported (Bryman, 2004).

3.3.2 Secondary data collection method

The researcher used different documents in order to access accurate and reliable data. Documents comprised of personal profiles (for small scale holder farmers), guidelines and directives (regarding irrigation techniques), policies and regulations (regarding irrigation agriculture), books and journals (used as literatures) and performance reports (quarterly and annual reports) obtained from the District Irrigation Development Authority (DIDA).

3.4 Data Analysis

Data collected were analyzed both qualitatively (using content analysis) and quantitatively. These data were summarized, coded and analyzed by Cropwat8.0. The collected data were also analyzed through description, interpretation and explanation. Tabulation and classification were used as the major method during data analysis. The analysis was generally based on the descriptive framework.

3.5. Canal Flow Measurement

The flow of Boji Tika River was measured using floating method used. The discharges of the main canals at selected points' were measured at the point required.

3.6. Estimation of Conveyance Efficiency

The conveyance efficiency was measured by taking the readings at locations 30 m apart for lined canal and 200 m for unlined canal. Based on the submergence ratio, inflow and outflow on the specified length of canal reaches were calculated. Then the conveyance loss in the specific length of canal reaches and the effective conveyance (Ec) ratio that represents the capability of a canal reach to carry water with loss were ratio that represents the capability of a canal reach to carry computed using equation bellow (Cui *et al.,* 2004):

$$l = Q_{in} - Q_{out} -- 3.1$$

$$Ec = \frac{Q_{out}}{Q_{in}} -- 3.2$$

Where l is conveyance loss, Q_{in} and Q_{out} are inflow and outflow in specified canal reached and E_c is effective conveyance ratio that represents the capability of canal reach to carry water with loss. Water with loss were computed using equations (3.1) and (3.2).

3.7 Crop Water Requirements and irrigation scheduling

3.7.1 Crop Water Requirement

Crop water requirements refer to the amount of water required to raise a successful crop with optimum yield in a given period or season. In another words crop water requirement is defined as "the depth of water needed to meet the water loss through evapotranspiration of a disease- free crop growing in large fields under no- restricted conditions including soil water and fertility and aimed at achieving full production potential of the crops under consideration. It comprises the water lost as evaporation from the crop field, water transpired and metabolically used by crop plants, water lost during application which is economically unavoidable, but can be reduced to some extent and the water used for special operations such as for land preparation and for leaching to bring the salinity level of the soil to salt tolerance level of the crop.

Water is one of the most critical inputs for obtaining maximum production of crops. Each crop has its own water requirement and maintains its own tolerance limits within which the moisture variations don't affect crop yields. Therefore, the moisture availability in the root zone of the crop could be maintained within the crop tolerance limits by adopting proper water management practices.

Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm/day or mm/period and this may be formulated mathematically as:

$$ET_{cr} = ET_O \times K.C. .... 3.3$$

To estimate the crop water requirements (CWR), irrigation scheduling and irrigation water requirement (IWR) of the irrigated crops at field levels, and the irrigation schemes as a whole, the CROPWAT 8.0 was used (FAO, 1992).

3.8 Internal process indicators

The internal performance indicators of the scheme were computed based on field measured data. The conveyance efficiency of the scheme was computed by taking discharges measurement at different points. The measurements were taken at the initial and final points of main canals.

3.9 External performance indicators

The external or comparative performance of the scheme was evaluated using some selected comparative indicators, which are normally classified into four groups, namely agricultural, water use, physical and performance as standardized by IWMI (Molden et al., 1998). The design feasibility study documents of the irrigation projects were collected from the Ambo District Irrigation development Authority for Boji Tika irrigation projects and were used as a source of information on the performance assessment of the irrigation projects.

3.10. Materials

The following materials and equipment were utilized during the organization and carrying out of the research project:

GPS, Measuring tape, Stopwatch, Scientific Calculator, photograph camera.

Software: CROPWAT 8.0 and GIS 9.3.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Characterization of the Irrigation Scheme

4.1.1. Source of water

The source of water for the irrigation scheme is Boji Tika River. Though the scheme is the modern small scale irrigation scheme, there is diversion structure at the head and has one main canal (MC) at right hand side of the weir (Figure 1). Water is flow to the lined main canal which starts from the headwork (diversion weir) and runs 60 m and all the rest is unlined canal. Farmers don't practice night storage and irrigation water flows 24 hours. Farmers irrigate in 24 hours cycle (day shift and night shift).

Figure 4.1 Diversion weir and main canal structure of the study site.

From the design document, the design discharge of the river was 40 l/s. But the actual water during this study was 36 l/s at the inlet of main canals. The scheme potential area available for irrigation was 60 ha. The lined rectangular main canal (LRMC) 60 m from headwork and the rest is earthen main canal which supply water to secondary canal (SC).

Table 4.2 Characteristics of the community managed scheme.

Characteristics	Descriptions
Source of water	Boji Tika River
Means of water abstraction	River diversion
Irrigable area, ha	60
Number of beneficiary household	103
Major crops	potato, onion, tomato, pepper, redroot and cabbage

4.1.2. Conveyance System and Water Control Structures

The conveyance canal of irrigation project of the study area is at the right bank of the river. The main canals were the only canals included in design document. Other canals (Secondary, tertiary and field canals) were constructed traditionally. The chainage of the main canal area soil is almost the same but at some places the existing earthen main canal has hole underground, and some eroded land. Water regulator at the headwork (diversion weir) installed which is used to control the amount of water diverted to the main canal. It is operated by farmers during water released from diversion weir.

4 .2 Problems pertaining to conveyance structure

The conveyance and distribution systems consist of canals transporting the water through the whole irrigation system. Canal structures are required for the control and measurement of the water flow. During the assessment, the following poor functions of canals were observed:

a. Road crosses the canal at several places, cattle climbing in and out the canal and these led to disturb canal width deterioration, reduced flow and frequent disorder of irrigation supply, frequent maintenance and losses.
b. Distraction of main canal and secondary canals due to run off which comes from upstream of canal and erode and knockdown embankment canals led to continuous maintenance, frequent failure and pause of water supply and loss of land.
c. Silt deposited on diversion weir which comes from upstream of the weir and causes close canal intake, overtopping and led to reduce water flow in the canal and required operation

frequently.

There were a few water control structures in canal system in the form of culverts, division box, and Sluice gate. The type and number of structures found during the study are summarized in Table 4. 1.

Table 4. 2 1Irrigation control structures in the scheme

C. Structure	main canal	secondary canal	Total
Division box	1	0	1
Shutter	1	0	1
Sluice gate	1	0	1
Foot culvert	1	0	1

4.3 Irrigation Water Management in Small Scale Irrigation Schemes

4.3.1 Small Scale Irrigation Management Activities

Water distribution is the main issue in any irrigation schemes. The most important performance indicators in the distribution of irrigation water include adequacy, timeliness and equity in the supply of water. The WUA is the lowest organized structure established in the study area. The major tasks of the WUA are to decide on the schedule for water distribution, to plan and organize canal clearance, and to solve problems arising from using water in the scheme. The study identified that irrigation schemes has Water Users Association (WUA) that are responsible for coordinating the operation, maintenance work and distribution of water. The WUA has nominated an individual who is responsible to open gate as per the program of each farm households.

4.3.2 Evaluation of the Operational and Maintenance of the Scheme structures

The Boji Tika Irrigation Scheme has been the high priority given to operation and maintenance activities. The whole operation and maintenance of earthen canal is carried by farmers. The Scheme staffs are involved in regular maintenance structures. The short and long term existence of the community irrigation scheme depends on the contribution of members in operation and maintenance of the irrigation network. This requires the cohesion as well as the motivation of the users to assume the system is their own. This will contribute to the establishment of successful community based organizations that help the distribution of irrigation water, enforce rules and regulations, respect water turns and other social disciplines. In the irrigation scheme the operation and maintenance (O and M) activities is full responsibility of the beneficiary farmers. Seasonally the irrigation systems are rehabilitated and all maintenance works are carried before the arrival of the rainy season. In irrigation systems the O and M work is organized by the Water Users Association (WUA) of the scheme. During O and M work the beneficiary community rehabilitates all the communal structures. The structures rehabilitated by shared labor include the diversion weir, the main, secondary and the tertiary canal. The maintenance and rehabilitation of field canals of each plot is the responsibility of individual farmer.

Table 4. 3 operation and maintenance cost

Year	Operation	Maintenance	Maintained structure	Total
2012	7,210	1,081.5	unlined canal	8,291.5
2013	10,094	1,236	unlined canal	11,330
2014	15,450	1,390.5	unlined canal	16,840.5
2015	18,540	171233	Line canal& wing wall	189,773

4.4. Irrigation System Performance

4.4.1. Conveyance efficiency

An estimate of the amount of water that is lost or mismanaged in the conveyance system is required for effective management decisions and equitable water distribution. Thus it is important to know where the water is going within the conveyance system. The main canal conveyance efficiency was estimated using measured discharges at 30 m and 200 m interval for lined and unlined canal respectively. The average main canal conveyance efficiencies investigated in the segments of 30 m and 200 m canal length were 92.05% and 77.8% for lined and unlined canal respectively (Table 4.3). Conveyance efficiency and conveyance loss calculated using equation 3.1 and 3.2. The measurement of conveyance efficiency of lined and unlined canal expressed in appendix table 4.

Table 4. 4 Conveyance efficiency on main canal

Canal Name	Segment no.	dist. b/n point(m)	Inflow (l/s)	Out flow (l/s)	Conveyance loss		Conveyance Efficiency (%)
					(l/s)	(l/s/m)	
lined canal	1	30	36	33.4	2.6	0.087	92.8
	2	30	33.4	30.5	2.9	0.097	91.3
	average					0.092	92.05
unlined canal	1	200	21.7	17.3	4.4	0.022	79.7
	2	200	17.3	13.3	4	0.02	76.9
	3	200	13.3	10.2	3.1	0.016	76.7
	average					0.019	77.8

4.5. Irrigation Requirements of Major Crops in the Study Area

The seasonal crop and irrigation water requirements of the major crops (onion, tomato and potato, pepper and cabbage) grown in the study area during the study period as estimated by the CROPWAT 8.0 model, are indicated in Appendix Table.

Irrigation requirement of a crop refers to the amount of water needed to be applied as irrigation to supplement the water received through rainfall and soil profile contribution in meeting the water needed of the crop for optimum growth and yield. It may be net and gross irrigation requirements.

4.5.1. Gross Irrigation Requirements.

Not all water available at the head of a canal is available to fulfill the net irrigation requirements. Part of the water is lost during transport through the canals and in the field. The remaining part is stored in the root zone and eventually used by the plants. In other words, only part of the water is used efficiently, the rest of the water is lost for the crops on the fields that were to be irrigated. Gross irrigation requirement denotes the amount of the water diverted through the scheme inlet including all the losses during transportation and application. It includes the losses that may occur in conveyance systems and in the farm application systems (including losses to deep percolation, evaporation, and surface runoff). This can be determined at the outlet canal. The losses generally, depend on lined or unlined canal networks. The gross irrigation water requirement (Gr.Irr) determined using Cropwat8.0 as table 4.4

4.5.2. Net Irrigation Requirements

The net irrigation requirement (net water depth application) is the depth of irrigation water needed to replenish the soil water deficit at the effective root zone to field capacity. The net irrigation requirement for a crop maintained without water stress for any time period and determined using Cropwat8.0 as table 4.4

Table 4. 5 Result of Gross and Net Irrigation for the major crops at the study site.

Irrigation Requirement	Crop				
	Potato	Onion	Tomato	pepper	Cabbage
Gr.Irr (mm)	239.3	187.4	210.2	174.8	299
Net Irr.(mm)	167.4	131.2	147.2	122.3	209.2

The gross and net irrigation result of the major crops estimated using Cropwat8.0 (Appendix table).

4.6. Crop and Water Requirements of Major Crops

4.6.1. Crop and Irrigation Water Requirement of Onion

The crop and irrigation water requirement of onion crop was calculated using the CROPWAT8.0 Software. The computation result using the software indicated that total irrigation water requirement of onion was 176 mm. The effective rainfall which could be available for the plant use was 197 mm. Therefore, the net irrigation requirement of onion crop was 131.2 mm (Appendix Table). As indicated in le 4.5, the peak irrigation demand of the crop occurs in

January and February. This is because in these months the depth of water from effective rainfall available for plant use was almost nil (0 and 8 mm); hence the crop water demand was high.

Table 4. 6 Crop Water Requirements of Onion

Planting date: 01/12 Harvesting date: 25/03

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.45	1.14	11.4	46.5	0
Dec	2	Init	0.45	1.09	10.9	43.8	0
Dec	3	Deve	0.49	1.25	13.7	30.8	0
Jan	1	Deve	0.71	1.87	18.7	12.9	5.8
Jan	2	Deve	0.94	2.55	25.5	0	25.5
Jan	3	Mid	1.12	3.23	35.6	1.4	34.2
Feb	1	Mid	1.13	3.46	34.6	2.9	31.7
Feb	2	Mid	1.13	3.66	36.6	2.1	34.5
Feb	3	Mid	1.13	3.63	29	8	21
Mar	1	Late	1.04	3.32	33.2	16.6	16.6
Mar	2	Late	0.88	2.79	27.9	22.7	5.1
Mar	3	Late	0.76	2.37	11.8	9.4	1.6
	total				289	197	176

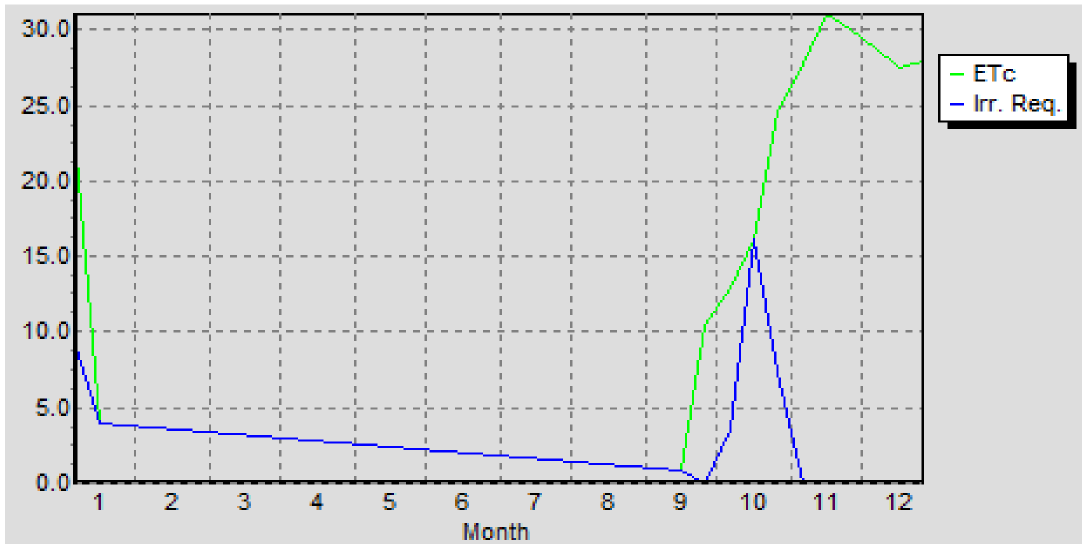

Figure 4.2 Crop Water Requirements Graph of Onion

4.6.2 Crop and Irrigation Water Requirement of Potato

The field survey showed that 25 % of the overall irrigated land was under potato. The irrigation water requirement and effective rain fall were calculated as illustrated in Table 4.6.

Table 4. 7 Crop Water Requirements of potato

Planting date: 01/12   Harvesting date: 04/03

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.5	1.27	12.7	46.5	0
Dec	2	Init	0.5	1.22	12.2	43.8	0
Dec	3	Deve	0.54	1.37	15	30.8	0
Jan	1	Deve	0.74	1.95	19.5	12.9	6.6
Jan	2	Deve	0.95	2.59	25.9	0	25.9
Jan	3	Mid	1.12	3.24	35.6	1.4	34.2
Feb	1	Mid	1.13	3.47	34.7	2.9	31.7
Feb	2	Mid	1.13	3.66	36.6	2.1	34.6
Feb	3	Mid	1.13	3.63	29.1	8	21
Mar	1	Mid	1.13	3.61	36.1	16.6	19.5
Mar	2	Late	1.04	3.3	33	22.7	10.3
Mar	3	Late	0.88	2.72	29.9	20.6	9.3
Apr	1	Late	0.75	2.26	9	6.4	1
	total				329.3	214.6	194.1

As it can be observed from Table 4.6 and Figure 21 that irrigation was needed throughout the growing season of the crop. The months of January and February were the peak period of water demand of potato crop. Hence the amount of peak irrigation demand during the months of January and February were 66.7 mm and 87.3 mm respectively. The total irrigation water requirement for the growing period of potato was 194.1 mm and the effective rainfall which is expected to be available for plant use was 214.6 mm.

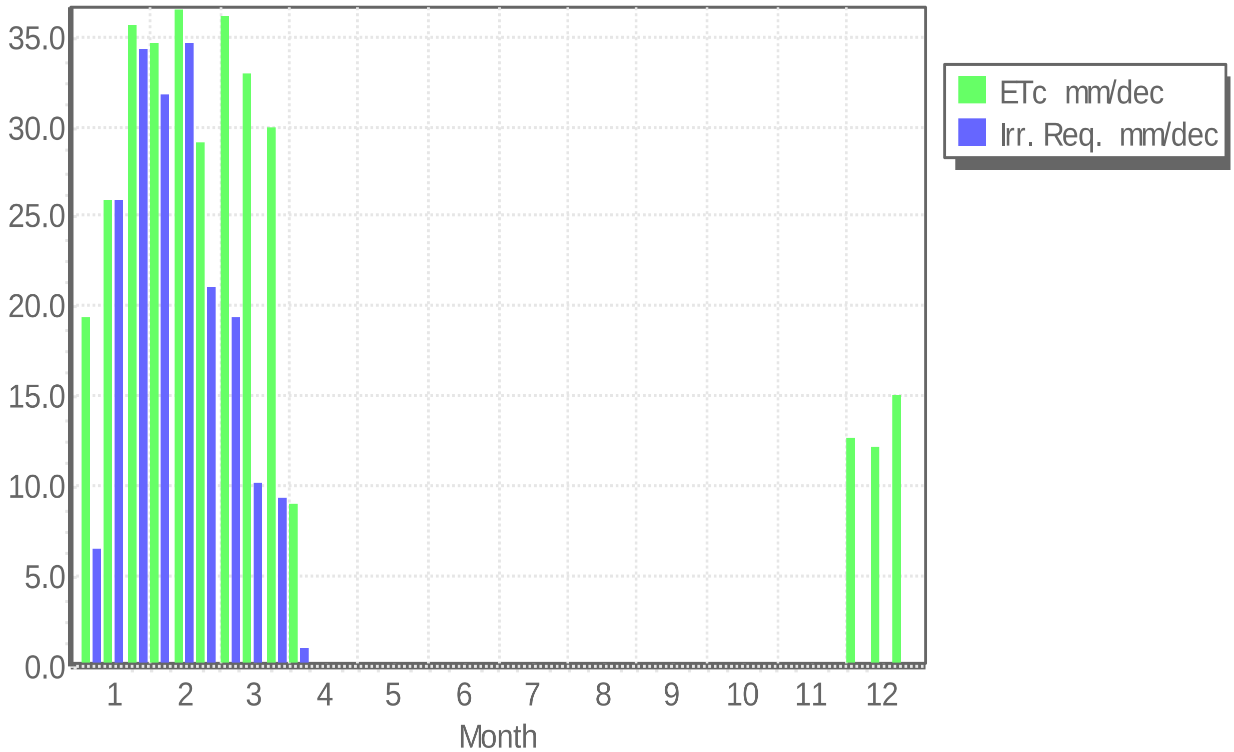

Figure 4.3 Crop Water Requirements Graph of Potato

4.6.3. Crop and Irrigation Water Requirement of Tomato

The field survey showed that 28 % of the overall irrigated land was under potato. The computation result using the software indicated that total irrigation water requirement of tomato was 183.2 mm. The effective rainfall which could be available for the plant use was 206.3 mm. Therefore, the net irrigation requirement of tomato crop was 147.2 mm (Appendix). As indicated in Table 4.7, the peak irrigation demand of the crop occurs in January and February. This is because in these months the depth of water from effective rainfall available for plant use was almost nil (0 and 1.4 mm); hence the crop water demand was high.

The irrigation water requirement and effective rain fall were calculated as illustrated in Table 4.7.

Table 4. 8 Crop Water Requirements of tomato

Planting date: 01/12 harvesting date: 30/03

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.6	1.52	15.2	46.5	0
Dec	2	Init	0.6	1.46	14.6	43.8	0
Dec	3	Deve	0.6	1.52	16.7	30.8	0
Jan	1	Deve	0.72	1.88	18.8	12.9	5.9
Jan	2	Deve	0.89	2.43	24.3	0	24.3
Jan	3	Mid	1.08	3.11	34.2	1.4	32.8
Feb	1	Mid	1.13	3.47	34.7	2.9	31.7
Feb	2	Mid	1.13	3.66	36.6	2.1	34.6
Feb	3	Mid	1.13	3.64	29.1	8	21.1
Mar	1	Late	1.11	3.54	35.4	16.6	18.8
Mar	2	Late	0.99	3.11	31.1	22.7	8.4
Mar	3	Late	0.84	2.63	26.3	18.7	5.7
	total				317	206.3	183.2

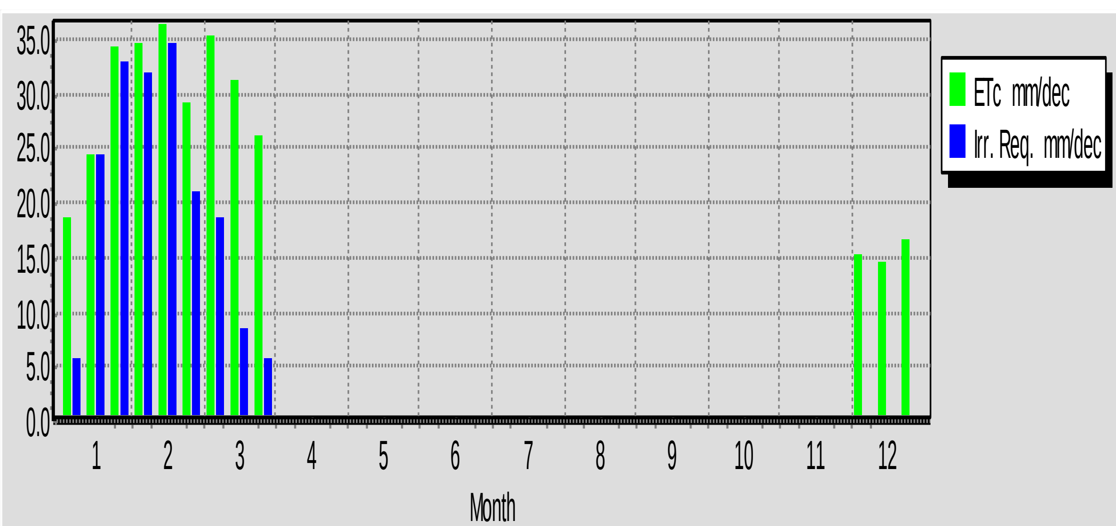

Figure 4. 4 Crop Water Requirements Graph of tomato

4.6.4. Crop and Irrigation Water Requirement of Pepper

The field survey showed that 11 % of the overall irrigated land was under potato. The irrigation water requirement and effective rain fall were calculated as illustrated in Table 4.8

As it can be observed from Table 4.8 and Figure 4.5, irrigation was needed throughout the growing season of the crop. The months of January and February were the peak period of water demand of pepper crop. Hence the amount of peak irrigation demand during the months of January and February were 54.9 mm and 78.2 mm respectively. The total irrigation water requirement for the growing period of potato was 173.3 mm and the effective rainfall which is expected to be available for plant use was 214.6 mm.

Table 4. 9 Crop Water Requirements of pepper

Planting date: 01/12 Harvesting date: 04/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.6	1.53	15.3	46.5	0
Dec	2	Init	0.6	1.46	14.6	43.8	0
Dec	3	Deve	0.6	1.52	16.7	30.8	0
Jan	1	Deve	0.68	1.78	17.8	12.9	4.9
Jan	2	Deve	0.8	2.18	21.8	0	21.8
Jan	3	Deve	0.93	2.69	29.6	1.4	28.2
Feb	1	Mid	1.03	3.14	31.4	2.9	28.5
Feb	2	Mid	1.03	3.33	33.3	2.1	31.3
Feb	3	Mid	1.03	3.31	26.5	8	18.4
Mar	1	Mid	1.03	3.28	32.8	16.6	16.2
Mar	2	Late	1.02	3.22	32.2	22.7	9.5
Mar	3	Late	0.95	2.95	32.4	20.6	11.8
Apr	1	Late	0.89	2.66	10.6	6.4	2.6
	total				315.1	214.6	173.3

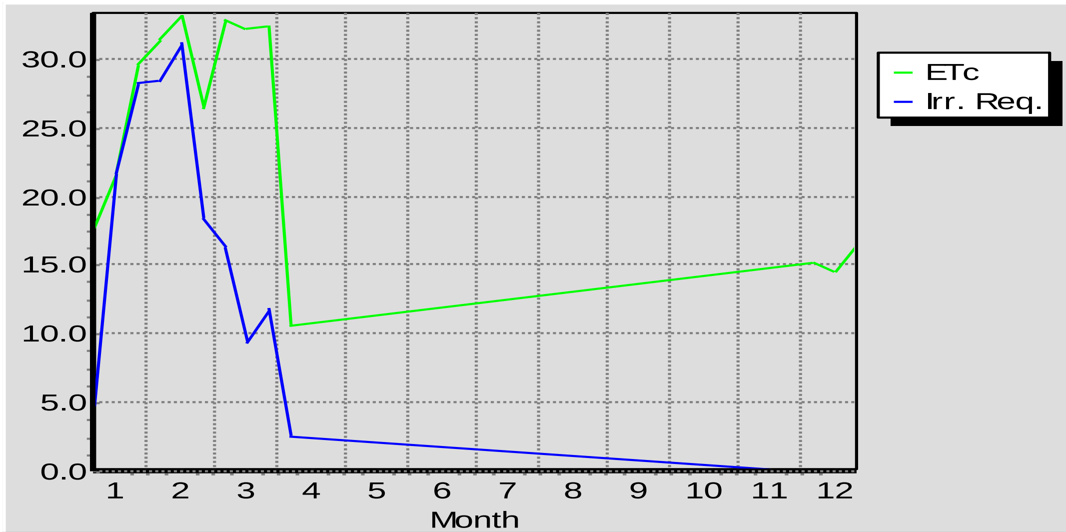

Figure 4. 5 Crop Water Requirements Graph of pepper

Table 4. 10 Crop Water Requirements of Cabbage

Planting date: 01/12 Harvesting date: 14/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.7	1.78	17.8	46.5	0
Dec	2	Init	0.7	1.7	17	43.8	0
Dec	3	Deve	0.72	1.82	20.1	30.8	0
Jan	1	Deve	0.83	2.17	21.7	12.9	8.8
Jan	2	Deve	0.94	2.55	25.5	0	25.5
Jan	3	Mid	1.03	2.97	32.6	1.4	31.2
Feb	1	Mid	1.03	3.16	31.6	2.9	28.7
Feb	2	Mid	1.03	3.34	33.4	2.1	31.3
Feb	3	Mid	1.03	3.31	26.5	8	18.5
Mar	1	Mid	1.03	3.29	32.9	16.6	16.3
Mar	2	Mid	1.03	3.27	32.7	22.7	9.9
Mar	3	Late	1.02	3.18	35	20.6	14.4
Apr	1	Late	0.97	2.91	29.1	16.1	13
Apr	2	Late	0.94	2.72	10.9	5.7	3.8
	total				366.8	229.9	201.5

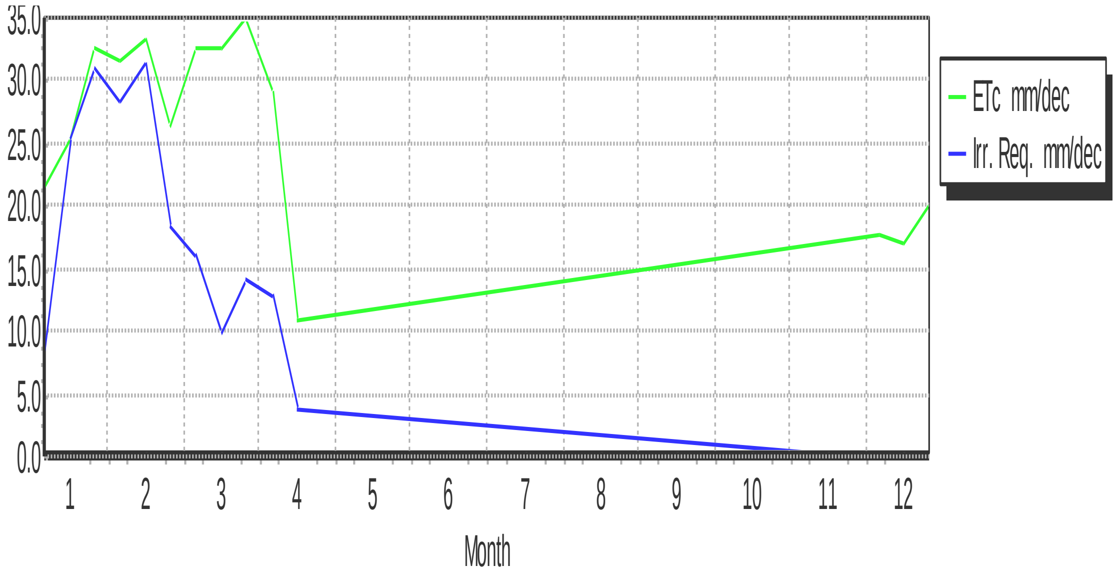

Figure 4. 6 Crop Water Requirements Graph of Cabbage

4.7 Irrigation Scheduling

The irrigation scheduling was calculated using Cropwat8.0 as table shown in 4.10. This helps to create similar conditions with the farmers' irrigation practices and facilitates to examine and compare the efficiencies of the selected fields against the optimum. Scheduling should consider application techniques through the growing stages because farmers are not in a position to measure and monitor the soil moisture contents of the soil prior to irrigation to use scheduling. These alternatives must be seriously studied and supported by location specific research recommendations.

Table 4. 11 Irrigation scheduling of onion

Planting date: 01/12 Harvesting date: 25/03

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr Mm	Deficit Mm	Loss mm	Gr. Irr mm	Flow l/s/ha
22-Jan	53	Dev	0	1	100	41	43.3	0	0	61.9	0.14
05-Feb	67	Mid	0	1	100	41	44.5	0	0	63.5	0.53
18-Feb	80	Mid	0	1	100	40	43.4	0	0	62	0.55
25-Mar	End	End	0	1	100	39					
	total						131.2			187.4	1.22

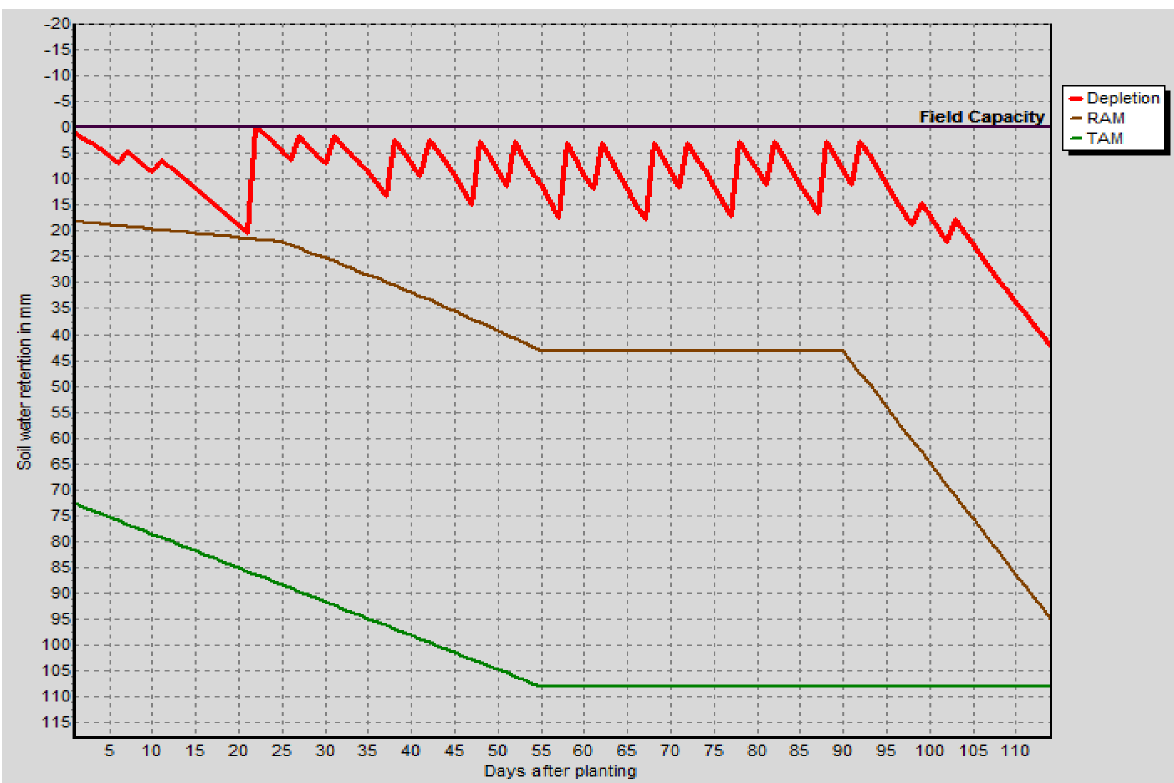

Figure 4. 7 Irrigation Scheduling Graph of onion

4.8 Total crop water requirement for the growing season

Total scheme water requirement was computed for the crops from beginning of land preparation to harvest of the crops for its optimum growth and increased yield. It includes the losses that occur in conveyance systems and in the farm application systems (including losses to deep percolation, evaporation, and surface runoff, as well as leaching requirements).

c

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Onion	65.4	87.2	23.2	0	0	0	0	0	0	0	0	0
2. Potato	66.7	87.3	39	1	0	0	0	0	0	0	0	0
3. Tomato	62.9	87.2	32.7	0	0	0	0	0	0	0	0	0
4. Pepper	55	78.1	37.4	2.6	0	0	0	0	0	0	0	0
5. Cabbage	65.6	78.5	40.7	17	0	0	0	0	0	0	0	0
Net scheme irr.req.												
in mm/day	1.2	1.8	0.7	0.1	0	0	0	0	0	0	0	0
in mm/month	38.4	50.9	20.5	2	0	0	0	0	0	0	0	0
in l/s/h	0.14	0.21	0.08	0.01	0	0	0	0	0	0	0	0
Irrigated area	60	60	60	31	0	0	0	0	0	0	0	0
(% of total area)												
Irr.req. for actual area (l/s/h)	0.24	0.35	0.13	0.02	0	0	0	0	0	0	0	0

Therefore, the net maximum scheme irrigation requirement of 0.35 l/s/h in the month of February is required (Table4.11). With overall system irrigation efficiency of 49% and with a daily irrigation cycle of 24 hours and irrigation duty of 0.71 lit/sec/ha is the required amount of irrigation water. With the continuous flow in the main canals the total irrigation water required to satisfy 60 ha of land will be:

$0.71\times$ cropped area for that month = 0.71×60 =42.6 lit/sec

The peak irrigation requirement (42.6 lit/sec) was determined for the irrigated area of 60 ha when the crops covering the area were taken from the actual discharge capacity of the main canal at the system head was 36 lit/sec. For the irrigation system of diversion weir, the canal capacity is the limiting factor.

$$Water\ Delivery Capacity (WDC) = \frac{\text{Actual canal capacity (ACC)}}{\text{Peak Irrigation Requirement (PIR)}}$$

$$WDC = \frac{36}{42.6} = 0.85.$$

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study focused on assessment of the performance of small scale irrigation (Boji Tika) schemes. There is an increasing interest in the performance of irrigation scheme and how performance can be assessed. This interest is due to regrets with many irrigation schemes around the world, particularly in the developing countries. For every existing irrigation scheme, there is a need to understand its current performance and reasons for its success or failure. This is with a view to understanding causes of low performance or maintaining or improving successful performance. If we do not understand current performance, then efforts to improve it may be misplaced. This study has contributed to the current debate on irrigation performance assessment, and provided a detailed case study of a typical small scale government assisted irrigation scheme in Africa. It has shown how complex performance assessment for irrigation schemes is as a result of the uniqueness of each system. However, it concludes that it is necessary to carry out detailed performance studies prior to redevelopment.

The study of small scale irrigation schemes in the study area has revealed some factors that are important for the successful implementation of small scale irrigation schemes. This research work tried to evaluate the water productivity of the selected field in terms of water applied and water consumed per season. The assessed irrigation scheme conform to the objectives of achieving food security as well as income generation for the rural people in the areas where the project are located and farmers are well aware of the existing problems of the area (low crop productivity, etc.) and their attitudes are favorable towards the implementation of the project.

In general, it can be concluded that, based on the discipline of the farmers of this particular scheme with their indigenous water management at the field level, water productivity can be improved by creating awareness about appurtenant structures how to operate and use, water loss due to over-irrigation and its consequences on the irrigation scheduling. It has been found that the performance of the Boji Tika irrigation scheme has been as good.

The result of this field-based study revealed that the weak performance of the project is due to carelessness handling appurtenant structures and due to the lack of awareness among the farmers about the real technical and economic advantages of SSI. This paper can be considered as a starting point to assess the performance of small-scale irrigation systems in Ethiopia and tried to reveal the application of the method developed by IWMI on the selected irrigation project. The nature of flow control structures and the operation rules are the main factors determining the condition of the water delivery to canal. For sustainable water management in this scheme and for the scheme to address the national objective of food security, government entities at various levels and WUA need to put a special concern, particularly on suitable institutional setups and hence on sustainable asset management (operation and maintenance). Different type of crop has different amount of water consumption rate. Therefore, the concerned body should be design rule and regulation that enforce crop rotation. Generally speaking more effort exerted by both governmental and NGO to provide training more frequently to enhance the understanding of beneficiary farm household on how to use irrigation water, effectively and efficiently and raise the awareness of farmers about the benefit and contribution of small scale irrigation in general. The establishment of well-organized water use associations, service and producers cooperatives will be appreciable to develop a well-structured and systematic water management system. Appropriate water and land management policy should be designed by the concerned governmental bodies to ensure the proper distribution of water and to make people equally benefited from the available water resource.

5.2 Recommendations

This research has identified some fundamental performance challenges with respect to small-scale irrigation schemes to be addressed.

The problem observed in the irrigation scheme is silt accumulation problem on the upstream diversion weir, and in the primary canals. Therefore, there is a need to ensure more reliable irrigation water supply by reducing risk of failure in the conveyance network and by increasing deliveries to commands by design operational sediment exclusion mechanisms that reduce silt accumulation over the irrigation structures so that the irrigation water conveyance efficiency of the modern irrigation structures are enhance.

In addition to designing appropriate sediment exclusion mechanism soil and water conservation works in the highlands which are serving as source of flood should be considered to minimize siltation problem in the irrigation systems.

The sustainability of the project is very much dependent on the full participation of the beneficiaries in all aspects of the project stages. Hence due attention should be given to involve the local community in problem identification, planning, prioritizing, implementation, monitoring and supervision processes.

To give solution for the events and circumstances in the area, government intervention in terms of sustainable use of scheme is the measure to be under taken. The participation of government and non-governmental organization with full involvement of the community should be ensured to develop small-scale irrigation and to attain the goal in poverty reduction and insure sustainable economic development. In this context to form irrigation farmers' cooperative and strengthen the existing farmers' cooperative in the area is vital to solve improper use of irrigation water and problems of appurtenant structure operation.

The beneficiaries should be encouraged to organize themselves for operation. Institutional support and continuous monitoring and evaluation of irrigation schemes is necessary to provide feedback and information important for the future planning of management of new schemes and maintenance of old schemes.

Periodical training and awareness creation has to be given to the farmers and field staffs.

Emphasis should be given for soil water conservation practices such as mulching and crop cultural practices, like weeding and cultivation reduce the evaporation loss and conserve more soil water for crop use. Thus, there is a reduction in irrigation requirement of crops.

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APPENDICES

APPENDIX I. TABLES

Appendix Table 1 Ethiopian surface water resources by major river basins

No.	River basin	Catchments area (km2)	Annual run off (10 9 m 3)	Specific discharge (liters/km2)	Irrigation potential (ha)
1	Abay	199,812,112	52.6	7.8	711,000
2	Awash	112,700	4.6	1.4	206,000
3	Baro Akobo	74,100	23.6	9.7	483,000
4	Genale Dawa	171,050	5.88	1.2	326,000
5	Mereb	5,900	0.26	3.2	38,000
6	Omo Gibe	78,200	17.96	6.7	348,000
7	Rift valley	52,740	5.64	3.4	46,500
8	Tekeze	90,000	7.63	3.2	302,000
9	Wabi Shebele	200,214	3.16	0.5	122,000
10	Danakil	74,000	0.86	0	_

Appendix Table 2 The potential Area and Actual Status of Small scale Irrigation in Ethiopia

CSA (1998) Source	Potential Irrigable Area (hectares)	Actual Irrigated Area (hectares)	Notes/Observations
CSA (1998)	-----	95/96 96/97 84640 68,210	An online database supported by (1998) FAO. Raises issue of need for rehabilitation
AQUASTAT(1998)	165,000 - 400,000		
MWR	180,000	64,000	Notes that some schemes are not functioning and in need of rehabilitation
Tahal (1998)	------	40,270	Traditional Schemes only- those without assistance from outside the community
IDD/MOA (1993)	352,000	70,000	Estimate of traditional irrigation without external assistance
FAO	270,000	-----	Potential for SSI using both ground water and surface water sources

Source: Tom (et al., 1999)

Appendix Table 3 Monthly climatic data used for determination of CWR for Boji Tika

Country: Ethiopia Station: Ambo

Altitude: 2175 m a. s. l

Latitude: 8.97^0 Longitude: 37.86^0

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind speed (km/day)	Sun shine (hours)	Solar Rad (MJ/m²/day)	ETo mm/day
January	8.9	26.2	55	2	6	16.6	2.72
February	10.1	28.6	47	2	7.2	19.4	3.23
March	11.2	29.2	51	2	5.1	17.1	3.16
April	11.6	28.2	53	2	4.1	15.8	3.01
May	11.2	28.4	62	11	7.8	21	4.03
June	11.5	12.8	62	1	3.4	14.1	2.35
July	10.9	24.6	73	12	2.9	13.5	2.53
August	10.3	23.8	75	1	3.8	15.1	2.82
September	10.2	24.6	69	1	0.7	10.3	2.11
October	9	25.9	57	1	6.4	18.4	3.13
November	8.2	26.2	54	17	5.1	15.4	2.76
December	8.5	26.1	57	1	4.7	14.4	2.43
Average	10.1	25.4	60	4	4.8	15.9	2.86

Appendix Table 4 Conveyance measurement of lined and unlined main canal

Canal Name	Segment no.	Wetted area of canal (m^2)	Flow velocity (m/s)	dist. b/n point (m)	Inflow (l/s)	Out Flow (l/s)	Conveyance loss		Conveyance Efficiency (%)
							(l/s)	(l/s/m)	
lined canal	1	0.24	0.15	30	36	33.4	2.6	0.087	92.8
	2	0.24	0.14	30	33.4	30.5	2.9	0.097	91.3
	average							0.092	92.05
unlined canal	1	0.32	0.07	200	21.7	17.3	4.4	0.022	79.7
	2	0.36	0.05	200	17.3	13.3	4	0.02	76.9
	3	0.48	0.03	200	13.3	10.2	3.1	0.016	76.7
	average							0.019	77.8

Appendix Table 5 Effective Rainfall

Month	Rain(mm)	Eff rain(mm)
January	14.5	14.2
February	13.2	12.9
March	67.2	60
April	53.4	48.8
May	99.5	83.7
June	169.8	123.7
July	230.2	145.4
August	216.2	141.4

September	100.9	84.6
October	27.6	26.4
November	304.7	155.5
December	164.3	121.1
Total	1461.5	1017.6

Effective rainfall calculated using USSCS formula: p_e = (125-0.2xp)/125, if p<250mm/month

P_e=0. 1P+125, if p>250. P =precipitation, p_e =effective rainfall

Appendix Table 6. Irrigation scheduling of potato

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	mm/day	%	mm	mm	mm	mm	l/s/ha
01-Dec	1	Init	0	1	1.3	2	0	1.3	0	0	0
02-Dec	2	Init	0	1	1.3	5	0	2.5	0	0	0
03-Dec	3	Init	35	1	1.3	2	0	1.3	0	0	0
04-Dec	4	Init	0	1	1.3	4	0	2.5	0	0	0
05-Dec	5	Init	0	1	1.3	6	0	3.8	0	0	0
06-Dec	6	Init	0	1	1.3	8	0	5.1	0	0	0
07-Dec	7	Init	35	1	1.3	2	0	1.3	0	0	0
08-Dec	8	Init	0	1	1.3	4	0	2.5	0	0	0
09-Dec	9	Init	0	1	1.3	6	0	3.8	0	0	0
10-Dec	10	Init	0	1	1.3	8	0	5.1	0	0	0
11-Dec	11	Init	0	1	1.2	10	0	6.3	0	0	0
12-Dec	12	Init	0	1	1.2	11	0	7.5	0	0	0
13-Dec	13	Init	28	1	1.2	2	0	1.2	0	0	0

14-Dec	14	Init	0	1	1.2	4	0	2.4	0	0	0
15-Dec	15	Init	0	1	1.2	5	0	3.6	0	0	0
16-Dec	16	Init	0	1	1.2	7	0	4.9	0	0	0
17-Dec	17	Init	28	1	1.2	2	0	1.2	0	0	0
18-Dec	18	Init	0	1	1.2	3	0	2.4	0	0	0
19-Dec	19	Init	0	1	1.2	5	0	3.6	0	0	0
20-Dec	20	Init	0	1	1.2	7	0	4.9	0	0	0
21-Dec	21	Init	0	1	1.4	8	0	6.2	0	0	0
22-Dec	22	Init	0	1	1.4	10	0	7.6	0	0	0
23-Dec	23	Init	19	1	1.4	2	0	1.4	0	0	0
24-Dec	24	Init	0	1	1.4	4	0	2.7	0	0	0
25-Dec	25	Init	0	1	1.4	5	0	4.1	0	0	0
26-Dec	26	Dev	0	1	1.4	7	0	5.5	0	0	0
27-Dec	27	Dev	19	1	1.4	2	0	1.4	0	0	0
28-Dec	28	Dev	0	1	1.4	3	0	2.7	0	0	0
29-Dec	29	Dev	0	1	1.4	5	0	4.1	0	0	0
30-Dec	30	Dev	0	1	1.4	7	0	5.5	0	0	0
31-Dec	31	Dev	0	1	1.4	8	0	6.8	0	0	0
01-Jan	32	Dev	0	1	1.9	10	0	8.8	0	0	0
02-Jan	33	Dev	0	1	1.9	12	0	10.7	0	0	0

03-Jan	34	Dev	6.8	1	1.9	7	0	5.9	0	0	0
04-Jan	35	Dev	0	1	1.9	9	0	7.9	0	0	0
05-Jan	36	Dev	0	1	1.9	11	0	9.8	0	0	0
06-Jan	37	Dev	0	1	1.9	13	0	11.8	0	0	0
07-Jan	38	Dev	6.8	1	1.9	8	0	6.9	0	0	0
08-Jan	39	Dev	0	1	1.9	10	0	8.9	0	0	0
09-Jan	40	Dev	0	1	1.9	12	0	10.8	0	0	0
10-Jan	41	Dev	0	1	1.9	14	0	12.8	0	0	0
11-Jan	42	Dev	0		2.6	16	0	15.4	0	0	0
12-Jan	43	Dev	0	1	2.6	19	0	18	0	0	0
13-Jan	44	Dev	0	1	2.6	21	0	20.6	0	0	0
14-Jan	45	Dev	0	1	2.6	24	0	23.2	0	0	0
15-Jan	46	Dev	0	1	2.6	26	0	25.7	0	0	0
16-Jan	47	Dev	0	1	2.6	28	0	28.3	0	0	0
17-Jan	48	Dev	0	1	2.6	31	30.9	0	0	44.2	5.11
18-Jan	49	Dev	0	1	2.6	3	0	2.6	0	0	0
19-Jan	50	Dev	0	1	2.6	5	0	5.2	0	0	0
20-Jan	51	Dev	0	1	2.6	7	0	7.8	0	0	0
21-Jan	52	Dev	0	1	3.2	10	0	11	0	0	0
22-Jan	53	Dev	0	1	3.2	13	0	14.3	0	0	0

23-Jan	54	Dev	0.6	1	3.2	16	0	16.9	0	0	0
24-Jan	55	Dev	0	1	3.2	19	0	20.2	0	0	0
25-Jan	56	Mid	0	1	3.2	22	0	23.4	0	0	0
26-Jan	57	Mid	0	1	3.2	25	0	26.7	0	0	0
27-Jan	58	Mid	0.6	1	3.2	27	0	29.3	0	0	0
28-Jan	59	Mid	0	1	3.2	30	32.6	0	0	46.5	5.39
29-Jan	60	Mid	0	1	3.2	3	0	3.2	0	0	0
30-Jan	61	Mid	0	1	3.2	6	0	6.5	0	0	0
31-Jan	62	Mid	0	1	3.2	9	0	9.7	0	0	0
01-Feb	63	Mid	0	1	3.5	12	0	13.2	0	0	0
02-Feb	64	Mid	0	1	3.5	15	0	16.7	0	0	0
03-Feb	65	Mid	1.4	1	3.5	17	0	18.7	0	0	0
04-Feb	66	Mid	0	1	3.5	21	0	22.2	0	0	0
05-Feb	67	Mid	0	1	3.5	24	0	25.6	0	0	0
06-Feb	68	Mid	0	1	3.5	27	0	29.1	0	0	0
07-Feb	69	Mid	1.4	1	3.5	29	0	31.2	0	0	0
08-Feb	70	Mid	0	1	3.5	32	34.6	0	0	49.5	5.73
09-Feb	71	Mid	0	1	3.5	3	0	3.5	0	0	0
10-Feb	72	Mid	0	1	3.5	6	0	6.9	0	0	0
11-Feb	73	Mid	0	1	3.7	10	0	10.6	0	0	0

12-Feb	74	Mid	0	1	3.7	13	0	14.3	0	0	0
13-Feb	75	Mid	0.9	1	3.7	16	0	17	0	0	0
14-Feb	76	Mid	0	1	3.7	19	0	20.7	0	0	0
15-Feb	77	Mid	0	1	3.7	23	0	24.3	0	0	0
16-Feb	78	Mid	0	1	3.7	26	0	28	0	0	0
17-Feb	79	Mid	0.9	1	3.7	28	0	30.8	0	0	0
18-Feb	80	Mid	0	1	3.7	32	34.4	0	0	49.2	5.69
19-Feb	81	Mid	0	1	3.7	3	0	3.7	0	0	0
20-Feb	82	Mid	0	1	3.7	7	0	7.3	0	0	0
21-Feb	83	Mid	0	1	3.6	10	0	11	0	0	0
22-Feb	84	Mid	0	1	3.6	14	0	14.6	0	0	0
23-Feb	85	Mid	4.3	1	3.6	13	0	13.9	0	0	0
24-Feb	86	Mid	0	1	3.6	16	0	17.5	0	0	0
25-Feb	87	Mid	0	1	3.6	20	0	21.2	0	0	0
26-Feb	88	Mid	0	1	3.6	23	0	24.8	0	0	0
27-Feb	89	Mid	4.3	1	3.6	22	0	24.1	0	0	0
28-Feb	90	Mid	0	1	3.6	26	0	27.7	0	0	0
01-Mar	91	Mid	0	1	3.6	29	0	31.3	0	0	0
02-Mar	92	Mid	0	1	3.6	32	34.9	0	0	49.9	5.78
03-Mar	93	Mid	9.3	1	3.6	3	0	3.6	0	0	0

04-Mar	94	Mid	0	1	3.6	7	0	7.2	0	0	0
05-Mar	95	Mid	0	1	3.6	10	0	10.8	0	0	0
06-Mar	96	Mid	0	1	3.6	13	0	14.4	0	0	0
07-Mar	97	Mid	9.3	1	3.6	8	0	8.8	0	0	0
08-Mar	98	Mid	0	1	3.6	11	0	12.4	0	0	0
09-Mar	99	Mid	0	1	3.6	15	0	16	0	0	0
10-Mar	100	Mid	0	1	3.6	18	0	19.6	0	0	0
11-Mar	101	End	0	1	3.3	21	0	22.9	0	0	0
12-Mar	102	End	0	1	3.3	24	0	26.2	0	0	0
13-Mar	103	End	13	1	3.3	15	0	16.7	0	0	0
14-Mar	104	End	0	1	3.3	19	0	20	0	0	0
15-Mar	105	End	0	1	3.3	22	0	23.3	0	0	0
16-Mar	106	End	0	1	3.3	25	0	26.6	0	0	0
17-Mar	107	End	13	1	3.3	16	0	17.1	0	0	0
18-Mar	108	End	0	1	3.3	19	0	20.4	0	0	0
19-Mar	109	End	0	1	3.3	22	0	23.7	0	0	0
20-Mar	110	End	0	1	3.3	25	0	27	0	0	0
21-Mar	111	End	0	1	2.7	28	0	29.7	0	0	0
22-Mar	112	End	0	1	2.7	30	0	32.4	0	0	0
23-Mar	113	End	12	1	2.7	22	0	23.6	0	0	0

24-Mar	114	End	0	1	2.7	24	0	26.4	0	0	0
25-Mar	115	End	0	1	2.7	27	0	29.1	0	0	0
26-Mar	116	End	0	1	2.7	29	0	31.8	0	0	0
27-Mar	117	End	12	1	2.7	21	0	23	0	0	0
28-Mar	118	End	0	1	2.7	24	0	25.8	0	0	0
29-Mar	119	End	0	1	2.7	26	0	28.5	0	0	0
30-Mar	120	End	0	1	2.7	29	0	31.2	0	0	0
31-Mar	121	End	0	1	2.7	31	0	33.9	0	0	0
01-Apr	122	End	0	1	2.3	33	0	36.2	0	0	0
02-Apr	123	End	0	1	2.3	36	0	38.4	0	0	0
03-Apr	124	End	8.7	1	2.3	30	0	32	0	0	0
04-Apr	End	End	0	1	0	30					
		total					167.4			239	27.7

Appendix Table 7.Irrigation scheduling of tomato

	Day	Stage	Rain mm	Ks fract.	Eta mm/day	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
01-Dec	1	Init	0	1	1.5	3	0	1.5	0	0	0
02-Dec	2	Init	0	1	1.5	6	0	3	0	0	0
03-Dec	3	Init	35	1	1.5	3	0	1.5	0	0	0
04-Dec	4	Init	0	1	1.5	6	0	3	0	0	0
05-Dec	5	Init	0	1	1.5	8	0	4.6	0	0	0
06-Dec	6	Init	0	1	1.5	10	0	6.1	0	0	0
07-Dec	7	Init	35	1	1.5	3	0	1.5	0	0	0
08-Dec	8	Init	0	1	1.5	5	0	3	0	0	0

09-Dec	9	Init	0	1	1.5	7	0	4.6	0	0	0
10-Dec	10	Init	0	1	1.5	9	0	6.1	0	0	0
11-Dec	11	Init	0	1	1.5	11	0	7.6	0	0	0
12-Dec	12	Init	0	1	1.5	13	0	9	0	0	0
13-Dec	13	Init	28	1	1.5	2	0	1.5	0	0	0
14-Dec	14	Init	0	1	1.5	4	0	2.9	0	0	0
15-Dec	15	Init	0	1	1.5	6	0	4.4	0	0	0
16-Dec	16	Init	0	1	1.5	7	0	5.8	0	0	0
17-Dec	17	Init	28	1	1.5	2	0	1.5	0	0	0
18-Dec	18	Init	0	1	1.5	3	0	2.9	0	0	0
19-Dec	19	Init	0	1	1.5	5	0	4.4	0	0	0
20-Dec	20	Init	0	1	1.5	6	0	5.8	0	0	0
21-Dec	21	Init	0	1	1.5	8	0	7.4	0	0	0
22-Dec	22	Init	0	1	1.5	9	0	8.9	0	0	0
23-Dec	23	Init	19	1	1.5	2	0	1.5	0	0	0
24-Dec	24	Init	0	1	1.5	3	0	3	0	0	0
25-Dec	25	Init	0	1	1.5	5	0	4.6	0	0	0
26-Dec	26	Init	0	1	1.5	6	0	6.1	0	0	0
27-Dec	27	Init	19	1	1.5	1	0	1.5	0	0	0
28-Dec	28	Init	0	1	1.5	3	0	3	0	0	0
29-Dec	29	Init	0	1	1.5	4	0	4.6	0	0	0
30-Dec	30	Init	0	1	1.5	5	0	6.1	0	0	0
31-Dec	31	Dev	0	1	1.5	7	0	7.6	0	0	0
01-Jan	32	Dev	0	1	1.9	8	0	9.5	0	0	0
02-Jan	33	Dev	0	1	1.9	10	0	11.4	0	0	0
03-Jan	34	Dev	6.8	1	1.9	5	0	6.5	0	0	0
04-Jan	35	Dev	0	1	1.9	7	0	8.4	0	0	0
05-Jan	36	Dev	0	1	1.9	8	0	10.2	0	0	0
06-Jan	37	Dev	0	1	1.9	9	0	12.1	0	0	0
07-Jan	38	Dev	6.8	1	1.9	6	0	7.2	0	0	0
08-Jan	39	Dev	0	1	1.9	7	0	9.1	0	0	0
09-Jan	40	Dev	0	1	1.9	8	0	11	0	0	0
10-Jan	41	Dev	0	1	1.9	9	0	12.9	0	0	0
11-Jan	42	Dev	0	1	2.4	11	0	15.3	0	0	0
12-Jan	43	Dev	0	1	2.4	12	0	17.7	0	0	0
13-Jan	44	Dev	0	1	2.4	14	0	20.1	0	0	0
14-Jan	45	Dev	0	1	2.4	15	0	22.6	0	0	0
15-Jan	46	Dev	0	1	2.4	17	0	25	0	0	0
16-Jan	47	Dev	0	1	2.4	18	0	27.4	0	0	0

17-Jan	48	Dev	0	1	2.4	20	0	29.8	0	0	0
18-Jan	49	Dev	0	1	2.4	21	0	32.3	0	0	0
19-Jan	50	Dev	0	1	2.4	22	0	34.7	0	0	0
20-Jan	51	Dev	0	1	2.4	23	0	37.1	0	0	0
21-Jan	52	Dev	0	1	3.1	25	0	40.2	0	0	0
22-Jan	53	Dev	0	1	3.1	26	0	43.3	0	0	0
23-Jan	54	Dev	0.6	1	3.1	28	0	45.9	0	0	0
24-Jan	55	Dev	0	1	3.1	29	0	49	0	0	0
25-Jan	56	Dev	0	1	3.1	30	0	52.1	0	0	0
26-Jan	57	Dev	0	1	3.1	32	0	55.2	0	0	0
27-Jan	58	Dev	0.6	1	3.1	33	0	57.8	0	0	0
28-Jan	59	Dev	0	1	3.1	34	0	60.9	0	0	0
29-Jan	60	Dev	0	1	3.1	36	0	64	0	0	0
30-Jan	61	Mid	0	1	3.1	37	0	67.1	0	0	0
31-Jan	62	Mid	0	1	3.1	39	0	70.2	0	0	0
01-Feb	63	Mid	0	1	3.5	41	73.7	0	0	105	12.2
02-Feb	64	Mid	0	1	3.5	2	0	3.5	0	0	0
03-Feb	65	Mid	1.4	1	3.5	3	0	5.5	0	0	0
04-Feb	66	Mid	0	1	3.5	5	0	9	0	0	0
05-Feb	67	Mid	0	1	3.5	7	0	12.5	0	0	0
06-Feb	68	Mid	0	1	3.5	9	0	15.9	0	0	0
07-Feb	69	Mid	1.4	1	3.5	10	0	18	0	0	0
08-Feb	70	Mid	0	1	3.5	12	0	21.5	0	0	0
09-Feb	71	Mid	0	1	3.5	14	0	24.9	0	0	0
10-Feb	72	Mid	0	1	3.5	16	0	28.4	0	0	0
11-Feb	73	Mid	0	1	3.7	18	0	32.1	0	0	0
12-Feb	74	Mid	0	1	3.7	20	0	35.7	0	0	0
13-Feb	75	Mid	0.9	1	3.7	21	0	38.5	0	0	0
14-Feb	76	Mid	0	1	3.7	23	0	42.2	0	0	0
15-Feb	77	Mid	0	1	3.7	25	0	45.8	0	0	0
16-Feb	78	Mid	0	1	3.7	27	0	49.5	0	0	0
17-Feb	79	Mid	0.9	1	3.7	29	0	52.3	0	0	0
18-Feb	80	Mid	0	1	3.7	31	0	55.9	0	0	0
19-Feb	81	Mid	0	1	3.7	33	0	59.6	0	0	0
20-Feb	82	Mid	0	1	3.7	35	0	63.3	0	0	0
21-Feb	83	Mid	0	1	3.6	37	0	66.9	0	0	0
22-Feb	84	Mid	0	1	3.6	39	0	70.5	0	0	0
23-Feb	85	Mid	4.3	1	3.6	39	0	69.8	0	0	0
24-Feb	86	Mid	0	1	3.6	41	73.5	0	0	105	12.2

25-Feb	87	Mid	0	1	3.6	2	0	3.6	0	0	0
26-Feb	88	Mid	0	1	3.6	4	0	7.3	0	0	0
27-Feb	89	Mid	4.3	1	3.6	4	0	6.6	0	0	0
28-Feb	90	Mid	0	1	3.6	6	0	10.2	0	0	0
01-Mar	91	Mid	0	1	3.5	8	0	13.8	0	0	0
02-Mar	92	Mid	0	1	3.5	10	0	17.3	0	0	0
03-Mar	93	Mid	9.3	1	3.5	6	0	11.6	0	0	0
04-Mar	94	Mid	0	1	3.5	8	0	15.1	0	0	0
05-Mar	95	Mid	0	1	3.5	10	0	18.7	0	0	0
06-Mar	96	End	0	1	3.5	12	0	22.2	0	0	0
07-Mar	97	End	9.3	1	3.5	9	0	16.5	0	0	0
08-Mar	98	End	0	1	3.5	11	0	20	0	0	0
09-Mar	99	End	0	1	3.5	13	0	23.6	0	0	0
10-Mar	100	End	0	1	3.5	15	0	27.1	0	0	0
11-Mar	101	End	0	1	3.1	17	0	30.2	0	0	0
12-Mar	102	End	0	1	3.1	19	0	33.3	0	0	0
13-Mar	103	End	13	1	3.1	13	0	23.6	0	0	0
14-Mar	104	End	0	1	3.1	15	0	26.8	0	0	0
15-Mar	105	End	0	1	3.1	17	0	29.9	0	0	0
16-Mar	106	End	0	1	3.1	18	0	33	0	0	0
17-Mar	107	End	13	1	3.1	13	0	23.3	0	0	0
18-Mar	108	End	0	1	3.1	15	0	26.4	0	0	0
19-Mar	109	End	0	1	3.1	16	0	29.5	0	0	0
20-Mar	110	End	0	1	3.1	18	0	32.6	0	0	0
21-Mar	111	End	0	1	2.6	20	0	35.3	0	0	0
22-Mar	112	End	0	1	2.6	21	0	37.9	0	0	0
23-Mar	113	End	12	1	2.6	16	0	29	0	0	0
24-Mar	114	End	0	1	2.6	18	0	31.6	0	0	0
25-Mar	115	End	0	1	2.6	19	0	34.3	0	0	0
26-Mar	116	End	0	1	2.6	21	0	36.9	0	0	0
27-Mar	117	End	12	1	2.6	16	0	28	0	0	0
28-Mar	118	End	0	1	2.6	17	0	30.7	0	0	0
29-Mar	119	End	0	1	2.6	18	0	33.3	0	0	0
30-Mar	End	End	0	1	2.7	18					
		total					147.2			210	24.3

Appendix Table 8. Irrigation scheduling of cabbage

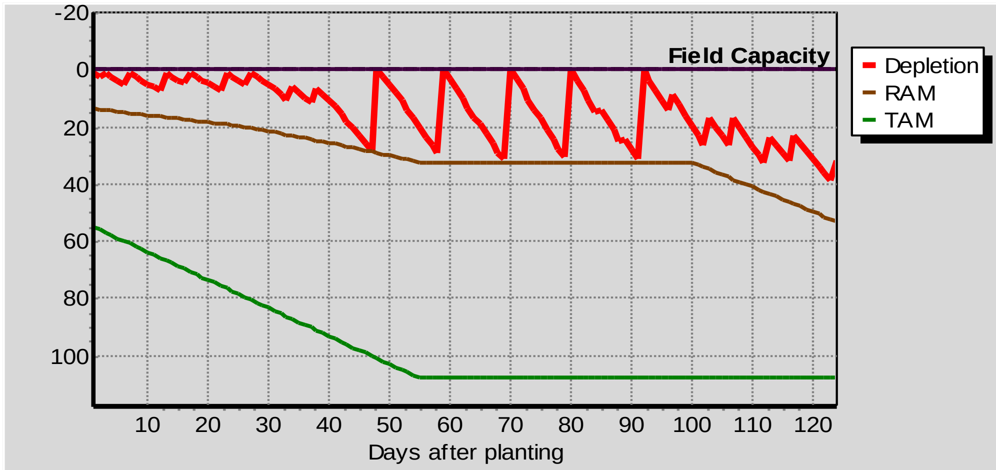
	Day	Stage	Rain mm	Ks fract.	Eta mm/day	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
01-Dec	1	Init	0	1	1.8	4	0	1.8	0	0	0
02-Dec	2	Init	0	1	1.8	8	0	3.6	0	0	0
03-Dec	3	Init	35	1	1.8	4	0	1.8	0	0	0
04-Dec	4	Init	0	1	1.8	7	0	3.6	0	0	0
05-Dec	5	Init	0	1	1.8	11	0	5.3	0	0	0
06-Dec	6	Init	0	1	1.8	14	0	7.1	0	0	0
07-Dec	7	Init	35	1	1.8	4	0	1.8	0	0	0
08-Dec	8	Init	0	1	1.8	7	0	3.6	0	0	0
09-Dec	9	Init	0	1	1.8	10	0	5.3	0	0	0
10-Dec	10	Init	0	1	1.8	13	0	7.1	0	0	0
11-Dec	11	Init	0	1	1.7	16	0	8.8	0	0	0
12-Dec	12	Init	0	1	1.7	19	0	10.5	0	0	0
13-Dec	13	Init	28	1	1.7	3	0	1.7	0	0	0
14-Dec	14	Init	0	1	1.7	6	0	3.4	0	0	0
15-Dec	15	Init	0	1	1.7	9	0	5.1	0	0	0
16-Dec	16	Init	0	1	1.7	12	0	6.8	0	0	0
17-Dec	17	Init	28	1	1.7	3	0	1.7	0	0	0
18-Dec	18	Init	0	1	1.7	6	0	3.4	0	0	0
19-Dec	19	Init	0	1	1.7	8	0	5.1	0	0	0
20-Dec	20	Init	0	1	1.7	11	0	6.8	0	0	0
21-Dec	21	Init	0	1	1.8	14	0	8.6	0	0	0
22-Dec	22	Init	0	1	1.8	17	0	10.5	0	0	0
23-Dec	23	Init	19	1	1.8	3	0	1.8	0	0	0
24-Dec	24	Init	0	1	1.8	6	0	3.6	0	0	0
25-Dec	25	Init	0	1	1.8	8	0	5.5	0	0	0
26-Dec	26	Dev	0	1	1.8	11	0	7.3	0	0	0
27-Dec	27	Dev	19	1	1.8	3	0	1.8	0	0	0
28-Dec	28	Dev	0	1	1.8	5	0	3.6	0	0	0
29-Dec	29	Dev	0	1	1.8	8	0	5.5	0	0	0
30-Dec	30	Dev	0	1	1.8	10	0	7.3	0	0	0
31-Dec	31	Dev	0	1	1.8	13	0	9.1	0	0	0
01-Jan	32	Dev	0	1	2.2	16	0	11.3	0	0	0

02-Jan	33	Dev	0	1	2.2	19	0	13.5	0	0	0
03-Jan	34	Dev	6.8	1	2.2	12	0	8.9	0	0	0
04-Jan	35	Dev	0	1	2.2	15	0	11	0	0	0
05-Jan	36	Dev	0	1	2.2	18	0	13.2	0	0	0
06-Jan	37	Dev	0	1	2.2	20	0	15.4	0	0	0
07-Jan	38	Dev	6.8	1	2.2	14	0	10.8	0	0	0
08-Jan	39	Dev	0	1	2.2	17	0	13	0	0	0
09-Jan	40	Dev	0	1	2.2	19	0	15.1	0	0	0
10-Jan	41	Dev	0	1	2.2	22	0	17.3	0	0	0
11-Jan	42	Dev	0	1	2.5	25	0	19.9	0	0	0
12-Jan	43	Dev	0	1	2.5	28	0	22.4	0	0	0
13-Jan	44	Dev	0	1	2.5	31	0	25	0	0	0
14-Jan	45	Dev	0	1	2.5	34	0	27.5	0	0	0
15-Jan	46	Dev	0	1	2.5	36	0	30	0	0	0
16-Jan	47	Dev	0	1	2.5	39	0	32.6	0	0	0
17-Jan	48	Dev	0	1	2.5	42	0	35.1	0	0	0
18-Jan	49	Dev	0	1	2.5	44	0	37.7	0	0	0
19-Jan	50	Dev	0	1	2.5	47	40.2	0	0	57.5	6.65
20-Jan	51	Dev	0	1	2.5	3	0	2.5	0	0	0
21-Jan	52	Dev	0	1	3	6	0	5.5	0	0	0
22-Jan	53	Dev	0	1	3	10	0	8.5	0	0	0
23-Jan	54	Dev	0.6	1	3	12	0	10.9	0	0	0
24-Jan	55	Dev	0	1	3	15	0	13.9	0	0	0
25-Jan	56	Mid	0	1	3	19	0	16.8	0	0	0
26-Jan	57	Mid	0	1	3	22	0	19.8	0	0	0
27-Jan	58	Mid	0.6	1	3	25	0	22.2	0	0	0
28-Jan	59	Mid	0	1	3	28	0	25.2	0	0	0
29-Jan	60	Mid	0	1	3	31	0	28.1	0	0	0
30-Jan	61	Mid	0	1	3	35	0	31.1	0	0	0
31-Jan	62	Mid	0	1	3	38	0	34.1	0	0	0
01-Feb	63	Mid	0	1	3.2	41	0	37.2	0	0	0
02-Feb	64	Mid	0	1	3.2	45	0	40.4	0	0	0
03-Feb	65	Mid	1.4	1	3.2	47	42.1	0	0	60.2	6.97
04-Feb	66	Mid	0	1	3.2	4	0	3.2	0	0	0
05-Feb	67	Mid	0	1	3.2	7	0	6.3	0	0	0
06-Feb	68	Mid	0	1	3.2	11	0	9.5	0	0	0
07-Feb	69	Mid	1.4	1	3.2	12	0	11.2	0	0	0
08-Feb	70	Mid	0	1	3.2	16	0	14.4	0	0	0
09-Feb	71	Mid	0	1	3.2	20	0	17.6	0	0	0

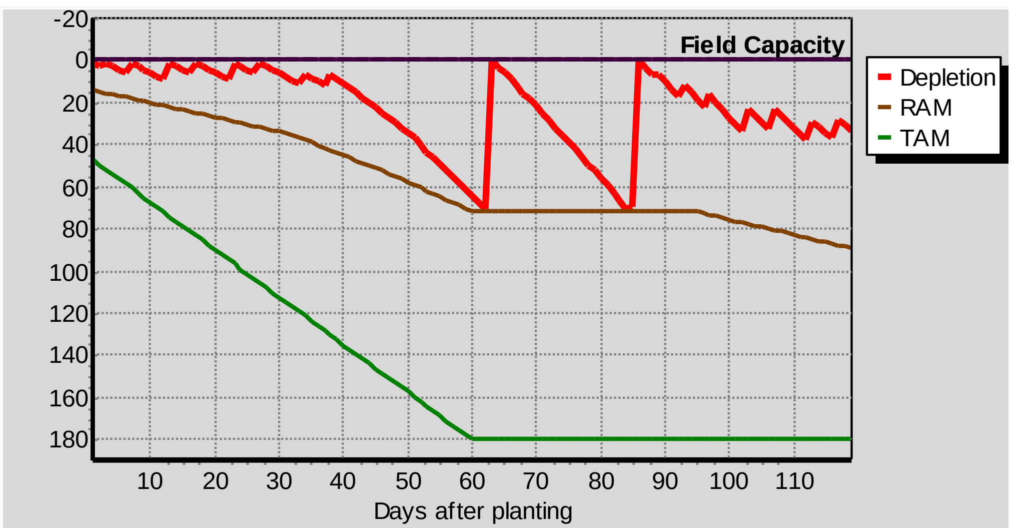
10-Feb	72	Mid	0	1	3.2	23	0	20.7	0	0	0
11-Feb	73	Mid	0	1	3.3	27	0	24.1	0	0	0
12-Feb	74	Mid	0	1	3.3	30	0	27.4	0	0	0
13-Feb	75	Mid	0.9	1	3.3	33	0	29.8	0	0	0
14-Feb	76	Mid	0	1	3.3	37	0	33.2	0	0	0
15-Feb	77	Mid	0	1	3.3	41	0	36.5	0	0	0
16-Feb	78	Mid	0	1	3.3	44	0	39.8	0	0	0
17-Feb	79	Mid	0.9	1	3.3	47	42.3	0	0	60.4	6.99
18-Feb	80	Mid	0	1	3.3	4	0	3.3	0	0	0
19-Feb	81	Mid	0	1	3.3	7	0	6.7	0	0	0
20-Feb	82	Mid	0	1	3.3	11	0	10	0	0	0
21-Feb	83	Mid	0	1	3.3	15	0	13.3	0	0	0
22-Feb	84	Mid	0	1	3.3	18	0	16.6	0	0	0
23-Feb	85	Mid	4.3	1	3.3	17	0	15.6	0	0	0
24-Feb	86	Mid	0	1	3.3	21	0	18.9	0	0	0
25-Feb	87	Mid	0	1	3.3	25	0	22.3	0	0	0
26-Feb	88	Mid	0	1	3.3	28	0	25.6	0	0	0
27-Feb	89	Mid	4.3	1	3.3	27	0	24.5	0	0	0
28-Feb	90	Mid	0	1	3.3	31	0	27.9	0	0	0
01-Mar	91	Mid	0	1	3.3	35	0	31.2	0	0	0
02-Mar	92	Mid	0	1	3.3	38	0	34.4	0	0	0
03-Mar	93	Mid	9.3	1	3.3	32	0	28.5	0	0	0
04-Mar	94	Mid	0	1	3.3	35	0	31.8	0	0	0
05-Mar	95	Mid	0	1	3.3	39	0	35	0	0	0
06-Mar	96	Mid	0	1	3.3	43	0	38.3	0	0	0
07-Mar	97	Mid	9.3	1	3.3	36	0	32.4	0	0	0
08-Mar	98	Mid	0	1	3.3	40	0	35.6	0	0	0
09-Mar	99	Mid	0	1	3.3	43	0	38.9	0	0	0
10-Mar	100	Mid	0	1	3.3	47	42.2	0	0	60.3	6.98
11-Mar	101	Mid	0	1	3.3	4	0	3.3	0	0	0
12-Mar	102	Mid	0	1	3.3	7	0	6.5	0	0	0
13-Mar	103	Mid	13	1	3.3	4	0	3.3	0	0	0
14-Mar	104	Mid	0	1	3.3	7	0	6.5	0	0	0
15-Mar	105	Mid	0	1	3.3	11	0	9.8	0	0	0
16-Mar	106	Mid	0	1	3.3	15	0	13.1	0	0	0
17-Mar	107	Mid	13	1	3.3	4	0	3.5	0	0	0
18-Mar	108	Mid	0	1	3.3	8	0	6.8	0	0	0
19-Mar	109	Mid	0	1	3.3	11	0	10.1	0	0	0
20-Mar	110	Mid	0	1	3.3	15	0	13.3	0	0	0

21-Mar	111	Mid	0	1	3.2	18	0	16.5	0	0	0
22-Mar	112	Mid	0	1	3.2	22	0	19.7	0	0	0
23-Mar	113	Mid	12	1	3.2	13	0	11.4	0	0	0
24-Mar	114	Mid	0	1	3.2	16	0	14.6	0	0	0
25-Mar	115	Mid	0	1	3.2	20	0	17.7	0	0	0
26-Mar	116	End	0	1	3.2	23	0	20.9	0	0	0
27-Mar	117	End	12	1	3.2	14	0	12.6	0	0	0
28-Mar	118	End	0	1	3.2	18	0	15.8	0	0	0
29-Mar	119	End	0	1	3.2	21	0	19	0	0	0
30-Mar	120	End	0	1	3.2	25	0	22.2	0	0	0
31-Mar	121	End	0	1	3.2	28	0	25.3	0	0	0
01-Apr	122	End	0	1	2.9	31	0	28.3	0	0	0
02-Apr	123	End	0	1	2.9	35	0	31.2	0	0	0
03-Apr	124	End	8.7	1	2.9	28	0	25.3	0	0	0
04-Apr	125	End	0	1	2.9	31	0	28.3	0	0	0
05-Apr	126	End	0	1	2.9	35	0	31.2	0	0	0
06-Apr	127	End	0	1	2.9	38	0	34.1	0	0	0
07-Apr	128	End	8.7	1	2.9	31	0	28.3	0	0	0
08-Apr	129	End	0	1	2.9	35	0	31.2	0	0	0
09-Apr	130	End	0	1	2.9	38	0	34.1	0	0	0
10-Apr	131	End	0	1	2.9	41	0	37	0	0	0
11-Apr	132	End	0	1	2.7	44	0	39.7	0	0	0
12-Apr	133	End	0	1	2.7	47	42.4	0	0	60.6	7.02
13-Apr	134	End	7.5	1	2.7	3	0	2.7	0	0	0
14-Apr	End	End	0	1	0	3					
		total					209.2			299	34.6

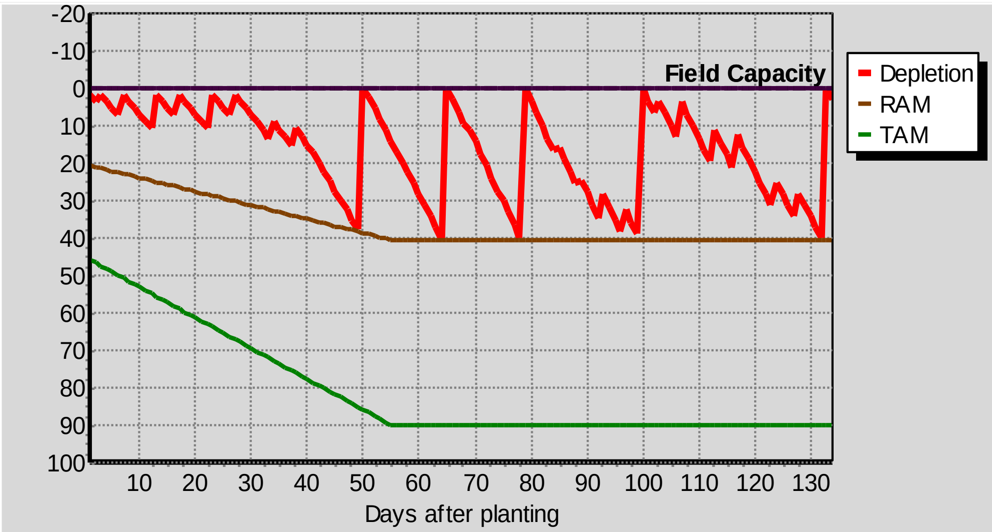
APPENDEX II. Figures



Appendix Figure 1. Irrigation scheduling graph of potato



Appendix Figure 2. Irrigation scheduling graph of tomato



Appendix Figure 3. Irrigation scheduling graph of cabbage

Appendix Figure 4. Intake Gate at Diversion Weir

Appendix Figure 5. Silt deposited at u/s of the weir

Appendix Figure 6. Sluice gate on main canal

Appendix Figure 7. Diversion weir

Appendix Figure 8. Canal with retention wall