PERFOMANCE OF REHABILITATED IRRIGATION SYSTEMS: A CASE STUDY OF IGOMELO IRRIGATION SCHEME IN TANZANIA

BY

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ABSTRACT

Many irrigation systems indicate failures with respect to their anticipated benefits. However, improvement of these schemes can be brought about through their rehabilitation. The aim of this study was to evaluate the performance of Igomelo rehabilitated irrigation scheme covering both the performance of irrigation water distribution systems and the roles of irrigators association.The scheme was divided into three reaches upper, middle and tail end. Three plots with maize, tomatoes and onions from each reach were randomly selected. Amount of water entering the plots were monitored for adequacy, equity, dependability and productivity analysis. Also three canals each from the mentioned reaches was assessed for seepage, maintenance and conveyance efficiencies. The IA wasevaluated using indicators such as structures' condition, effectiveness in fees collection (EFC) and financial self sufficiency (FSS). A structured questionnaire was administered in order to obtain information on irrigation and roles of irrigators association. The conveyance efficiencies in the main canal were 68.2% with values between 69and 87% for tertiary canals. Seepage ranging between 0.044 and 0.104l/s per meter lengthwas also observed in the canals. A SCI of 90% was obtained showing structures in good working condition.Despite a good FSS (1.10 -2.21) some structures lack some components. Adequacy in water supply is good with Relative Water Supply (RWS) between 0.92 and 3.96with highest RWS at the middle reach. However, the dependability in water supply was low while equity in water supply was observed in tomato plots than in maize and onions. The output per unitwater supply for tomato was between 684.4 and 14492.55 US$ha^{-1}while the highest output per unit water

supply for tomato and maize were (1.68kg/m^3)and (0.83kg/m^3)respectively. However, not significantly different ($p < 0.01$). From both the IA and the water distribution systems the performance of the scheme is good.

DECLARATION

I Amy Richard Mchelle do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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DEDICATION

To my lovelyhusbandVictor Stephen Labaa who gave to me full support in all aspects during the studies. I also dedicate this work to my mother Christine Mchelle, who has always been there for me through prayers and encouragement, may she live longer to enjoy the fruits of her prayers.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIWS Adequacy of irrigation water supply

AU Area Uniformity

CSWD Coefficient of Spatial Water Distribution

CV Coefficient of Variation

CV_R Spatial coefficient of Variation over the region R

D_{AVE} Average water depth supplied to the whole system

DITS Department of Irrigation and Technical Services

DIWS Dependability of Irrigation Water Supply

D_W Water depth for the worst supplied area in the system

ET_C Crop water requirement

ET_O Reference evapotranspiration

FAO Food Aid Organisation

FMIS Farmer Managed Irrigation Systems

IC Irrigators Cooperatives

IMT Irrigation Management Transfer

IWM Irrigation Water Management

IWMI	International Water Management Institute
IWRn	Net irrigation requirement
Kc	Crop factor or crop coefficient
NGO	Non Governmental Organisation
O&M	Operation and Maintenance
P_A	Adequacy
P_E	Equity
Pe	Effective rainfall
PIM	Participatory Irrigation Management
Q_D	Amount of water delivered
Q_R	Amount of water required
R	Region or sub region served by the system over a time period T
RBM	River Basin Management
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SGVP	Standardized Gross Value of Production
T	One irrigation season (days)
TIP	Traditional Irrigation Improvement Programme
URT	United Republic of Tanzania
USDA	United State Department of Agriculture
WUAs	Water Users' Associations

CHAPTER ONE

1.0 INTRODUCTION

One of the greatest challenges in the world for the coming decades will be to increase food production (FAO, 2002).A large proportion of that increase will have to come from intensified agricultural systems supported by irrigation to feed the steadily growing world population (Maton *et al*., 2005). Even where water is plentiful, water demand for purposes other than agriculture (drinking water, leisure, industry, etc.) is increasing and can become a source of conflict between different components of the society (FAO, 2002).

A comprehensive assessment of water management in agriculture in 2007, found small and medium size community managed irrigation schemes to have features for ensuring food security, settlement success and integration of cultural traditions (Mateos *et al*., 2010). Jones (1995) summarizing World Bank's experience in irrigation concluded that operation and maintenance procedures were unsatisfactory in 55 percent of completed projects in the world.

Tesfaye *et al*. (2008) and Gebregziabher *et al*. (2008) in Ethiopia, Connor *et al*. (2008) in Senegal and Sishuta (2005) in South Africa demonstrated that, smallholder community managed irrigation schemes are key elements to guaranteed food supply in sub -Saharan Africa. While it is true that many irrigation systems have been constructed in this region in the past, their performance records indicate failure with regard to their anticipated benefit (Kuscu *et al*., 2009a; Alam, 1991). Despite their promise as engines of agricultural growth, irrigation projects typically perform far below their potential (Small and Svendsen,1992). Head-Tail problems, leaky canals and malfunctioning structures (because of delayed maintenance), leading to low water use efficiency and low yields, are some of the commonly expressed problems. A large part of low performance may be due to inadequate water management at system and field level (Cakmak *et al*., 2004). Generally, irrigation scheme management and consultants were primarily oriented to dealing with the technical and or agronomic, and not the human challenges associated with irrigation development. Farmers in all cases were situated at the bottom of the production chain. Farmers worked in a tightly controlled environment which emphasized compliance with all the irrigation management directives (Sishuta, 2005).

Sustainable production increase in irrigated agriculture can be achieved by two ways. Either new irrigation projects can be developed or existing schemes can be evaluated and their performance can be improved. In recent years improving irrigation systems performance is more preferable than developing new irrigation areas since investment in irrigation has failed to produce the expected result in many countries (Sener *et al*., 2007).

Over the past two decades, many nations have attempted to reform water management by decentralizing water management responsibilities in order to improve the performance of irrigation systems. This concept was adopted by many countries as "Participatory Irrigation Management (PIM)" or “Irrigation Management Transfer (IMT)”. The purpose of IMT was to involve farmers in irrigation management including operation and maintenance (O&M) and to encourage efforts byindividuals to take responsibility for the management of resources in the belief that individuals have greater stake and better information for making efficient resource allocations (Brewer *et al.,* 1999). It is now widely understood that irrigation schemes will not be able to perform as needed without basic institutional reform and this generally means devolution of some or all responsibility and authority for irrigation management to water users' associations (Vermillion, 2000).

In Turkey, Sri Lanka, India, Japan and Mexico, success has been noted in areas of operation and maintenance, more equitable water distribution, increased fee collection, decrease in wasteful use of water, enhanced durability of irrigation facilities, reduction in government burden and facilitation of cost recovery. The achievements have been observed due to irrigators/water users' associations' participatory approach in making decisions, managing the irrigation water and infrastructure at their schemes which all together created a sense of ownership (Chieko *et al.,* 2004; Tanaka *et al*., 2005).

Tanzania has an irrigation potential area of about 29.4 million hectares with 2.3 million hectares as high potential, 4.8 million hectares as medium potential and 22.3 million hectares as low potential (URT, 2002a). Although the potential area for irrigation is huge, it is only 310 745 hectares equivalent to 1% of the total potential area that has been developed for irrigation. Irrigation development in Tanzania has gone through stages. First, the government imposed smallholder irrigation practice.

The small-scale farmer managed/smallholder irrigation schemes are less than 400 ha while large scale farmer-managed schemes are more than 400 ha (Mnzava and Makonta, 1994). Then there was the large-scale practice in which only the Government was involved in irrigation development. In all these stages, farmers did not participate in their planning, design, and construction.Hence, many of the smallholder farmer managed schemes are underperforming due to inadequate operation and maintenance of irrigation infrastructure, low irrigation efficiencies, insufficient water supplies and poor water productivity (Omari, 1996; Masija and Kabugila, 1994).

Some interventions such as rehabilitation or upgrading traditional schemes, introduction of schemes based on rainwater harvesting and construction of new smallholder schemes have been suggested by the Government in order to improve the irrigation efficiency, water management, operation and maintenance and attaining a sustainable irrigated agriculture (Matiku, 2000). In all the interventions farmers were required to be sensitized and organized into workable Water Users' Associations (WUA)'s or Irrigators' Associations (IA)'s (URT, 2008). In Tanzania the WUA's approach gained momentum from the 1990s Government participatory policy reform (Burra, 1999). The reforms aimed at making the WUA's self sustaining economic entities that could also manage their natural resources and especially water. It is important that impacts of management reforms on the performance of irrigation systems are carefully analyzed and understood, in order to set the record straight, and more crucially because of the significance of such analyses for policy decisions pertaining to the irrigation sector (Samad and Vermillion, 1999).

Igomelo irrigation scheme in Tanzania was rehabilitated through the River Basin Management Smallholder Irrigation Improvement Project (RBMSIIP) and handed over to the Igomelo Irrigators' Association in 2002. Since then, the scheme's performance has not been evaluated. Through evaluation of rehabilitated irrigation system, it will be easier to identify challenges that may be useful in improving other irrigation system. The principal objective of evaluating an irrigation system is to identify alternatives that may be both effective and feasible in improving the system's performance (Walker and Skogerboe, 1987). Evaluations of surface irrigated fields yield not only data which can be used to detect problems but also information essential to achieving high levels of management and control.

1.1 Objectives of the Study

The main objective of this study was to evaluate the performance of Igomelo irrigation scheme in Mbarali District, Mbeya Region.

The specific objectives of the study included:

i) To evaluate the performance of water distribution systems.

ii) To assess IA's roles in operation, maintenance and management of the distribution systems.

iii) To determine the relationship between IA's roles and the performance of the scheme

iv) To recommend ways of improving the performance.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Irrigation Management Transfer (IMT)

Irrigation management transfer is defined as the transfer of authority and responsibility to manage irrigation systems from government agencies to water users' organizations (Yercan *et al.*, 2004). Water users' organizations can be in several forms. If an irrigation network goes through one local authority area, the management of the irrigation network can be transferred to that authority. If an irrigation network serves more than one administrative unit, it could be transferred to water users' associations (WUA). Irrigation schemes which serve the area of only one administration unit could be transferred to irrigation cooperatives (ICs) as well as municipalities and village authorities (Chieko *et al.*, 2004).

Irrigation management transfer is a reform which has been strongly supported by many governments due to financial pressures, lack of sufficient funds allocated to irrigation management, widespread deterioration and poor performance of irrigation systems and failure to collect sufficient water charges from farmers (Yercan *et al.*, 2004; Sener *et al.*, 2007). This was aimed at a number of issues such as sustainability of irrigation systems; improving the performances of irrigation systems; reduction in operation, maintenance and management costs and effective use of resources (Cakmak *et al.*, 2003).

The aims of the transfer in Sri Lanka for example were to relieve the government from the financial burden of funding recurrent expenditures for irrigation, improve the maintenance of irrigation facilities and irrigation services and enhance the productivity of irrigated land and water (Samad and Vermillion,1999) while in Turkey it aimed to decrease operation and maintenance expenditures (personnel, energy, maintenance and repair costs) and ensure more equitable, reliable and adequate water distribution (Kuscu *et al*., 2009b; Sener *et al*., 2007).

In a study on assessmentof participatory management of irrigation schemes in Sri Lanka (Samad and Vermillion, 1999) reported that irrigation management transfer alone has not resulted in an appreciable improvement in crop yields, quality of irrigation services or the value of agricultural production. Similarly, rehabilitation alone has not created significant effects. However, where both rehabilitation and management transfer has occurred, significant improvements in agricultural productivity levels and return to land and have been observed.

The significant outcomes have also been observed in Ethiopia through increased availability of water, improved reliability of water supply and flexibility in cropping pattern which have enabled the farmers to make shifts in cropping pattern towards high value crops. Farmers have reported some improvement in yields for the crops that were cultivated (Naik and Karlo, 1998).There has also been a more equitable water distribution and therefore a reduction in conflicts.

2.2 Operation and Maintenance of Irrigation Systems

Operation in irrigation refers to the management of the central task in an irrigation scheme which is to supply irrigation water whereby maintenance is about the efforts that have to be made to keep the scheme in good working order (FAO, 1996).

Maintenance performance is regarded as keeping the canals and structures in good physical condition to provide the desired service. Operation and maintenance (O&M) is crucial for the sustainable running of the scheme leading to better water use and hence improved agricultural output. The O&M and agricultural productivity have a cause effect relationship; the sustenance of the one depends on the good performance of the other (Tanaka *et al*., 2005). Operation and maintenance works are essential to well achieve water distribution. Tanaka *et al*. (2005) classified these works into three categories; water distribution management, facilities maintenance and repair of facilities. Water distribution management can be achieved by central control which involves channeling water into the fields, releasing water from the source to the main canal and regulating the water distribution when necessary. Facility maintenance creates an environment that facilitates smooth water distribution, compared with other parts of irrigation management. Facility repair includes repairing of channels, division works and other facilities.

Structures are considered to be in poor condition when there is constriction or enlargement of the canal cross section, visible siltation, visible seepage, slippage, scouring, or other defect in embankment, cracks or other damage to canal lining, grass and algae covering up the canals and mud pilling up on the channel so that the flow of water is blocked (Brewer and Sakthivadiel, 1999; Tanaka *et al*., 2005).Based on such characterization of the condition of structures, Samad and Vermillion (1999) found that the average percentage of the main canal length that was defective was 15% which was considered relatively high for a main canal in an irrigation scheme in Sri Lanka. However for the distributary channels it was 3.2%

which was considered as significantly better. Some problems such as head tail problems, leaky canals and malfunctioning structures because of delayed maintenance have also been reported by Kuscu *et al*. (2009b) in Turkey leading to low water use efficiency and low yields.

Behailu (2005) found that in five years time, Tekeze scheme in Ethiopia had not received maintenance such as repairing some worn out portions of the canals and other structures instead only cleaning of canals was done. Inadequate maintenance of the existing infrastructure and silting of the reservoir was a key challenge to the future sustainability of the scheme. There were canal sections which needed lining; otherwise the seepage loss from these sections would have continued to cause water-logging problems. Vandersypen *et al*. (2007) reported on diminished capacity of the tertiary drains due to neglected maintenance.

According to Department of Water Affairs and Forestry, (DWAF,2000) seepage is simply defined as the loss of water due to infiltration through the bed or banks of an irrigation channel. Sharma and Sharma (1990) noted that there are several methods of measuring seepage and operational losses from canal systems. An estimate of the magnitude of the seepage loss for a channel can be obtained either by direct or indirect measurement. Indirect techniques involve the measurement of the groundwater profile. Direct measurement technique may be using inflow- outflow or ponding technique for measuring seepage loss for relatively long sections of the channel. Normally, estimates are made with an inflow-outflow approach by using the records of diversion and delivery for the system. Seepage losses are normally expressed in liters per second per 1000 m^2 wetted areas of the canal lining.Seepage losses can be estimated by Equation 1.

$$Q_s = \left(\frac{Q_u - Q_o - Q_D}{D} \right) 1000 \quad \text{……………………..………………………….(1)}$$

Where:

Q_S	=	Seepage loss within one kilometer reach [l/s/m]
Q_U	=	Discharge at upstream section of the measured reach [l/s]
Q_O	=	Sum of all discharges abstracted from the measured reach of the canal[l/s]
Q_D	=	Discharge at downstream section of the measured reach [l/s]
D	=	Distance apart between the two sections of the measured reach [m]

Vandersypen *et al*. (2007) and Wegerich *et al*. (2008) identified weeds as a common problem in unlined irrigation and drainage canals. The estimated and measured discharges in the presence of weeds were about 50% of canal capacity losses in the main canal which incorporated spills due to overflow and seepage losses. Seepage without proper weeding was 0.04 liters per second per meter while after weeding it decreased to 0.025 liters per second per meter.

2.3 Irrigation Water Management

Irrigation water management is an integrated process of coordinating and organizing means of production (land, labour and water) in operating and maintaining irrigation systems so that it can deliver the right amount of water to the right place at right time. Irrigation water management (IWM) involves the managed allocation of water and related inputs in irrigated crop production, such that economic returns are enhanced relative to available water (Tyagi *et al*., 2005). Conservation and allocation of limited water supplies is central to irrigation management decisions, whether at the field, farm, irrigation-district, or river-basin level (USDA, 1994). Knowing how much water is applied with any method of irrigation is a key to good management. For proper monitoring, the amount of water applied into the field should be measured and recorded. Such practices help in judging whether the amount of water deliveries match with the predicted quantities or distributed equitably, adequately, and timely among different farmers in irrigation canal systems (Subira, 2000).

Irrigation water management should focus on the adoption of practices that enhance the efficient use of water so that other sectors can have more water for economic use (Mateos *et al*., 2010). Efficient irrigation systems and water management practices can help maintain farm profitability in an area of limited higher-cost water supplies. Efficient water management may also reduce the impact of irrigated production on offsite water quantity and quality. A better knowledge of crop water requirements is essential for efficient water distribution and management (Kihupi, 2008). It has been reported in Mali (Vandersypen *et al*., 2006) little knowledge on crop water requirements led to hardship in establishment of an irrigation schedule. Behailu and Nata (2005) reported that 90% of respondents at an irrigation scheme in Ethiopia did not monitor or know whether the field is being over-irrigated or not as a result, misuse of water was identified.

2.3.1 Drainage management

Drainage is a practice of removing excessive water and dissolved salts from the surface and subsurface of land intended to enhance crop growth and soil conservation. Too much subsurface water can be counterproductive to agriculture by preventing root development and inhibiting the growth of crops.

Drainage is a very crucial aspect in water management since it helps in removing excess water. It is also helpful in solving problems such as water logging, soil erosion, and salinisation in irrigated agriculture. Kips and Ndondi (1990) noted that, there could be no suitable irrigated agriculture without proper attention to drainage.Drainage management aims atkeeping drain systems functioning effectively and efficiently.

2.3.2 Irrigation scheduling and its methods

The process of irrigation scheduling is concerned with the application of water at the right time and in proper amounts to achieve optimum water supply to the crop while maintaining high irrigation efficiency (Abdulmumin and Bastiaansen, 1991). At field level, effective irrigation scheduling requires reliable and timely water delivery through coordinated action between irrigation authority and farmers (Mbozi, 2006). The main assumption of most irrigation scheduling techniques is that irrigation water is available on demand, which may not always be the case especially where farmers are organized and receiving water on rotation basis. However, rotational supply could be tailored to closely follow individual needs (Tarimo *et al.*, 2004b).

There are several methods for determining both the timing and the depth of water to be applied to a crop. Methods can be classified as crop based, soil based and climatic or a combination of these methods (Kihupi, 2008). In most cases, the skill of the farmer and financial capacity determines the effectiveness of irrigation scheduling at field level (Itier *etal*., 1996).

Crop based approaches are the most direct in determining when to irrigate, as the primary objective is to supply plants with water when it is needed. Monitoring plants can be achieved by observing plant appearance, growth, leaf temperature, leaf water potential and stomata resistance (Tarimo *et al*., 2004b). Crop appearance and growth are not effective parameters for scheduling full irrigation since plants are stressed long enough to adversely affect yield before changes in appearance can be detected. Visual plant stress indicators must be carefully interpreted, since diseases and improper nutrient levels produce changes similar to those associated with water stress (Tarimo *et al*., 2004b).

Soil based methods typically measure or infer the soil moisture content or matric potential. The amount of soil moisture available to the plant determines when and how much irrigation to apply. Soil indicators of when to irrigate also provide data for estimating the amount of water to apply per irrigation (Kihupi, 2008). One of the methods most widely used by farmers is thesoil based scheduling techniquewhich is the soil feel and appearance. With experience, irrigators can judge water content by appearance and feel of the soil (Tarimo *et al*., 2004a). The method is easy in implementation but requires some skill. This requires some judgement, but with enough practice, estimates can usually be obtained within ± 10 -15% of the true soil moisture content.

As for climate based irrigation scheduling, water use for crop production depends on the interaction of climatic parameters that determines crop evapotranspiration and water supply from rain (Mbozi, 2006). The analysis of climatic information for crop water use is therefore a key element in developing strategies to face the global water crisis and looming food shortages (Smith, 2000). Climate based methods of irrigation scheduling; typically use meteorological data to estimate potential evapotranspiration for a well-watered crop and use site specific crop coefficient curves to further refine crop water use.

2.4 Performance Indicators

A performance indicator is basically a quantitative measure of an aspect of irrigation standards which helps to evaluate and monitor irrigation efficiency (Alegre *et al*., 2000). Performance indicators are therefore relationships between two or more magnitudes of an irrigation zone (Rodríguez *et al*., 2004). The improvement in performance management plays a key role in using organization's current resources appropriately and creating competitive advantage (Jeston, 2008). Sarma and Rao (1997) reported the importance of adequate monitoring and evaluation of performance as a means to improve water management practices in order to achieve an increase in overall efficiency. Performance assessment through the use of performance indicators are one result of information management for irrigation system control. Information management includes collection, processing and presentation of primary and secondary data and from this data sources parts are used to calculate or to serve as performance indicators. It helps irrigation managers to allocate and conveywater from a source to a field by managing irrigation facilities. Efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure so as to keep the system running and the service aspects of water delivery can be addressed. The performance has been assessed for individual, basin, and nationalSchemes for specific types such as those public-operated and transferred to users' organizations or cross-system comparison of irrigation systems all over the world.

In the past few years**,** there has been considerable interest in the development of indicators, which could describe different internal processes and outputs of irrigation systems. A number of researchers have conducted studies to assess the performance of irrigation management process using financial and physical indicators (Molden and Gates, 1990; Sakthivadivel *et al*., 1993; Merdun, 2004, Yercan *et al*., 2004; Degirmenci *et al.*, 2006). Most authors propose to use different indicators and different methodologies or tools to measure the same indicators (Bos *et al*., 1994; Molden *et al*., 1998). However, Bos *et al.* (1994) presented a framework of using performance indicators grouped into four namely: economic, process, agricultural output and performance of structures indicators.

2.4.1 Economic performance indicators

When evaluating a scheme under a water users association or irrigators association economic indicators can be used. These indicators deal with how much fee is collected from water users is used yearly in maintenance and operation expenditure and whether the system is self sufficient or not (Vermillion, 2000). Some economic indicators have been suggested for system performance evaluation. These include:

i) Effectiveness of Fee Collection (EFC) which is the annual irrigation fees collected, divided by the total annual fees assessed (Bos, 1997). This indicates the effectiveness of the collection program, but it can also be affected by the economic condition of the irrigators and the degree to which the irrigators feel the system is worth supporting. Sener *et al*. (2007) reported EFC values to be between 5.6-61.1% in Turkey which were not at a satisfactory level compared to the systems either managed by government or by water users' association elsewhere. The EFC was low although the management was under the water users. The average for Turkey generally was 78% at the end of 1998 (Yercan *et al*., 2004). According to Yercan *et al*. (2004), systems EFC higher than 75% are fully mature and sustainable.

ii) Maintenance Budget Ratio (MBR) which is the annual maintenance expenditures dividedby the total operation and maintenance (O&M) expenditures (Ijir and Burton, 1998). Unfortunately there is no range which could be regarded as optimal or acceptable.

iii) Financial Self Sufficiency (FSS) is the annual revenue from water user fees and other local income (not including subsidies), divided by total annual expenditures. For self-sufficiency, this indicator should be near one. Molden *et al.* (1998) and Ijir and Burton (1998) used this indicator, but divided only by O&M expenditures, not total expenditures. Using only O&M expenditures ignores other cost related to self sufficiency, especially investment repayment costs.

iv) Sener *et al*. (2007) reported a low percentage of operation and maintenance expenditure supported by fee collection from water users. Average FSS under government management was 70% which dropped to 29% after turnover. The Water Users Association FSS was found to be insufficient for O&M expenditure. Sener *et al*. (2007) found the transfer of management to WUA to have failed from this point of view.

2.4.2 Process indicators

Kloezen *et al*. (1998) described another type of indicators which can be used in evaluation of irrigation systems to be process indicators. These are used to assess actual irrigation performance relative to system specific management goals and operational target. Murray-Rust and Snellen, (1993) described some process indicators (Equity, Efficiency, Adequacy, Flexibility and Dependability) to focus on mechanisms of irrigation projects and to provide selective enhancement of those mechanisms for the purpose of improving irrigation performance (Burt and Style, 1999; Molden and Gates, 1990). These indicators are described in detail in the following paragraphs:

i) Equity of water supply (P_E)

Equity of irrigation water supply can be defined as the delivery of fair share of irrigation water to all irrigators throughout the system (Bhutta and Vander

Velde, 1992). This is a measure for spatial uniformity of water deliveries and shows the fairness of water delivery across delivery points. This concept deals with supply of irrigation water among irrigators in a fairly equal and just manner. Vandersypen *et al*. (2006a) as cited by Molden and gates (1990) calculated the indicator as:

$$P_E = \frac{1}{T}\sum CV_R\left[\frac{Q_D}{Q_R}\right] \qquad \text{……………………………………………………….(2)}$$

Where:

P_E = Equity of irrigation water supply

CV_R = Spatial coefficient of variation over region R = Q_D/Q_R

Q_D = Amount of water delivered

Q_R = Amount of water required

T = One irrigation season (days)

Siwale (2005) found the indicator to be more comprehensive since it does not only relate the delivered flows to the required flows but also describe the degree of variability relative to water delivery from point to point over the region. The closer the value of P_E to zero, the greater the degree of equity in water delivery.

Equity cannot be easily achieved in the field due to poor water management, changed channel physical condition resulting from low levels of maintenance, changes in outlet from tampering, installation of physical interventions to appropriate water, especially head and middle location (Siwale, 2005). Some studies carried in Asia and Africa have shown that variation in water supply may be due to nature of supply, design default, poor maintenance of canals and drains, construction faults and management faults (Bhutta and Vander Velde, 1992).

FAO (1989) presented Uniformity of Christiansen's Coefficient (UCC) as another parameter to quantify inequity. When UCC is close to zero the degree of inequity is high and there is totally no uniform distribution of water and vice versa when it is unity (Kongola, 2000).

The Coefficient of Spatial Water Distribution (CSWD) is another parameter used to quantify inequity. The parameter has the advantage that it is easy to compute. Its values range from 1 and above. Relative Water Supply (RWS) which is the ratio of total water supplied to the crop water requirement is the parameter which is used in computation of the CSWD. The parameter (CSWD) is computed by dividingother RWS values by the smallest RWS value (Kongola, 2000). Whenever CSWD values are high, the degree of inequity is high and there is totally no uniform distribution of water and vice versa when they are equal. Kongola (2000) obtained the lowest CSWD value of 1 while the highest value was 3.4. Differences in CSWD indicated inequity meaning that one plot obtained 3.4 times more water than the other plot.

Although UCC offers simple computations and reveal non-uniformity in water distribution and supply among irrigators, at the farm level the concept of CRWS give better representation of inequity situation because at the end of the season it is shows how much water the plant used(Abernethy, 1986).

ii) Dependability of irrigation water supply (DIWS)

Dependability of irrigation water supply (DIWS) is defined as the supply of fairly uniform quantity of irrigation water to farmers to meet crop irrigation water requirement and in time throughout the irrigation system (Makongoro, 1997). This indicator expresses the degree of temporal variability of irrigation delivery compared to requirements (Vandersypen *et al*. 2006a). It thus assesses whether adequate water quantities arrive at the required time and place. When delivery exceeds requirements in a certain period, it is considered fully adequate.

Dependability of irrigation water supply is quantified by the coefficient of variation of the ratio of water supply to demand over the time period in consideration (Makongoro, 1997). This indicator has been presented by Molden and Gates (1990) as:

$$P_D = \frac{1}{R}\sum CV_R\left[\frac{Q_D}{Q_R}\right] \qquad (3)$$

Where:

P_D = Dependability of irrigation water supply

CV_R = Spatial coefficient of variation over region R

Q_D = Amount of water delivered

Q_R = Amount of water required

Vandersypen *et al*. (2006) obtained dependability values of 0.78 and 0.71 in Mali. The values were classified to be far beyond the threshold accounting for poor which is 0.25. The indicator did not imply that water supply is unreliable or unfair but rather presented a measure of temporal and spatial variability in over-supply. Makongoro (1997) obtained mean dependability values of 0.3 in Tanzania which showed dependability in water supply. In some few plots the dependability values were between 0.5 and 0.6 which could be explained by the habit of farmers of irrigating more frequently and preferring higher levels of water in their fields. According to Gates *et al*. (1991) the closer the dependability values to zero the more dependable is the irrigation water supply.

iii) Adequacy of irrigation water supply (AIWS)

Adequacy (P_A) assesses whether the requirement has been met by the amount of water delivered (Vandersypen *et al*. 2006).When delivery exceeds requirement in a certain period, it is considered fully adequate. Molden and Gates (1990) classified classes for Equity and Adequacy as shown in Table 1.

Table :Performance classes for Equity and Adequacy

Measure	**Performance Classes**		
	Good	Fair	Poor
P_E	0 -0.11	0.11 - 0.25	> 0.25
P_A	0.9 - 1.00	0.80 - 0.89	< 0.80

Source: Molden and Gates (1990)

The most comprehensive measure of adequacy, recommended by International Water Management Institute (2000) is Relative Water Supply (RWS). The RWS shows the water available for crops need. The indicator provides information about the relative abundance or scarcity of water (Siwale, 2005). It is defined as the ratio of water supply to the water demand (Equation 4) associated with crops actually grown with the cultural practices actually used, and for the actual irrigated area (IWMI, 2000). This ratio is the most crucial factor in design, planning, management and operation of irrigation systems. The values for RWS are obtained from field measurements, (Makongoro, 1997).

$$RWS = \frac{Totalwatersupply}{Totalcropwaterdemand} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The RWS concept has been proved to be a useful tool for understanding the performance of irrigation systems by irrigation managers and farmers (Siwale, 2005). Despite its numerous advantages, the RWS concept has some weaknesses, which may be overcome by the use of Cumulative Relative Water Supply (CRWS) as explained by Sakthivadiel *et al*.(1992).

Sener *et al*. (2007) in an evaluation on water use performance in Hayrabolu, Turkey obtained a RWS of 1.91 which satisfied the crops. However the value obtained implied that the relationship between the water supply and crop demand was poor. Upadhyaya*et al.* (2005) obtained RWS values of 0.93, 0.84 and 1.14 for head, middle and tail reaches in Patna main canal command in India. Improvements were suggested in relative water supply to meet crop water demand in middle and head reaches. Vandersypen *et al*. (2006) obtained a RWS value of 0.91 in Mali which was judged as good according to Molden and Gates (1990). Kongola (2000) in Tanzania obtained RWS values between 1 and 3.4 suggesting inefficient water management practices. Tyagi *et al*. (1996) obtained RWS values of 0.72 for upstream and 0.58 at the tail reach watercourses. The significant reduction in RWS towards the tail end was due to seepage losses occurring in the watercourses.

iv) Irrigation efficiency and productivity

When determining the performance of farm irrigation system it is often useful to examine the efficiency of each system component (Kongola, 2000). This allows components that are not performing well to be identified. According to Mdemu *et al*. (2003) irrigation efficiency and water productivity should be used complementarily when assessing performance of irrigation management systems. While efficiency concepts provide indicative figures for a system performance in terms of water use for the intended purpose, the productivity concept provides full information on the amount of products that can be produced within a given amount of available water. Productivity, especially the physical one (kg crop m^{-3}) has long been used as one of the indicators for irrigation efficiency.

Conveyance losses are defined as those that occur from the time water is released from the reservoir to when it is delivered to the farm gate (Fairweather *et al*., 2003). It includes evaporation, seepage losses and other leakages such as filling losses. The conveyance efficiency$E_c$is the efficiency of water conveyance in the main canal system from the scheme headworks to the main canal outlet or an inlet to block of fields. It is normally calculated as the ratio of water received at inlet to a block of fields and that released (diverted) at the project headworks as shown in Equation 5. It is normally affected by the canal length, seepage of the canal bed, lined or unlined, soil type and rate of evapotranspiration. Conveyance efficiencies, in unlined canal range from 100% to 70% for area with effective management and 70%

to 0% for area with ineffective management (FAO, 2000). The conveyance efficiency is normally calculated as:

$$E_C = \frac{Q_d + Q_2}{Q_c + Q_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where:

Q_c Q_c = Discharge diverted or pumped at the headworks (l/s)

Q_d Q_d = Discharge delivered to the distribution system (l/s)

Q_1= Discharge inflow from other sources to the conveyance system (l/s)

Q_2 = Non-irrigation deliveries from conveyance system (l/s)

According to FAO (1996) canal conveyance losses are defined as the fraction of irrigation water lost between water released at a canal headworks and water delivered to the farm offtakes. Abdulmumin *et al*. (1990) recommended the acceptable canal conveyance efficiencies to be within the range of 90% and 80% for the schemes with effective management and 70% to 65% for schemes with respective problematic communication and less effective management. Matiku (2000) obtained a conveyance efficiency of 65% for the main canal. The value was found to be low (Abdulmumin *et al.*, 1990) due to losses through evaporation, seepage and unlined condition of the main canal.

Distribution efficiency E_d is the efficiency of the water distribution canals and conduits supplying water from the conveyance network to individual fields. It can be expressed shown in equation 6.

$$E_d = \frac{V_f + V_3}{v_d} \quad \text{……………………………..…………………………..(6)}$$

Where:

V_d = Volume delivered to the distribution system (m^3)

V_f = Volume of water furnished to the fields (m^3)

V_3 = Non irrigation deliveries from the distributary system (m^3)

Field application efficiency (Ea) is the relation between the quantity of water furnished at the field inlet and the quantity of water needed and made available for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

$$E_a = \frac{V_m}{V_f}$$

$$E_a = \frac{V_m}{V_f} \quad \text{...(7)}$$

Where:

V_m is the volume of irrigation water needed and made available for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout at the growing cycle (m^3).

The volume of water needed and made available to the crops can be estimated using average values for soil physical properties (FAO, 1999). Tables to be used for the estimated values have been prepared (FAO, 1999). For earth canal network with surface irrigation, the application efficiency should be between 40 % and 50 %. For a lined field canals in South Africa an application of 70% for Dzinzi irrigation scheme was reported (Nthai, 2007).

However, process indicators have been reported to have some limitations such as being based on the existence of clearly defined management goals and operational targets. Kloezen *et al*. (1998) reported that many irrigation systems do not have goals and targets or too widely defined and inconsistent with one another. Also measurement of process indicators require complicated data collection procedure. These indicators generally address how input especially water is used but do not provide information on what wider hydrological, agricultural, economic, social and environmental impact the input may have led to (Siwale, 2005).

Other indicators have been suggested by the International Water Management Institute (IWMI, 2000). Recently some researchers have advocated the use of IWMI comparative indicators in assessing performance of irrigation systems in irrigation schemes and project since IWMI indicators can be applied within the limited time, money and information resources available to the typical manager or water users associations (Sener *et al*., 2007; Nelson, 2002; Degirmenci *et al*., 2003). These indicators are oriented towards the existing system, aspects that do not require major modification of the infrastructure.

2.4.3 Indicators of irrigated agriculture output

The Standard Gross Value of Production (SGVP) is the output of the irrigated area in terms of gross or net value of production measured at local or world prices (Sener *et al*., 2007). It makes possible to compare the performance of systems, no matter where they are or what kind of crops are being grown. Output per unit of irrigation supply in Turkey can be compared to the one in India.

$$SGVP = \left[\sum cropsA_i Y_i \frac{P_i}{P_b}\right] Pworld \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

Where:

A_i = Cropped with crop i,

Y_i = Yield of crop i,

P_i = Local price of crop i,

P_b = Local price of the base crop (predominant locally grown, internationallytraded crop) and

P_{world} = Value of the base crop traded at the world prices.

IWMI described four indicators relating the monetary value of the system's output, agricultural production, to the input of land and water. Through standardization of the agricultural production value, the indicators make possible comparison of different systems.

$$Outputpercroppedarea = \frac{SGVP}{Irrigatedcroppedarea} \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$Outputperunitcommandarea = \frac{SGVP}{Commandedarea} \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

$$Outputperunitirrigationsupply = \frac{SGVP}{Divertedirrigationsup\,ply} \ldots\ldots\ldots(11)$$

$$Outputperunitcommandarea = \frac{SGVP}{VolumeofwaterconsumedbyET}.(12)$$

Output per unit cropped area gives an indication as to which crop can produce more value and can vary according to crop pattern and price of the base crop (Molden *et al*., 1998). Siwale (2005) obtained values between 372.4 US$ ha^{-1} and 761.6 US$ ha^{-1} in Herman irrigation scheme in Tanzania. The values were low due to inadequate water distribution which led to a large area being cultivated and fluctuation in cropping pattern. Behailu *et al*. (2004) in a study in Tekeze Basin in Ethiopia got a value in the range 1151.89-1682.07 US$/ha. Cakmak (2003) reported a range between 359 US$ ha^{-1} and 6179 US$$ha^{-1}$ which were believed to be low due to high rate of rice growing area of the cultivated land.

Output per unit irrigation supply indicates the magnitude of irrigation needs (Siwale, 2005). The indicator is high in humid area from the fact that the irrigation water requirements are generally lower. Upadhayaya*et al*. (2005) reported values for output per unit supply of 0.0490, 0.045 and 0.0298 (US$/$m^3$) for head, middle and tail reaches in India and described the production value per unit irrigation supply in head reach as better than middle and tail reach while Degirmenci *et al*. (2003) reported values between 0.12 and 2.16 (US$/$m^3$) in Southern eastern Anatolia Project, Turkey. The differences in the output per unit water consumed in respective cultivated areas may be caused by the cropping pattern adopted and farmers' abilities.

Output per unit water consumed specifies production value per unit volume of water consumed. Cakmak *et al*. (2003) obtained values in the range of 0.15 – 1.55 ($/$m^3$) in Turkey. The difference was attributed to the cropping pattern and abilities of the farmers and system managers.

Crop water productivity is the amount of water required per unit of yield and a vital parameter to assess the performance of irrigated and rainfed agriculture. Crop water productivity will vary greatly according to the specific conditions under which the crop is grown (FAO, 2004). Behailu and Nata (2005) obtained values of water productivity of 1.07 kg/ m^3 and 0.23 kg/m^3 in Ethiopia for onions and maize respectively.

2.4.4 Performance indicators for structures

Some authors have suggested other indicators which can be useful when assessing the performance of irrigators associations. Nelson (2002) suggested the use of some indicators when evaluating structures in schemes managed by associations such as water users association or irrigators associations. These indicators can usually be applied within the limited time and financial resources available to the typical manager or association. The indicators are mostly oriented toward aspects that affect water deliveries, rather than indicators like crop yields that are also affected by other factors. Nelson (2002) described these indicators as:

i) The Poor Structure Ratio (PSR) which is the number of structures in poor condition divided by the total number of structures. Ideally, this ratio should be zero. Ijir and Burton (1998) used the Structure Condition Index (SCI) which is the number of structures working normally divided by the total number of structures (Equation 13).

$$SCI = \frac{Number\ of\ structures\ working\ normally}{Total\ number\ of\ structures} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

ii) Bos (1997) used the same indicator but called it “Effectivity of Infrastructure”. PSR and SCI are similar, but PSR emphasizes on structures that aren't functioning adequately; while SCI emphasizes structures that are functioning adequately. For example, if PSR is0.05then 5% of the structures are in poor condition whereas SCI of 0.05 means95% of the structures are in good condition.

2.4.5 Economic performance Indicators

Economic performance can be obtained using the Effectiveness in fee collection (EFC) and the financial self sufficiency (FSS) indicators. The indicators can be obtained through Equation 14 and 15 expressed as:

$$EFC = \frac{Annualirrigationfeescollected}{Totalannualfeesassessed} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$FSS = \frac{Annualrevenue}{Totalannualexpenditure} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter describes materials and methods used in this study. It gives the general background of the study area, materials and methods used to measure and obtain some parameters required to achieve the study objectives.

3.1 Description of the Study Area

3.1.1 Location

Igomelo Irrigation Scheme is located in Mbarali District, Mbeya Region. It lies at latitude 8^o 47' 47'' South and longitude 34^o 23' 13'' East with a mean altitude of about 1050 masl. The scheme is 120 km from Mbeya municipality and 5 km south of Igawa village (Fig.1). The scheme is located in Igomelo village which is formed by ten hamlets namely; Kamficheni, Nyanyanjo, Kanisani, Faru, Temeke, Kaloleni, Sangu, Nyuki, Mji Mwema and Mpunga (DITS, 2002).

3.1.2 Scheme Layout

The command area of the scheme is 312 ha whereby water diversion is effected by means of a concrete weir built across the Mbarali river, through a gated structure in which the main canal follows on the right bank of the river. Due to the topography of the scheme area, it did not need secondary canals. Instead, tertiary canals abstract water directly from the main canal (Fig.2). Farmers control irrigation water from tertiary canals into their fields through small division boxes.

The main canal feeds a total of 11 tertiary canals (TC). Tertiary canals number four, six eight and eleven irrigate on the right of the main canal and terminate in Liganga natural drainage system. The rest irrigate on the left hand side of the main canal and drains into Mbarali river. The command areas for the canals are as shown in Table 2.

Table :Canals command areas for tertiary canals

Tertiary Canal	Command area (ha)
1	10

2	20
3	15
4	60
5	35
6	37
7	20
8	15
9	25
10	45
11	30

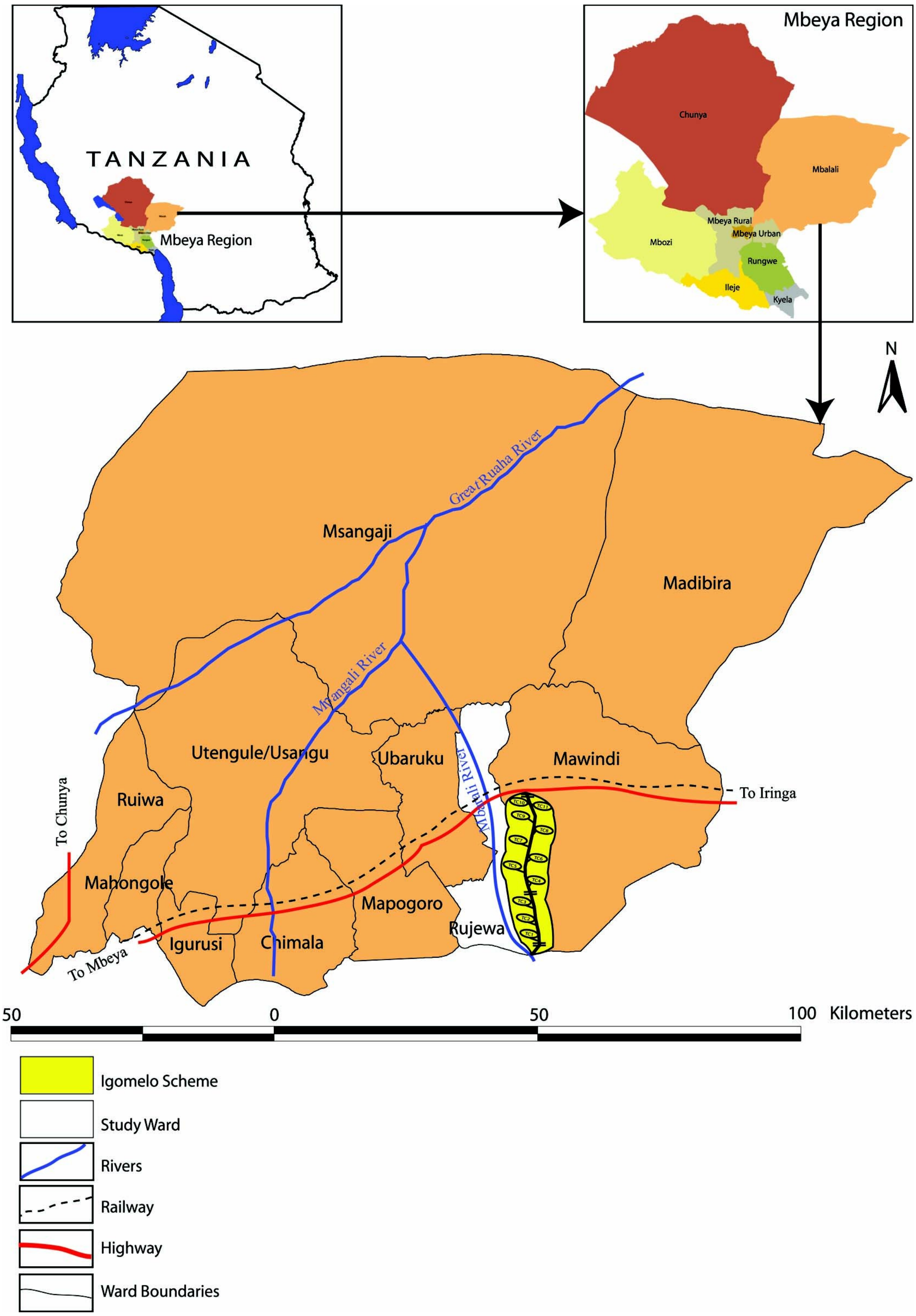

Figure :Location Map of Igomelo Irrigation Scheme

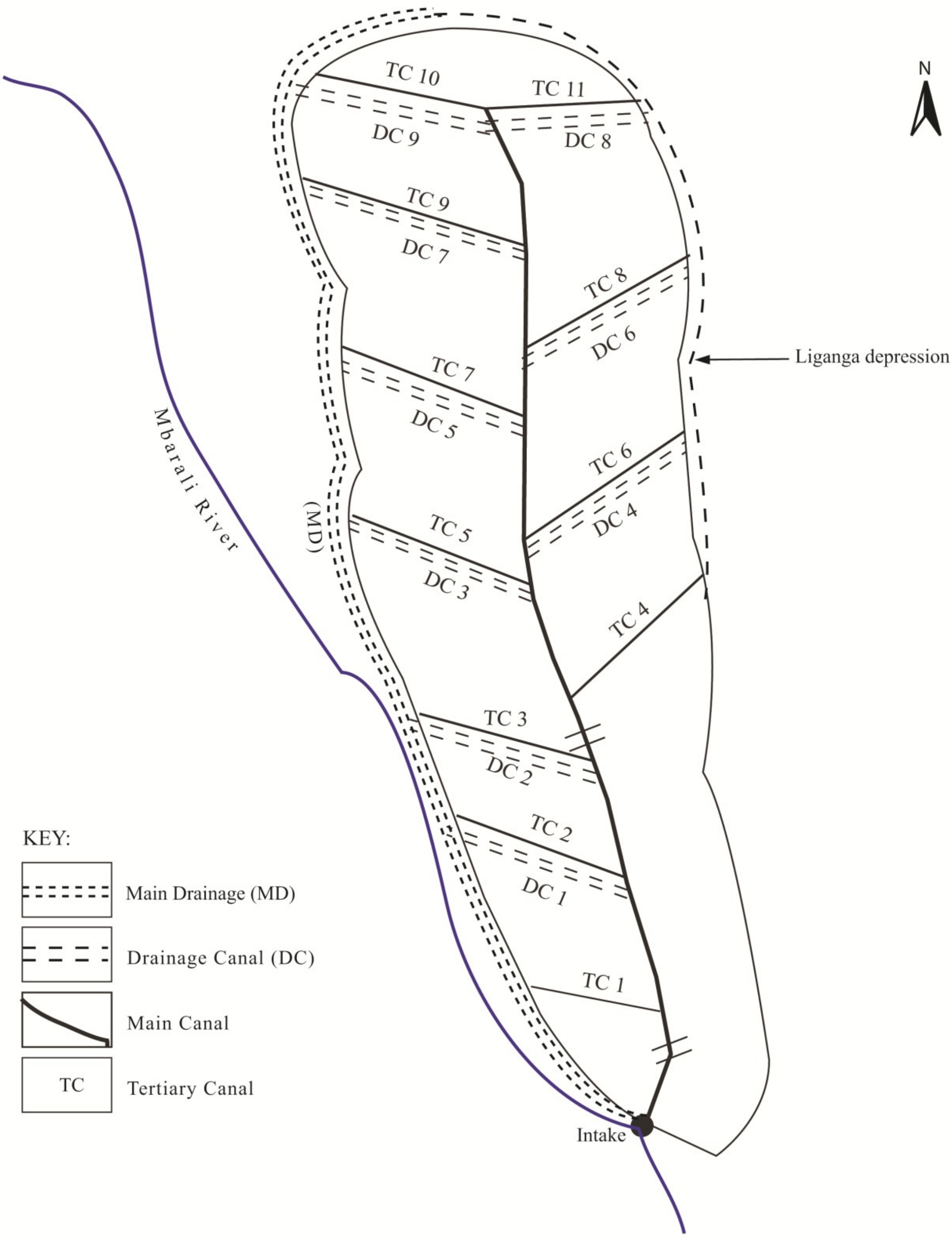

Figure :Layout of Igomelo Irrigation Scheme

3.1.3 Topography

The scheme area has a complex terrain with main slope running in the south - north direction and cross slopes in the east - west direction towards Mbarali river and a reverse in direction in some places towards Liganga natural drain. The scheme lies in volcanic outwash plain within the low and high terraces of Mbarali river. The dominant soils are basically alluvial and minor colluvial deposits of the Cainozoic era that consists of a mixture of sand, gravel silt and clay(DITS, 2002).

3.1.4 Climate

The climate of the area can be described as semi arid with highly erratic and unimodal rainfall starting from November to April.Mean annual rainfall in the area is estimated at 681 mm.The overall rainfall distribution in the study area is generally poor with about 65% of the total rains falling in a period of less than three months.

The variation in mean monthly temperature is small which can be described as fairly constant over the year. The mean monthly temperature is highest in November (25.8^{0}C) just before the onset of rains. Lowest mean monthly temperature is in June and July when the temperature is 21.2^{0}C. The mean monthly sunshine hours is 8 h/day. The wind speed varies from 63 km/day in February to 191 km/day in September with an annual average of 128 km/day. The prevailing wind condition in the area can be described as light to moderate.

The mean daily evaporation varies from 3.9 mm/day in February to 7.2 mm/day in October. The average annual pan evaporation is 2697mm.Over 200 mm per month pan evaporation have been recorded between July and December with the highest value being 317 mm in October and the lowest being 159 mm in February.

3.1.5 Soil and Land Classification

DITS (2002) grouped the soil according to mapping units namely Over flow basin mapping unit, Levee mapping unit and Tread and riser mapping unit. The soil differs in depth, drainage, texture and sodicity levels. In the Overflow basin mapping unit (25 ha) 7.9% was found to be moderately suitable for growing of irrigated paddy. The moderately limiting factors are low soil fertility and slight sodicity observed in the soil. Use of fertilizers and provision of adequate drainage were recommended. This unit had however been classified as marginally suitable for the upland crops. Most limiting factor was the heavy texture of the soil which had resulted in poor soil drainage, a condition not favourable for growth of the upland crops. The levee soil units, which cover 103 ha of the scheme area, could be moderately suitable for upland crops if the farmers would make use of appropriate fertiliser application. The Levee mapping unit was also found to be marginally suitable for upland crops due to low soil fertility. Tread and riser soil units, which cover 187 ha of the scheme area, were found to be moderately suitable for upland crops. The limiting factors are similar to those of Levee mapping unit. The unit is moderately suitable for irrigated upland crops. Due to the light textured topsoil, irrigation intervals have to be frequent at least twice a week.

3.1.6 Hydrology

The Igomelo scheme abstracts water from Mbarali river which is at the extreme south of the scheme. Mbarali river is a perennial river with good quality of irrigation water. It has mean flows of 39.2 m^3/s in March and 4.2 m^3/s in October (DITS, 2002). The dry season flows, though much lower than the wet season flows, are still substantial for irrigation purposes.

3.2 Data Collection

This study touches social as well as technical issues hence appropriate measures were adopted in data collection.

3.2.1 Baseline survey

During respondents' selection, both random and purposive sampling techniques were applied. The sample was designed in such a way that it was representative of the total number of farmers using the irrigation scheme. The survey was done in phases such as interviews, key informants, focus group discussion and direct observations in the field. In the interview, 30% of the total farmers were interviewed while fifteen others were involved in a focus group discussion through questions prepared in a checklist.

Key informants involved some personnel from the District Executive office; Zonal irrigation unit and old farmers who have been there even before the formulation of the IA, leaders of the association and rich farmers. Some of the information extracted was:

- Background information;
- Land use;
- Baseline data on irrigation (type of irrigation practiced, factor (s) that influence the choice of crop grown under irrigation); and

- Duties of irrigators associations (formulation of irrigators associations, responsibilities on irrigation schedule, involvement in formulation of schedule, factors considered in preparing schedule, irrigation agriculture experience)

3.2.2 Climatic Data Collection

Historical data for rainfall,temperature, relative humidity, wind speed and sunshine hours were obtained from meteorological station number IKA11A, located at Igawa, latitude8^{0}46’ South, longitude 34^{0}23’ East and altitude 1047 (masl), situated 4 km from the scheme. These data were used to estimate reference crop evapotranspiration, effective rainfall, net and gross irrigation requirements.

3.3 Field Measurements and Sampling

3.3.1 Plot sampling and flow measurements

The scheme was divided into three sample blocks namely upstream, middle and downstream. Three plots with major crops as tomatoes, onions and maize were selected from each block. Selection of the plots aimed at plots with crops planted during time of the study. Flows and irrigation duration into the plots were recorded throughout the season. This was done through a rectangular weir installed at the entrance to the plot. Calibration of the weir was done using a Pigmy current meter. The duration of irrigation was recorded using a stop watch. Also, a rain gauge was installed at the site for rainfall data collection during the study.

3.3.2 Structures’ condition

A field visit was made to identify the number of working and non working structures. The main canal and three other tertiary canals (2, 4 and 10) were purposively sampled for the structure condition inspections and cleanliness and conveyance efficiency determination.The three canals mentioned above were selected as representative from each location of the scheme such as the head, middle and tail respectively and also they were operational at the time of the study.

3.3.3 Seepage rate

Seepage rates in the canals were measured as suggested by Omari (1996).The lengths of lined portions of the main and tertiary canals were measured so as to determine the level and awareness on water management through canal lining.

3.3.4 Water sampling

Water samples from the scheme were taken to a laboratory for quality analysis. Levels for Calcium, Sodium, Magnesium, pH and Electrical conductivity were determined. The samples were taken from the Main canal, Canal 2, Canal 4, Canal 6 and Canal 10. Water quality analysis had to be done because not only it affects crop yield and soil physical conditions but also affects fertility needs, irrigation system performance longevity and how water can be applied (Bauder *et al.*, 2007).

3.4 Data Analysis

3.4.1 Social economic data

The information extracted from the structured questionnaire was analyzed using computer software known as Statistical Package for Social Science (SPSS) to obtain descriptive statistics of respondents.

3.4.2 Seepage rate determination

The seepage rate in the main canal and the three tertiary canals (Canal 2, Canal 4 and Canal 10) were calculated using Equation 1.

3.4.3 Determination of crop water requirements

In order to calculate the crop water requirements for the irrigated crops, crop evapotranspiration was calculated. Crop evapotranspiration was estimated as a product of crop factors (Kc) and reference evapotranspiration ET_o. Crop factors for cultivated crops were obtained from FAO guidelines for crop water requirements (Allen *et al.,* 1998). Using the climatic data collected, the reference evapotranspiration was calculated using the FAO Penman-Monteith equation as presented by Allen *et al*. (1998).Computer software CropWat Version 8 was used to estimate crop water requirements (ET_c). Data for crop coefficients at different crop stages, soil type and rooting depth were used by the software as inputs. The results were the crop water requirements, effective rainfall and net irrigation requirements.

3.4.4 Determination of agricultural output

From the data for yields which were collected in the sampled plots, local price of crop, world price of the base crop, area cropped with the crops and local price of the base crop were determined and indicators of agricultural output calculated using Equations 8, 9, 10, 11 and 12.

3.4.5 Determination of Process indicators

i) **Determination of adequacy of irrigation water supply**

Adequacy was determined using Relative Water Supply (RWS), (Equation 4).

ii) **Determination of dependability in water supply**

The dependability of irrigation water supply was calculated using the coefficient of variation of the monthly RWS. Dependability was calculated through Equation 3.

iii) **Determination of equity in water supply**

The equity in irrigation water supply among the same crops was determined using the coefficient of spatial water distribution (CSWD) as suggested by Kongola (2000).

iv) **Conveyance efficiency**

Conveyance efficiencies for the main and tertiary canals were calculated using Equation 5.

v) **Economic performance**

Equation 14 and Equation 15 for effectiveness in fees collection (EFC) and financial self sufficiency (FSS) were used for determination of the economic status of the scheme under the IA.

vi) **Determination of structures' condition**

The structure condition index (SCI) was calculated using Equation 13.

3.4.6 Water quality and soil classification

Water quality classification was done according to Shahinasi and Kashuta (2008) while soil fertility classification was according to Baize (1993) and Euroconsult (1989).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents and discusses the results of the study which involved the effectiveness of irrigators' associations on performance of irrigation systems in operation, maintenance and management.

4.1 Water Right

The Water Utilization Act came into action in 1974 and then supplemented by the Water Resources Management Act of 2009. This is the principle legislation governing the utilization and pollution control of water resources, (URT, 2009). In the policy under on Legal and Regulatory Framework for Water Resources Management, the Basin Water Offices have been strengthened to enable these offices to:

a) Enforce and follow up on existing legislation, regulations and operating rules governing water use and control of pollution.

b) Become the legal authority to collect various water use charges.

c) Facilitate the establishment of lower level water management organizations which will bring together users and stakeholders of the same source.

d) Become centers for conflict resolutions in water allocation, water use and pollution.

According to the Water Resources Management Act of 2009, when the supply of water from any source is insufficient for the needs of the people using it, the Basin Water Board may at any time suspend or vary all or any water use permits from that source (URT, 2009).

In order to abstract and utilize water from Mbarali River, the scheme requested for a water right from Rufiji Basin Water Office. This is in accordance with the Water Resources Management of 2009. The scheme was granted a water right number 4630 of300 litres per second. However, the amount of water granted was less than the requested amount of450 litresper second.According to the farmers, this amount was not sufficient to irrigate the whole scheme at the same time. Due to the mentioned constraint, conflicts on water use occurred. During dry seasons, the scheme uses approximately 17 million litres while in rainy season it uses about half that of the dry season amount. According to the Irrigators Association the amount provided is not sufficient for the scheme requirements. One of the reasons for the amount provided not to be sufficient is probably due to poor land leveling of the scheme area leading to wastage of water along the way. Others are inadequate knowledge on water management.From field observation, if all the canals are lined the scheme may be sufficient with 370 litres per second.

4.2 Soil and Irrigation Water Quality

The electrical conductivity of water (ECw) ranged from 0.0435 dS/m to 0.0582 dS/m (Table 3). From the irrigation water quality criteria as revised by the Colorado University State in 2007(Bauder *et al*., 2007), the quality of water is excellent for irrigation (Appendix 5). Shahinasi and Kashuta (2008) suggested that normal ranking in irrigation water should be in a range between 0-3 dS/m.

Table : Results of Electrical Conductivity Levels for Irrigation Water at Igomelo Scheme

Sample location	ECw (dS/m)
Main Canal	0.0582
Tertiary Canal 2	0.0435
Tertiary Canal 4	0.0567
Tertiary Canal 6	0.0519
Tertiary Canal 10	0.0471

From the five samples taken, ECw values were not significantly different at 5% level.The chemical properties of the irrigation water in various canals are summarized in Table 4. The water is suitable for irrigation because all the parameters are within the normal ranking as shown in the Guidelines for interpretation of irrigation water (Appendix 6).

Table : Chemical properties of irrigation water

Canal	Chemical composition				
	Ca^{2+} (Mg/l)	Mg^{2+} (Mg/l)	Na^{+} (Mg/l)	TDS*	pH
Main canal	4.65	4.24	0.02	29.1	7.2
Canal 2	5.04	1.65	2.8	19.4	7.4
Canal 4	4.23	2.31	2	27.3	7.3
Canal 10	4.38	3.65	1.8	22.3	7.4

*Total dissolved solids

4.3Irrigated agriculture

Table 5 shows that 57.8% of the farmers have an experience in irrigation of less than 5 years, 18.6% between 5 to 10 years, and 22.5% of more than 10 years. The high proportion of inexperienced farmers is a result of most of the interviewed farmers being immigrants. Landlords may not have been practicing irrigation due to the high cost of inputs. The same has been reported by Mbozi (2006) and Subira (2000) whereby many farmers rented plots as compared to those who were allocated field plots by a village government.

Table : Experience in irrigated agriculture

Irrigation agricultural Experience	Number of respondents	Percentage of respondents
Less than 5 Years	59	57.8
Between 5-10 years	19	18.6
More than 10 Years	23	22.5
Total	**102**	**100**

Lessexperience in irrigation farming may lead to difficulties in irrigation water management specifically through water applications (Mbozi, 2006).

4.3.1 Land tenure

Access to land is critical and acquisition occurs in a number of ways. It can be hired or given by a village government. The plots are small starting from less than 0.25 acre. The relationship between land acquisition and area under irrigation is as shown in Table 6.The sizes of the plots are a summation of all plots owned by the respondents. However, many amongthese farmers had rented these plots. This has undermined efforts in mobilizing farmers for collective activities such as cleanliness of the canals. A similar problem has been reported in Rombo irrigation scheme in Kenya where informal tenants are given access to land (Krugmann, 2005).Tenants have no incentives to conserve water and resources or maintain infrastructure (Mbozi, 2006).Social and institutional factors also affect farmers' willingness to invest (Kijne *et al*., 2003).The current land tenure system needs to be understood by all stakeholders because in many cases farmers need incentives to make long term investments in soil and water conservation (Mbozi,2006).

Table : Land Tenure

Size of the plots	**Number of respondents**	**Percentage of**
0.5 acre	15	15.7
1 acre	36	35.3
2 acres	36	35.3
3 acres	5	4.9
4 acres	5	4.9
More than 5 acres	4	3.9
Total	**101**	**100**

4.3.2 Formulation of the Irrigators' association

From the interview with the key informants, it shows clearly that the executing agency initiated the formation of the IA providing all the expertise. This can be seen in the 28.4% and the 10.8% (Table 7).By the time the expertises were to leave, the IA was strong enough such that farmers who came later believed that the IA formulation was their fellow farmers' initiative. 54.9%of therespondents taking in consideration that most of themhad rented plots and were not there at the establishment of the scheme. Reduction in conflicts among irrigators especially on water allocation and distribution was one of the problems that acted as a motivation to strengthen the IA. They believed it is easy for them to be assisted as an association rather than on individual basis. Together with other factors like finances, water, land, and incentives from the government sustainability of the IA can be assured (Abernethy, 1986).

Table :Responses on formation of the scheme's IA

How the irrigators association was	Number of respondents	Percentage of respondents
It was own initiative	56	54.9
Through advice and technical	29	28.4
Through advice and technical	1	1
Forced to formulate by the	11	10.8
Total	**102**	**100**

4.3.3 Farmers' knowledge on crop water requirements

It was observed that most of farmers lack an understanding that a crop requires different amount of water at different stages of its development. This is because 80.4% (Table 8) of the respondentsapplied the same amount of water to the crops at all growth stages. Despite the fact that 19.4% of the responded had the knowledge that a crop requires different amount of water at different stages, still they had inadequate knowledge on the appropriate stage of which they are supposed to apply a certain amount of water. It was observed that 55.6% (Table 9)of the later respondents applied more water at growth stage while 27.7, 11.1 and 5.6 % applied more water at flowering, germination and fruiting stage respectively.Most crops require more water at flowering and fruiting stages (Al-Kais and Broner, 2009). This shows only 33.3% (a total of those who answered at flowering and fruiting) of the respondents had a clear understanding of crop water requirement and how to practice proper irrigation. It has also been noted that inadequate knowledge on crop water requirement is a common problem to many irrigation schemes. Similar results have been reported by Siwale (2005) in Herman irrigation scheme in Tanzania. Fifty four percent of the farmers were lacking skills of measuring water and knowledge on crop water requirement as a result they were applying the same amount of water to the crops throughout the growth. Similarly it has also been reported in Ethiopia (Behailu and Nata, 2005) that 90% of respondents indicated that they did not monitor or know whether the field is over-irrigated or not which led to misuse of water. In Office du Niger, Mali, little knowledge on crop water requirement has also been reported(Vandersypen *et al*., 2006). Also Mbozi (2006) reported that majority of farmers are lacking general knowledge on crop water requirement. Inadequate knowledge has been a major hindrance in determining the crop water needs with respect to both crop type and growth stage (Mbozi,2006). A better knowledge of crop water requirements is essential to distribute water efficiently (Vandersypen *et al*., 2006).

Table : Farmers understanding on crop water requirements

Are all crops given the same amount ofWater	Number of respondents	Percentage of respondents
Yes	82	80.4
No	18	19.6
Total	**100**	**100**

Table : Farmers understanding on the rate of water application at differentcrop growth stages

Growth Stages	Number of respondents	Percentage of respondents

Germination stage	10	55.6
Vegetative	2	11.1
Flowering stage	5	27.7
Fruiting stage	1	5.6
Total	**18**	**100**

4.3.4 Water Allocation and Distribution

The irrigation water allocation wasdone at a general meeting whereby 87% of the farmers were involved (Table 10). Some respondents who claimed not to be involved could be some of the new comers and the laborers. The approved irrigation frequency is 3 days (Table 11). This irrigation interval of 3 days for the scheme is good because the soil is light in texture and the evaporative demand is high which requires short intervals between successive applications as it can be seen in the crop water requirements at the scheme (Appendix1).

The factors which were considered during water distribution schedule preparation were mainly availability of water in the main canal (55.9%) and reduction of conflicts among irrigators (42.2%) as shown in Table 12. From the discussion with the key informants, before the formulation of the IA water distribution was poor as a result it created water shortages especially at the middle and tail plots. Due to shortage of water conflicts occurred frequently. Through the IA, it has been possible to involve farmers in preparation of the water distribution schedule and ensuring the sustainability of the scheme. According to Masinja (1995) andKloezen (2002) water distribution is a core activity in any irrigation scheme hence involving them in decision making makes them feel more powerful.

Table : Involvement of farmers in water distribution scheduling

How farmers were involved in preparation of the distribution schedule	Number of respondents	Percentage of respondents
In a general meeting of all irrigators	89	87.3
Informed by the ward extension officer	3	2.9
Not involved at all	10	9.8
Total	**102**	**100**

Table : Water allocation interval

Irrigation interval	Number of respondents	Percentage of respondents
Three days	96	94.1
Eight days	4	3.9
Others	1	2
Total	**101**	**100**

Table : Factors considered in preparing the schedule

Factors considered in preparing irrigation scheduling	Number of respondents	Percentage of respondents
Type of crops grown	1	1
Availability of water in the main canal	57	55.9
Reduction of conflicts among irrigators	43	42.2
Total	**102**	**100**

Table 12 shows an irrigation water distribution schedule which was prepared through a participatory approach between the IA and the farmers. With this schedule, water distribution has been smooth leading to satisfaction (88%) as shown in (Table 14) of farmers which has in turn led to an encouraging maintenance of the irrigation infrastructures and a satisfactory fee collection. From the smooth water distribution agricultural productivity has also increased leading to improved incomes for the farmers as can be seen in Table 17.

Table :Water distribution schedule for Igomelo irrigation Scheme

Day	Irrigation schedule
Monday	Canal 1 to Canal 6
Tuesday	Canal 1 to Canal 6
Wednesday	Canal 7 to Canal 11
Thursday	Canal 7 to Canal 11
Friday	Canal 1 to Canal 6
Saturday	Canal 7 to Canal 11
Sunday	Canal 1 to Canal 11

Source: Igomelo Irrigators office

Table : Farmers satisfaction on the schedule

Satisfaction on the schedule	Number of respondents	Percentage of respondents
Very good	89	87.3
Good	10	9.8
Moderate	3	2.9
Total	**102**	**100**

Table :Annual Incomes

Annual Income	Number of respondents	Percentage of respondents
Less than TAS 10 000	6	5.9
Between TAS 100 000-500 000	28	27.5
Between TAS 500 000-1 000 000	28	27.5
Between TAS 1 000 000- 3 000 000	31	30.4
Above TAS 3 000 000	8	7.8
Total	**102**	**100**

Van Dam and Malik (2003) reported low irrigation performance in India due to an irrigation schedule which was prepared by the WUA without involvement of the farmers. Farmers were given same hours to irrigate regardless of the soil type, size of the plot and the crop type. This lead to problems such as inequity in water allocation, low yield due to shortage of water, quarrelsand low performance of the scheme.

Sixty eighty percent of the farmersallocate water into their plots depending on dryness of the soil (Table 16). Farmers determine the state of the soil moisture from appearance and feel (Qassim and Ashcroft, 2006). The appearance of the soil has a disadvantage because judging moisture levels of the soil by feel and appearance is not the most accurate method and it needs experience. It is the easiest method but it requires the irrigator to have extensive experience (Kihupi, 2008). Nineteen percent of the farmers look at color of the leaves, and if there is a sign of wilting, irrigation is done while 5.9 decide when to irrigate by measuring soil moisture. The remaining6.9% follow the scheme water distribution schedule. Crop indicators must be carefully interpreted since diseases and improper nutrient levels may produce changes in appearance similar to those associated with water stress (Qassim and Ashcroft, 2006). Similar results were found by Mbozi (2006) and Siwale (2005) in Tanzania where farmers were allocating water to their plots by observing and feeling their soils to determine when to irrigate. To minimize stress on crops, other plants may be used as indicator for scheduling irrigation based on the wilting symptoms noticed in such plants planted alongside. Such plants need to be more sensitive to water stress than the crops being irrigated (Tarimo *et al*., 2004b).

Table :Decision on when to irrigate

Decision on when to irrigate	Number of respondents	Percentage of respondents
Depends on the dryness of the	69	67.6
Depends on the color of the	19	18.6
Measuring soil moisture	6	5.9
Other method	7	6.9
Total	**102**	**100**

In understanding farmers' perception on the dependability of the irrigation schedule, 75.5% (Table 17) of the respondents find the irrigation schedule to be highly dependable in the sense that the schedule is not violated no matter what happens. Through the IA representatives at each canal, it has been possible to adhere to the prepared irrigation schedule. Without these canal leaders' adherence to the schedule could have not been smooth as it is. However, to a small extent some farmers at the upstream and middle violates the timetable by blocking water which is intended to go downstream. The IA using its bylaws has an imposed penalty for this kind of offense.

Table :Dependability of the irrigation schedule

Dependability	Number of respondents	Percentage of respondents
Very high	77	75.5
High	14	13.7
Satisfactory	9	9.8

4.4 Cropping Pattern and Calendar

The cropping pattern can be defined as the sequence in which crops in a given area are grown, whereas the cropping calendar provides information on the sequence of the crops grown and on the timing of their cultivation such as transplanting, sowing dates and harvest dates.

The crops grown are Paddy (6.1%), maize (33.3%), Onions (32%), tomatoes (21.5%), beans (3.9%) and to a smaller extent vegetables (Table 18). Individual farmers are free to plant any crop upon their choice although experience shows that after harvesting onions, maize is grown. They do so because onions use a lot of fertilizers compared to maize, and once onions are harvested, some of the fertilizer remains in the soil (residual) which reduces fertilizer application to the maize crop. Maize is normally planted between September and November whereas onions are planted between April and June.It has been easy for the farmers to go for higher value crops due to assurance in water distribution.

Table : Crops grown at IgomeloIrrigation Scheme

Crops grown	Number of respondents	Percentage of respondents
Paddy	14	6.1
Maize	76	33.3
Beans	9	3.9
Onions	73	32
Vegetables	5	2.2
Tomatoes	49	21.5
Others	2	0.9
Total	**228**	**100**

Crops grown in the rainy season are paddy, maize and tomato. Paddy is normally planted in seed beds early to end December and later transplanted to paddy fields which are in a form of basins for preventing runoff and allowing infiltration. Harvesting is done from May five months after transplanting. Onions are not grown in rainy season as they are prone to rotting while paddy is not grown throughout the year due to shortage of water as it requires a lot of water.

Farmers do the farming for income generation (Table 19) with maize, onions and tomatoes as main cash crops.The three mentioned crops are the main cash crop for the area. Paddy, Beans and Vegetables are grown for food security.

Table : Reasons for choice of crops to grow

Reasons for choice of the crops	Number of respondents	Percentage of Respondents
Food security	37	16.4
Income	137	60.9
Income and food	51	22.7
Total	**225**	**100**

The scheme is a major source of income for many of the farmers. As it can be seen in Table 19 most of the crops grown are cash crops and a small amount for food security. This signifies that the IA has created a desirable environment in areas of availability of irrigation of water which has made the situation possible for 60.9 % to rely on cash crops. A few farmers (16.4%) chose crops for food security only because of inadequate funds for agricultural inputs especially fertilizers and pesticides which cost a lot of money.

4.4.1 Irrigation water management

Irrigation water management still needs some improvement especially during water allocation to the canals. For example, even when few farmers are remained with crops in the field, the amount of water released in the canals remains the same as the one when all farmers are irrigating. This leads to wastage of water. A Similar problem was reported in Mali (Vandersypen *et al.*, 2007) but was addressed by allocating water on demand which necessitated the canal leaders to compile water demands by farmers and forward the same to the water bailiff. Low education level on basic concepts of water management led to the farmers to resort to ponding water in furrows and basins. This has also been reported in Ethiopia (Behailu and Nata, 2005).

From the key informants, it showed that a lot of training has been carried out in the scheme after the formation of the IA with the assistance from the District Administration. Also some study visits involving a few farmers have been carried out to other schemes in the North. From the results above it shows 73.6 % (Table 20) of the farmers have not attended any training in water management. The number is high due to the reason that many farmers who were farming during the study had rented the plots whereas in other plots it is the children of the owners who managed the farms. Participatory rural appraisal (PRA) and interviews with farmers by other researchers (Kasele, 2005; Mkoga *et al.*, 2005) in Usangu plains have shown a high level of demand for such knowledge. Such skill training can be provided by a variety of organizations but should arise from careful discussions between WUA and support level agencies.

Table : Farmers attendance in water management training

Have you attended any	Number of respondents	Percentage of respondents
Yes	27	26.5
No	73	73.6
Total	**100**	**100**

4.4.2 Soil Management

From the soil analysis done in June 2009 (Table 21) and classified according to Baize 1993 and Euroconsult 1989 (Appendix 10), it was determined that the soil has a very low total nitrogen (TN) of about 0.09 % and 0.9 % organic carbon (OC) which can be classified as low (Appendix 10.1). Total Nitrogen was classified as very low because TN was less than 0.10% and low OC because it was between 0.6 and 1.25%. The available extractable phosphorus was 7.08 mg/kg while the Cation Exchange Capacity (CEC) was 14.6cmolckg^{-1}(Table 21). Both were moderate as the range 5-10 mg/kg for available phosphorus and 12.1-25.0 cmolckg^{-1}for CEC are classified as medium (Appendix 10.2 and Appendix 10.3). The exchangeable bases for Calcium, magnesium and Sodium were classified as medium (Appendix 10.4, Appendix 10.5, Appendix 10.7) with values 4.51, 2.02 and 0.37cmolckg^{-1}. However, the exchangeable Potassium was 0.22 which is low (Appendix 10.6).

Table : Soil analysis for chemical and Physical Properties

TN (%)	OC (%)	Ext.P Ols (mg/kg)	SO4-S (mg/kg)	Exch.Bases (cmolckg^{-1})				
				CEC	Ca2+	Mg2+	K+	Na+
0.09	0.9	7.08	19.8	14.6	4.51	2.02	0.22	0.37

Source: Mbarali District Agricultural Livestock Development Office (2009)

The low levels of Nitrogen necessitate the addition of Nitrogen. The types of fertilizers frequently used are Urea, NPK, Ammonium Sulphate (SA) and Calcium Ammonium Nitrate (CAN). From the interview it was found that 53.9% of the farmers use more than 100 kg of fertilizers per acre per season so as to improve the fertility (Table 22).

Table : Fertilizer application

	Number of respondents	Percentage of respondents
Less than 50 kg per acre	17	16.7
Between 50 -100 kg per	30	29.4
More than 100 kg per acre	54	53.9
Total	**101**	**100**

In order to reduce accumulation of salts in the soil, IA encourages farmers to use manure and make sure the drain canals are clean so the water used from the fields is drained and goes back to the river. So far, salinity and water logging are not a serious problem and therefore the whole area is used for agriculture.

4.5 Organization Structure of the IA

The primary objectives of an irrigation organization include allotment of land; transport and division of water; maintenance of the system; and the overall management of the use of the system such as planning for a growing season. The existing organization structure is as shown in Fig.3. The IA has three committees namely finance resources; construction works; and water allocation and distribution. The finance committee applies for water right, registers water users association, collect fees from the members, chart out ways and mechanisms of generating income and make bylaws. The construction works committee does the repair and maintenance of the irrigation structures at the scheme. It also works out bills of quantities with the help of experts. The water allocation and distribution committee has a duty tonominate and supervise thegate rider whose operation is based on water distribution schedule agreed by the farmers. The other duty for this committee is to check the state of all the canals and determine the course of action to take in case of any problems. Together with the three committees the scheme has a secretary and chairman whom together are responsible to the general meeting.Compared to other standard irrigators'organizations as explained by Tarimo *et al*. (2004b), the scheme lacks an agricultural input and market committee. This could be useful in securing agricultural inputs and markets. Farmers are faced by problem of securing fair prices of their produce as selling of the produce is done individually. The scheme was supposed to have a general maintenance committee to deal with maintenance as at the moment it does not have a prepared timetable for yearly maintenance of the structures as a result most of the revenue are executed on overheads. It could also be better if the IA could have a treasurer instead of the finance committee to collect and handle all the financial matters.

IA General meeting

Chairman

Secretary

Finance Resources Committee

Construction works Committee

Members

Water allocation
and distribution
Committee

Figure : Igomelo irrigators Association organization structure

4.5.1 Roles of the Irrigators' Associations

The roles of the IA were evaluated using some performance indicators that includes economic, physical and condition of the structures.

i) Economic performance criteria

The association works hard to find sources of fund for the scheme. Currently the main source of funds is from fees paid by farmers who are charged on a unit area basis. Given that not all farmers are members of the IA, the fees are charged differently for members and non- members. Non-members pay more than members. This has been done purposely asa motivation of being a member in the IA. On average, the effectiveness of fee collection (EFC) for Igomelo Irrigation scheme is 66.8% (Table 23) of which according to Yercan *et al*. (2004) EFC less than 70% is unsatisfactory. The trend of the EFC seems to fluctuate as the mode of fee payment is after harvesting. The lower the prices for the agricultural produce the lower the fee collection. Another reason is lack of seriousness of the IA to implement its by-laws. When the leaders in position are strong and use effectively the bylaws, the collections are good (Personal communications, 2009).

The Financial Self Sufficiency (FSS) of Igomelo Irrigation Scheme ranged between 1.10 and 2.21 for the period 2002-2009 (Table 24). It shows that the expenditure is consistently lower than the collected fees. Although most of the structures are in good working condition, there are some structures such as turn outs or stop logs in the division boxes which are missing and could be replaced easily and cheaply. The IA does not have a work plan framework for maintenance as a result it is done on ad hoc basis. This can be verified by the expenditure which shows a large sum of money is spent on overheads (Appendix 11). In Turkey average FSS under government management was 0.70 but it dropped to 0.29 after being transferred to the water users which was insufficient for operation and maintenance expenditure (Sener *et al*., 2007). FSS is the factor which determines financial capability of a scheme in operation and maintenance expenditures (Yercan *et al*., 2004). From the values of FSS it appears that Igomelo is financially capable for its operation and maintenance.

Table : Effectiveness of fee collection

Years	Actual collected Fee	Estimated Fee	EFC (%)
2003/2004	2 550 000	3 290 000	77
2004/2005	2 688 400	4 725 000	56
2005/2006	5 250 000	7 353 100	71
2006/2007	4 260 750	6 814 000	62
2007/2008	2 765 000	7 270 000	38
2008/2009	5 830 500	6 000000	97
Average		66.8	

Table :Financial self sufficiency

Years	Revenue (Tshs)	maintenance (O&M)expenditure(Tshs)	Financial self-sufficiency
2003/2004	2 550 000	2 313 128	1.10
2004/2005	2 688 400	2 434 350	1.10
2005/2006	5 250 000	4 297 478	1.22
2006/2007	4 260 750	3 053 428	1.39
2007/2008	2 765 000	1 936 500	1.42
2008/2009	5 830 500	2 633 200	2.21

ii) Physical perfomance

Physical perfomance indicators are related with the changing or losing of irrigated land in the command area for different reasons (Sener *et al.*, 2007). After the rehabilitation and turn over of the scheme to the IA, irrigation ratio in dry season was 83.9% which is a ratio of the irrigated area 262 ha to 312 ha irrigable area. However during the rainy season all the command area is cultivated. The irrigation ratio for the scheme is good suggesting that water distribution is good through properly maintained infrastructure and a well established schedule. This emphasizes the need for farmers' participation in decision making on matters related to scheme operation and maintenance.

The higher the ratio suggests that irrigated land is almost the same as irrigable land. The closer the irrigated land to the irrigable land the higher the irrigation ratio. Poor irrigation ratio means low irrigated land.This may be lead to fee decreasebecause the charges are collected per unit area. It also negatively affects the profitability of irrigation projects and farmers shifts from irrigated agriculture to rain-fed agriculture. Sener *et al*. (2007) reported from a study in Hayrabolu irrigation scheme in Turkey, that effective water delivery can be one of ways for improving high irrigation ratio in a scheme.

iii) Condition of the structures

It was observed that the IA considers the main canal with its hydraulic structures as the heart of all irrigation activities in the scheme. Compared to the tertiaries, it iswell maintained. It is cleaned after every three months while some of the tertiary canals were observed to be chocked with grass, they did not have a maintenance schedule.Cleaning the canals without specific standards has made some of its sections to enlarge.The top width currently ranges from 2.4 m to 4.0 m while the design specification was 2.28 to 3.84 m. Out of the 5000 m of the main canal, a total of 200 m has been affected by such changes of the width. Since the affected area is only 4%, the main canalcould be said to be in good condition. From the three sampled canals, canal 4 and canal 10 have been affected by 2.6% and 26% respectively (Table 25). Their maintanance can be said to be poor. Canal 2 has not been affected probably because it is shorter (500 m) than Canal 4 (4028 m) and Canal 10 (1344 m) which makes it is easier to clean.

Table : Canal maintenance

Canal name	Poorly maintaned length (m)	Total canal length (m)	Percentage of poorly maintanedlength (%)
Main	200	5000	4
Canal 4	108	4028	2.6
Canal 10	350	1344	26

Samad and Vermillion (1999) in a study on assessment of participatory management in Sri Lanka determined the maintenance level for the main canal to be defective by an average of 15% which was considered to be relatively high. For the distributor channels, it was 3.2% which was considered as significantly better.

The scheme has a total of 90 structures which includes 11 turnouts, 14 dropsructures, 2 culverts, 4 aqueducts and 59 division boxes. A structure condition index (SCI) as suggested by Ijir and Burton (1998) cited by Nelson (2002) was used to identify the status of the structures. Only 9 division boxes were found to be not working due to technical problems as they were built above field levels making water conveyance to the fields impossible.Farmers have thus diverted the canals in those areas so as to make conveyance of water possible. However the working division boxes do not have stop logs which leads to wastage of water(Fig.4).

Figure : A division box without a stop-log

Eight division boxes and 1 turnout were scoured but still working. A Structure Condition Index (SCI) of 0.9 was obtained indicating that 90% of the structures are in good working condition. One of the factors that led to the high proportion of structures in good working condition is the simplicity in mode of operation. Dedicated leadership on the part of the management could also be a contributing factor. Vandersypen *et al*. (2006) in Mali reported that due to sophisticated structures, operation of the irrigation network was inadequate. Nelson (2002) reported values for SCI of 89% in Nigeria and between 80% and 99% in the USA.

A total of 104 m out of 5000 m of the main canal has been lined in the seriously damagedportions due to the nature of the soil. This is only 1% of the total length of 10313 m which covers the eleven tertiary canals and the main canal (Appendix 14). However, there are many portions of the canals which need lining. Canal lining in phases is possible as indicated in the FSS (Table 24) of the scheme that expenditure are always lower than the collected fees. From the seepage measurement a significant amount of water is wasted through seepage(Table 26, Table 27, Table 28 and Table 29). It could be possible to line in phases some of the portions that are seriously affected.

From the sections of the main canal where the banks experience scouring, seepage rate was determined according to Omari (1996) and results are shown in Table 26. High seepage rates of about 0.17 L/s/ per m length were identified in the main canal while the seepage rates of canals 2, 4 and 10 were 0.104, 0.044 and 0.088 L/s/ m length (Table 27, Table 28 and Table 29) respectively. The difference in the tertiary canals can be attributed to the level of cleanliness. It was observed that canal 4 was far cleaner than canals 2 and 10. Timing of the study could in part explain the lack of maintenance of the two canals as this was done towards harvesting time when only few plots were being irrigated. Proper weeding can reduce seepage rates (Wegerich *et al.*, 2006). Despite the fact that financially the IA is doing well, itappears very littleeffort is put to the canal maintenance.

Table : Average seepage rates for the main canal

Main canal	**Upstream flow rate (m^3/s)**	**Downstream flow rate (m^3/s)**	**Distance apart (m)**	**Seepage losses (L/s per m length**
Up	74.13	71.07	33.33	0.09
Middle	110.60	105.03	33.33	0.16
Tail	106.10	97.83	33.33	0.25

Table : Seepage rates for the Canal 4

Period	**Upstream flowrate (m^3/s)**	**Downstream flow rate (m^3/s)**	**Seepage(L/s per m length)**
week 1	89.9	88.1	0.072
week 2	92.1	89.9	0.088
week 3	87.6	85.8	0.072
week 4	90.1	89.3	0.032
week 5	86.3	85.3	0.04
week 6	84.2	83.1	0.044
Avarage			**0.044**

Several authors have reported that weeds in the canals increases seepage rates (Vandersypen *et al*. (2007) and Wegerich *et al*. (2008). The reason behind effective maintenance of canal 4 is due to its high command area. As it serves many farm plots, the users are keen on maintenance in order to avoid any unnecessary water shortages.

Table : Seepage rates for the Canal 2

Period	Upstream flow rate (m^3/s)	Downstream flow rate (m^3/s)	Seepage (L/s per m length)
week 1	25.1	24.1	0.04
week 2	24.9	23.2	0.068
week 3	22.1	20.3	0.072
week 4	21.3	18.3	0.12
week 5	18.9	16.3	0.104
Average			**0.104**

Canal 2 was full of weeds and mud most of the time and as shown in Table 28, the seepage rates were also high. Also few plots were being irrigated during that time. The effect of weed could not be felt becausewater was being shared by few farmers as many had already harvested.

Table : Seepage rate for Canal 10

Period	Upstream flow rate (m^3/s)	Downstream flow rate (m^3/s)	Seepage(L/s per m length)
week 1	38.1	37.1	0.04
week 2	35.1	34.2	0.036
week 3	36.1	35.3	0.032
week 4	35.1	34.5	0.024
week 5	32.1	31.9	0.008
week 6	30.1	27.9	0.088
Average			**0.088**

4.6 Performance of Water Distribution Systems

A number of indicators were used to evaluate the water distribution system. These included the process and agricultural production indicators.

4.6.1Process indicators

i) **Equity of water supply**

Using the coefficient of spatial water distribution (CSWD) for maize plots the values ranged between 1 and 2.75 (Table 30).These values were within the range reported by Kongola (2000) which were between 1 and 3.4.The range of CSWD for other crops was between 1 and 1.49 for tomatoes and between 1 and 1.77 for onions. Generally the scheme has CSWD values ranging between 1 and 2.75.However, it has been observed that there was high degree of inequity among maize plots as compared to other crops. Inequity can be explained by farmers' lack of experience in irrigated agriculture and inadequate knowledge on crop water requirements(Kongola, 2000).

Table :Calculations for Equity using Coefficient of spatial water Distribution (CSWD)

Location of the plot	RWS	CSWD	Crops
Head of the main canal	1.79	1.24	Maize
	1.94	1.39	Tomato
	1.63	1.77	Onion
Middle of the main canal	3.96	2.75	Maize
	2.09	1.49	Tomato
	1.91	1.33	Maize
Tail of the main canal	1.4	1.00	Tomato
	0.92	1.00	Onion
	1.44	1.00	Maize

ii) **Adequacy of irrigation water supply**

From the sampled plots relative water supply (RWS) values ranging from 0.92 to 3.96 were obtained.Generally this range indicates that the farmers at Igomelo irrigate their crops more than they were supposed.The mean RWS for the upstream, middle and downstream reaches were 1.78, 2.65 and 1.25 respectively (Table 31). Molden and Gates (1990) classified values from 0.90 to 1 for adequacy as good. From that range then all plots in the head, middle and tail had adequate supply of irrigation water. Plot 4 from middle stream showed the highest value of 3.96 while plot 8 at the tail showed the lowest value of 0.92. The RWS were significantly different at 5% among the plots with a coefficient of variation (CV) of 36% showing moderate variations in water supply at the three locations (upstream, middle and tail end). Adequacy seemed to decrease towards the downstream as the RWS values at the tail reach plots were low compared to the ones upstream and in the middle. This could be due to conveyance losses (due to lack of stop logs in the division boxes) in the canals, seepage losses of the canals and weeds in the canals because water abstraction in the upper and middle parts is rare.Similar results were obtained by Tyagi *et al*. (1996) where RWS of 0.72 for upstream and 0.58 at the tail reach watercourses were observed. It was argued that the significant reduction in RWS towards the tail end was due to seepage losses occurring in the watercourses. The IA has enhanced the adequacy in water supply through the irrigation schedule despite inadequate amount of water granted in the water right.

Table :Relative Water Supply within plots

Canal No.	Distance from the canal (m)	Plot No.	RWS	Crop
2	30	Plot 1	1.79	Maize
	5	Plot 2	1.94	Tomato
	15	Plot 3	1.63	Onion
4	10	Plot 4	3.96	Maize
	20	Plot 5	2.09	Tomato
	35	Plot 6	1.91	Maize
10	40	Plot 7	1.40	Tomato
	80	Plot 8	0.92	Onion
	100	Plot 9	1.44	Maize

Upadhayaya *et al.* (2005) reported RWS values of 0.93, 0.84 and 1.14 in India for head, middle and tail reaches suggesting an improvement in RWS to meet crop water demand in the middle and head so as to meet crop demand. Kuscu *et al*. (2009b) obtained a mean RWS value of 0.77 in Karacabey, Turkey for the period of 2002 - 2007 suggesting that the crops were not getting enough water. It would appear from this study that adequacy in irrigation water supply for the scheme is good although some improvements in water management practices by the IA are needed to avoid unnecessary wastage of water. Table 31 suggests over irrigation in all plots except plot 8. This implies a serious wastage of water.

iii) **Dependability**

The total water delivery with respect to requirement varies considerably among head, middle and tail reaches and within the plots. Values of dependability for the three sections under the study were 0.70, 0.62 and 0.84respectively (Appendix 3). These values show poor dependability according to Molden and Gates (1990) who suggested values above 0.25 to be poor. Low level of dependabilitymay have been caused by poor timeliness in water allocation by the water allocation and distribution committee. Dependability can be improved by matching the period when water is diverted from the source to the period when water is needed (Akkuzu *et al*., 2007). Also lack of flow measuring structures may have led to irregularities in water allocation. Vandersypen *et al*. (2006) obtained comparable results in Niger of 0.78 and 0.71 suggesting poor dependability which was attributed to poor water management practices. Due to poor dependability farmers at Igomelo scheme used much time in irrigating small plots. Also, it led to over-irrigation and under irrigation in some plots as farmers compensate for the time whenthere were little water without considering the crop water requirements at the appropriate stages.

4.6.2Agricultural output

i) Output per unit cropped area

The output per irrigated area in the head, middle and tail reaches were 684.44, 1040.7 and 1492.55 US$ ha^{-1} respectively (Appendix 9.1). The value of the base crop traded at the world prices used to calculate was according to Fapri Outlook 2009. The values for head and middle plots were lower than for the tail plots. The tail had the highest output probably because most of the IA leaders were located at the tail and the middle thus ensuring them availability of water. The other reasons could be due to poor management of the plots through poor weeding and lack of pesticides and fertilizer application. This suggests an improvement in field management through agricultural inputs and providing proper support price for the produce.

Siwale (2005) obtained values between 372.4 US\$ ha^{-1} and 761.6 US\$ ha^{-1} in Herman irrigation scheme in Tanzania. Behailu *et al*. (2004) in a study in Tekeze Basin in Ethiopia obtained values ranging from 1151.89-1682.07 US\$ ha^{-1}.Cakmak (2001) reported a range between 359 US\$ ha^{-1} and 6179 US\$$ha^{-1}$. The values of Output per unit cropped area obtained at Igomelo are within the range as those obtained outside Tanzania by Cakmak (2003) and Behailu *et al*. (2004). However, the values in the study were much better than the ones obtained by Siwale (2005) in a farmer managed irrigation in Tanzania.

ii) **Output per unit water supply (Water productivity)**

Three crops (onions, tomatoes, and maize) were monitored in the upstream (US), and downstream (DS) reaches of the scheme while in the middle (MS) only maize and tomatoes were considered. It was found that water productivity was high for tomatoes than onions and maize in all the three selected scheme locations (Figure 5). While maize had the highest water productivity in the upstream of the scheme (0.83kg/m^3). It was however not significantly different ($p < 0.01$) from the WP of tomatoes (1.68 kg/m^3) and onions (1.65 kg/m^3). The values of water productivity for the downstream users for tomatoes and onions (8.011 and 3.09 kg/m^3 respectively) were observed to be higher than those at the upstream (1.68 and 1.65 kg/m^3 respectively). Generally for all the observed crops, the downstream farmers used water more efficiently than those in the middle and the upstream farmers(Appendix 9.2).This was due to the little amount of water used at the tail as compared to the middle and head plots.Behailu and Nata (2005) obtained values of water productivity of 1.07 kg/ m^3 and 0.23 kg/m^3 in Ethiopia for onions and maize respectively.

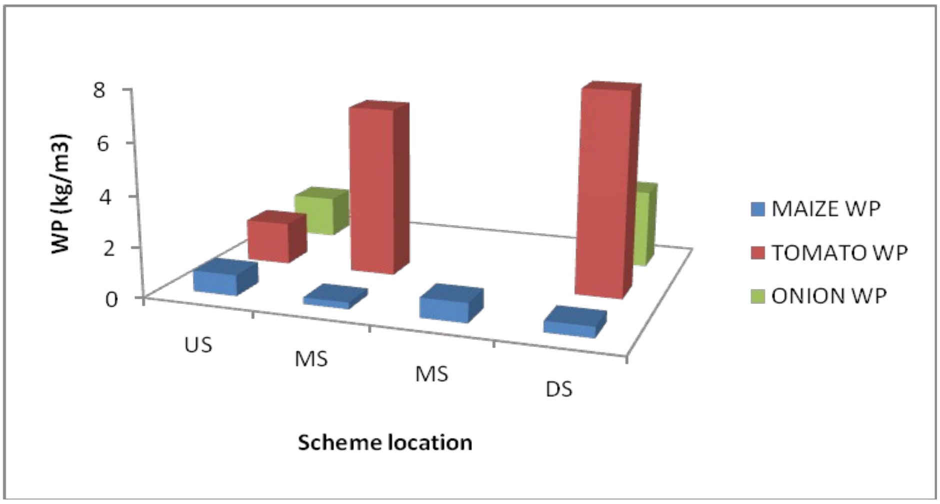

Figure :Water productivity vs Scheme location

The reasons for this situation could have been due to difference in management of crops by the irrigators and the use of agricultural inputs such as fertilizers and pesticides.

iii) **Output per unit water consumed**

The indicator specifies production value per unit volume of water consumed. The values obtained for different crops (maize, tomatoes and onions) were 0.25, 0.54 and 0.44 ($\$/m^3$) for head, middle and tail of the scheme as shown in Appendix 9.3.This shows that the middle reach fared better than tail and head reaches. The difference may be explained by the way farmers managed their plots through weeding and fertilizer application. The difference could also be attributed to the cropping patterns. Carmak *et al*. (2003) reported values in the range of 0.15-1.55 ($/m^3) in Turkey.

4.6.3 Conveyance efficiency for the main canal

The conveyance efficiency for the main canal was found to be 68.2% (Appendix 4) which is below the value for adequately maintained earthen canals which is 70% (Abdulmumin and Bastiaansen, 1991). High seepage rates have been observed in worn out sections of the main canal which are mainly made up of sandy soils (Table 26).

4.6.4 Tertiary canal conveyance efficiency

The conveyance efficiency was determined in three sampled tertiary canals at the head, middle and tail of the main canal. The canal at the head reaches had a lower efficiencyof 69% compared to the other canalsat the middle (78%) and tail (87%) of the main canal as shown in Appendix 4.3 and 4.4 respectively.The difference in efficiency could be due to weeds in some locations, seepage losses and conveyance losses.Efficiency should be higher than 70% under good management (Abdulmumin and Bastiaansen ,1991). Canal 4 and canal 10 are performing well as compared to canal 2. Canal 2 was poorly maintained with full of weeds. The IA has failed to reduce the losses by lining the problematic portions. This may be due to lack of knowledge to minimize water losses. The losses are also due to poor maintenance of some division boxes and delayed maintenance of the canals leading to weed growth. The IA at need skills on how to use the money collected in maintenance of the infrastructure.Wegerich *et al*. (2008) reported that lack of weeding greatly affected canal capacity. The estimated and measured discharges in the presence of weeds were about 50% of canal capacity losses. Seepage without proper weeding was 0.04 liters per second per meter while after weeding it decreased to 0.025 liters per second per meter.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Conclusionsdrawn from the study are as follows:

i) The rehabilitation done did not take into account the issues of water management. Its purpose was to increasing the command area.

ii) The participatory approach that was usedby the IA to set irrigation schedules improved irrigation water distribution to farmers.

iii) Most farmers lacked experience in irrigated agriculture.

iv) Agricultural output has increased due to adequacy and equity in irrigation water supply.

v) Most structures of the scheme are in good working condition as a result of their simplicity and affordability.

5.1 Recommendations

Recommendations drawn from the study include:

i) Farmers should be trained on irrigation water management aspects including crop water requirements. Also the IA needs skills on how to use the money on maintenance.

ii) Flow measurement structures should be installed at the intake and turnouts of each canal.

iii) Canals should be lined with burnt bricks or stone masonry to reduce seepage and weed growth.

iv) Records on water use, crop production and farm inputs such as fertilizers, seed varieties and mechanization should be kept by the IA.

v) Further studies should be carried out in other schemes to compare situations before and after rehabilitation of a farmer managed irrigation scheme.

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APPENDICES

Appendix : Crop water requirements for the sampled plots

Appendix 1.1: Plot 1. Planting date 25/10/2009

Month	Decade	Stage	Kc	Etc	Etc	Eff rain	Irr. Req.	appl.depth	Tot. water.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	mm
Oct	1	Init	0.4	2.22	20	0	20	341.36	462.32
Oct	2	Deve	0.42	2.41	24.1	0	24.1		
Oct	3	Deve	0.64	3.53	38.9	0.1	38.7		
Nov	1	Deve	0.88	4.8	48	14	34		
Nov	2	Mid	1.08	5.75	57.5	20.9	36.6		
Nov	3	Mid	1.11	5.51	55.1	21.5	33.6		
Dec	1	Mid	1.11	5.15	51.5	20	31.5		
Dec	2	Late	1.09	4.71	47.1	20.5	26.6		
Dec	3	Late	0.99	4.14	41.4	25.3	13.6		
					383.6	122.3	258.8		

Appendix 1.2: Plot 2: Planting date 2/10/2009

Mont	Decad	Stage	Kc	Etc	Etc	Eff rain	Irr. Req.	appl.dept	Total water
			Coe	mm/da	mm/de	mm/de	mm/dec	mm	mm
Oct	1	Init	0.45	2.5	22.5	0	22.5	388.58	509.54
Oct	2	Deve	0.47	2.68	26.8	0	26.8		
Oct	3	Deve	0.67	3.73	41.1	0.1	40.9		
Nov	1	Deve	0.91	4.92	49.2	14	35.2		
Nov	2	Mid	1.09	5.8	58	20.9	37.1		
Nov	3	Mid	1.12	5.55	55.5	21.5	34		
Dec	1	Mid	1.12	5.19	51.9	20	31.9		

Dec	2	Late	1.08	4.66	46.6	20.5	26.1
Dec	3	Late	0.86	3.6	36	25.3	8.2
					387.7	122.3	262.8

Appendix 1.3: Plot.3 Planting date 20/09/2009

Mont	Deca	Stage	Kc	ETc	ETc	Eff rain	Irr.	appl.dept	Tot.
			Coeff	mm/da	Mm/de	mm/de	mm/dec	mm	mm
Sep	2	Init	0.5	2.65	2.7	0	2.7	356.08	477
Sep	3	Init	0.5	2.71	27.1	0	27.1		
Oct	1	Deve	0.5	2.78	27.8	0	27.8		
Oct	2	Deve	0.58	3.3	33	0	33		
Oct	3	Deve	0.71	3.96	43.6	0.1	43.4		
Nov	1	Deve	0.84	4.59	45.9	14	31.9		
Nov	2	Mid	0.97	5.13	51.3	20.9	30.3		
Nov	3	Mid	1	4.98	49.8	21.5	28.3		
Dec	1	Mid	1	4.65	46.5	20	26.6		
Dec	2	Mid	1	4.32	43.2	20.5	22.7		
Dec	3	Late	1	4.16	45.7	27.8	17.9		
Jan	1	Late	0.91	3.67	36.7	38	0		
Jan	2	Late	0.82	3.18	22.2	32	0		
					475.6	194.8	291.9		

Appendix 1.4: Plot.4 Planting date 30/10/2009

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	appl.depth	Tot. water
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	mm
Oct	3	Init	0.4	2.22	4.4	0	4.4	277.81	364.37
Nov	1	Init	0.4	2.17	21.7	13.6	8.2		
Nov	2	Deve	0.46	2.46	24.6	20.3	4.3		
Nov	3	Deve	0.69	3.42	34.2	22.5	11.6		
Dec	1	Deve	0.92	4.26	42.6	23.5	19.1		
Dec	2	Mid	1.08	4.67	46.7	25.8	20.9		
Dec	3	Mid	1.09	4.54	50	31.3	18.6		
Jan	1	Mid	1.09	4.39	43.9	39	4.9		
Jan	2	Late	1.05	4.09	40.9	45.1	0		
Jan	3	Late	0.96	3.74	26.2	27.3	0		
					335	248.4	92		

Appendix 1.5: Plot 5 Planting date 27/10/2009

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.	appl.depth	Total water
			Coeff	mm/day	Mm/dec	mm/dec	mm/dec	mm	mm
Oct	3	Init	0.5	2.78	13.9	0.1	13.8	210	376.56
Nov	1	Init	0.5	2.71	27.1	1.2	25.9		
Nov	2	Deve	0.59	3.14	31.4	1.9	29.6		
Nov	3	Deve	0.76	3.78	37.8	9.9	27.9		
Dec	1	Deve	0.93	4.31	43.1	20.9	22.2		
Dec	2	Mid	1	4.33	43.3	29.2	14.1		
Dec	3	Mid	1	4.19	46.1	27.9	18.2		
Jan	1	Late	1	4.04	40.4	24.3	16.1		
Jan	2	Late	0.91	3.56	35.6	23.4	12.2		
Jan	3	Late	0.82	3.18	12.7	10.4	0		
					331.5	149	180.1		

Appendix 1.6: Plot 6 Planting date 30/10/2009

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.	appl.depth	Total water
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	mm
Oct	3	Init	0.4	2.22	4.4	0	4.4	213.42	373.18
Nov	1	Init	0.4	2.17	21.7	1.6	20.1		
Nov	2	Deve	0.46	2.46	24.6	2.4	22.2		
Nov	3	Deve	0.69	3.42	34.2	8.8	25.4		
Dec	1	Deve	0.92	4.26	42.6	17.5	25.1		
Dec	2	Mid	1.08	4.67	46.7	24.1	22.6		
Dec	3	Mid	1.09	4.54	50	23	27		
Jan	1	Mid	1.09	4.39	43.9	19.2	24.6		
Jan	2	Late	1.05	4.09	40.9	18.1	22.8		
Jan	3	Late	0.96	3.74	26.2	15.9	1.2		
					335	130.4	195.6		

Appendix 1.7: Plot 7 Planting date 28/10/2009

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.	appl.depth	Total water
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	mm
Oct	3	Init	0.5	2.78	11.1	0	11.1	278.4	363.92
Nov	1	Init	0.5	2.71	27.1	3.6	23.5		
Nov	2	Deve	0.58	3.05	30.5	5.4	25.1		
Nov	3	Deve	0.74	3.7	37	3.8	33.2		
Dec	1	Deve	0.91	4.23	42.3	0.2	42.1		
Dec	2	Mid	1	4.33	43.3	0	43.3		
Dec	3	Mid	1	4.19	46.1	1.4	44.7		
Jan	1	Mid	1	4.05	40.5	16.6	23.8		
Jan	2	Late	0.93	3.61	36.1	24.7	11.4		
Jan	3	Late	0.83	3.2	16	13.3	1.3		
					330.1	69.1	259.7		

Appendix 1.8: Plot 8 Planting date 20/09/2009

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.	appl.depth	Total water
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	mm
Sep	2	Init	0.5	2.65	2.7	0	2.7	303.19	389.91
Sep	3	Init	0.5	2.71	27.1	0	27.1		
Oct	1	Deve	0.5	2.78	27.8	0	27.8		
Oct	2	Deve	0.58	3.31	33.1	0	33.1		
Oct	3	Deve	0.72	3.99	43.9	0.1	43.7		
Nov	1	Deve	0.85	4.63	46.3	3.6	42.7		
Nov	2	Mid	0.98	5.18	51.8	5.4	46.4		
Nov	3	Mid	1.01	5.04	50.4	3.8	46.6		
Dec	1	Mid	1.01	4.71	47.1	0.3	46.8		
Dec	2	Mid	1.01	4.38	43.8	0	43.8		
Dec	3	Late	1.01	4.21	46.3	1.3	44.9		
Jan	1	Late	0.92	3.72	37.2	16.9	20.3		
Jan	2	Late	0.83	3.24	22.6	17.6	0		
					480.2	49	426.1		

Appendix 1.9: Plot 9 Planting date 3/10/2009

Mont	Decade	Stag	Kc	ETc	ETc	Eff rain	Irr.	appl.depth	Total
			Coeff	mm/day	mm/dec	mm/dec	mm/dec	mm	
Oct	1	Init	0.4	2.22	17.8	0	17.8	300.36	438.92
Oct	2	Deve	0.41	2.35	23.5	0	23.5		
Oct	3	Deve	0.61	3.4	37.4	0.1	37.3		
Nov	1	Deve	0.86	4.67	46.7	2.2	44.5		
Nov	2	Mid	1.07	5.68	56.8	3.3	53.6		
Nov	3	Mid	1.11	5.51	55.1	9.1	45.9		
Dec	1	Mid	1.11	5.14	51.4	18.5	32.9		
Dec	2	Late	1.1	4.73	47.3	25.4	22		
Dec	3	Late	1	4.16	45.8	18.5	27.3		
					381.9	77.1	304.7		

Appendix : Calculations for reference evapotranspiration (ETo)

Climatic data							
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	Hours	MJ/m?/day	mm/day
January	18	29.2	78	69	5.6	18.6	3.89
February	18.1	29.2	80	63	5.6	18.7	3.86
March	18.1	29.7	74	68	6	18.8	3.94
April	17.8	29.4	71	91	7.4	19.7	4.07
May	16.6	28.9	65	124	8.7	19.8	4.13
June	14.3	28.3	62	122	9.9	20.3	4.01
July	14.7	27.9	63	158	10	20.9	4.25
August	16	27.2	62	189	10	22.6	4.7
September	17.2	29.9	61	191	9.5	23.6	5.3
October	19.3	31	60	187	9.3	24.2	5.68
November	19.8	31.4	64	161	8.1	22.4	5.3
December	19.1	29.7	71	108	6.2	19.4	4.32

Appendix :Water dependability for the 9 plots

Appendix 3.1: Dependability for the plots

PLOT 1	water required (Q_D)	Water delivered(Q_R)	Q_D/Q_R
Oct	82.8	43.2	0.521739
Nov	104.2	93.56	0.897889
Dec	71.7	199.02	2.775732

PLOT 2	water required	Water delivered	Q_D/Q_R
Oct	90.2	235	2.605322
Nov	106.3	117.86	1.108749
Dec	66.2	35.72	0.539577

PLOT3	water required	Water delivered	Q_D/Q_R
Oct	104.2	178.68	1.714779
Nov	90.5	55	0.607735
Dec	67.2	26	0.386905
		std deviation	0.822365
		Cv	0.647311
		P_D	0.705667

PLOT 4	water required	Water delivered	Q_D/Q_R
Month			
Oct	4.4	43	9.772727
Nov	24.1	253	10.49793
Dec	58.6	100	1.706485

PLOT 5	water required	Water delivered	Q_D/Q_R
Oct			
Nov	13.8	34.5	2.5
Dec	83.4	141	1.690647
	78	34.5	0.442308

PLOT 6	water required	Water delivered	Q_D/Q_R
Oct	4.4	17.2	3.909091
Nov	67.7	75.23	1.111226
Dec	74.7	68	0.910308
		Mean	1.976875
		std deviation	3.680063
		Cv	1.86
		P_D	**0.62**

PLOT 7	water required	Water delivered	QD/QR
Oct	11.1	51.7	4.657658
Nov	81.8	93	1.136919
Dec	130.1	51.7	0.397387

PLOT 8	water required	Water delivered	
Oct	104.6	47.45	0.453633

Nov	135.7	113.2	0.834193
Dec	135.5	52.54	0.387749
		Mean	0.558525

PLOT9	water required	Water delivered	
	78.6		
Oct	144	82.6	1.050891
Nov	82.2	79.7	0.553472
Dec		77	0.93674
		Mean	0.847034
		Cv	1.054965
		standard deviation	1.249764
		Mean	1.18465
		P_D	**0.8365**

Appendix : Conveyance efficiencies

Appendix 4.1: Conveyance efficiency for the main canal

Diverted Water	**MC/TC 1**	**MC/TC2**	**MC/TC3**	**MC/TC 4**	**MC/TC 5**	**MC/TC6 A**	**MC/TC6B**	**Efficiency**
300	14.5	30.1	20.4	86.1	60.5	30.1	27.5	0.89733
300	13.9	29.7	22.1	87.3	68.2	28.1	20.1	0.898
300	12.9	28.3	24.1	85.3	56.3	28.9	27.1	0.87633
300	14.3	30.3	23.1	87.2	67.1	29.7	23.1	0.916
300	12.1	28.9	22.9	86.1	68.1	30.1	26.1	0.91433
	MC/TC 7	MC/TC 8	MC/TC 9	MC/TC1 0	MC/TC1 1			
300	15.8	31.1	50.1	85.1	44.2	0.75433		
300	14.1	29.1	50.6	86.1	43.9	0.746		
300	15.9	30.3	49.1	84.1	44.01	0.7447		
300	14.8	29.8	51.3	89.3	43.9	0.76367		
300	14.9	29.8	50.8	87.6	44.01	0.75703		
Overall efficiency								0.6825

Appendix 4.2: Conveyance Efficiency for canal 2

CANAL 2	MC/TC 2	TC 2/FC 1	TC2/FC2	TC 2	TC 2/FC3	TC2/FC4	TC 2/FC 5
4/11/2009	40.20	17.20	18.10	35.30	15.20	9.10	8.10
E_c			0.88				0.92
9/11/2009	35.30	17.80	12.10	30.50	9.10	8.50	8.80
E_c			0.85				0.87
27/11/2009	43.20	25.10	14.20	42.10	19.10	9.10	9.20
E_c			0.91				0.89
Conveyance efficiency	0.69						
Average	37.75						
Standard Deviation	3.46						
CV	0.09						

Appendix 4.3: Conveyance Efficiency for canal 10

CANAL 10	MC/TC10	TC10/FC1	TC10/FC 2	TC10/FC3	TC10/FC4	TC10/FC 5
28/10/2009	85.10	55.10	25.60	85.60	48.10	35.40

E_c			0.95			0.98
2/11/2009	89.30	62.50	25.80	89.00	45.10	42.70
E_c			0.99			0.99
7/11/2009	89.30	60.70	25.50	88.10	48.30	37.10
E_c			0.97			0.97
16/11/2009	87.60	68.10	13.20	86.10	47.30	38.20
E_c			0.93			0.99
Conveyance Efficiency	0.78					
Average	87.83					
Standard Deviation	1.99					
CV	0.02					

Appendix 4.4: Conveyance Efficiency for canal 5

CANAL 5	**MC/TC5**	**TC5/FC1**	**TC5/FC2**	**TC5**	**TC5/FC3**	**TC5/FC4**	**TC5**	**TC5/FC5**	**TC5/FC6**
2/12/2009	6990.50	31.20	28.10	58.20	30.10	27.30	59.30	30.00	28.10
E_c			0.98			0.99			0.98
7/12/2009	68.20	42.10	25.20	60.20	35.10	24.60	63.80	33.60	29.10
E_c			0.99			0.99			0.98
11/12/2009	56.30	30.10	25.20	53.20	39.10	13.10	50.10	29.10	20.10
E_c			0.98			0.98			0.98
16/12/2009	67.10	31.20	35.10	64.80	32.80	30.90	60.10	29.80	29.10
E_c			0.99			0.98			0.98
Conveyance Efficiency	0.87								
Average	63.03								
Standard Deviation	5.63								
CV	0.09								

Appendix : Suggested criteria for irrigation water use based upon conductivity

Classes of water	Electrical conductivity (dS/m)
Class 1, Excellent	≤≤ 0.25
Class 2, Good	0.25-0.75
Class 3, Permissible	0.76-2.00
Class 4, Doubtful	2.01-3.00
Class 5, Unsuitable	≥≥ 3.00

Source: Bauder *et al*., (2007)

Appendix : Guideline for interpretation of irrigation water quality

Water parameters	**Units**	**Normal ranking in irrigation water**
Electrical conductivity	dS/m	0-3
Total dissolved salts	mg/l	0-2000
Calcium	mg/l	0-20
Magnesium	mg/l	0-5
Sodium	mg/l	0-40

Source: Shahinasi and Kashuta (2008)

Appendix :Indicative Values of the conveyance efficiency for adequately maintained canals

	Earthen Canals			Lined canals
Soil type	Sand	Loam	Clay	
Canal length				
Long > 2000m	60%	70%	80%	95%
Medium>200-2000m	70%	75%	85%	95%
Short < 200m	80%	85%	90%	95%

Source: FA0, (2008)

Appendix : Statistical difference in RWS among three crops

Percentage Level	T-Calculated	T-Tabulated
5%	0.3145	2.771
25%	0.3145	2.771
10%	0.3145	2.771

Appendix : Standardized Gross Value of Production

Area(ha)	Crop	Yield(kg/ha)	ton/ha	Local price (us$/kg)	base crop price (us$/kg)	world prices (us$/ton)	water diverted (m^3)	pi/pb	Ai*Yi	Ai*Yi* (pi/pb)	∑Ai*Yi(Pi/Pb)	ET (mm)	ETvolume(m^3)	SGVP
0.073	Maize	2862.73	2.86	0.38	0.38	162.98	249.67	1.01	0.21	0.21		0.26	189.29	
0.069	Tomato	7988.36	7.99	0.25	0.38	162.98	327.58	0.66	0.55	0.36		0.26	180.61	
0.056	Onion	7888.35	7.89	0.22	0.38	162.98	267.29	0.58	0.44	0.26	0.83	0.29	163.56	135.45
0.032	Maize	1392.44	1.39	0.38	0.38	162.98	170.79	1.01	0.05	0.05		0.19	62.17	
0.040	Tomato	25138.26	25.14	0.25	0.38	162.98	149.79	0.66	1.00	0.66		0.18	71.64	
0.064	Maize	2486.23	2.49	0.38	0.38	162.98	204.65	1.01	0.16	0.16	0.87	0.20	125.03	141.62
0.062	Tomato	22727.27	22.73	0.25	0.38	162.98	175.88	0.66	1.40	0.93		0.26	159.98	
0.065	Onion	13127.01	13.13	0.22	0.38	162.98	275.68	0.58	0.85	0.49		0.43	275.91	
0.036	Maize	1890.00	1.89	0.38	0.38	162.98	158.26	1.01	0.07	0.07	1.49	0.30	109.84	242.39

Local prices for maize, onion and tomato were 450, 298 and 260 Tshs per Kg respectively.1US$ =1200Tshs (By June 2010); World food prices for maize (Fapri,2009).

Appendix 9.1 Output per cropped area

Location	Total area cultivated	SGVP	Output per cropped area
Head	0.198	135.5	684.0909
Middle	0.136	141.6	1041.324
Tail	0.163	242.4	1487.055

Appendix 9.2 Output per unit water supply (Productivity)

Crop	Water (m^3)	Weight(kg)	Productivity
Maize	249.67	208.98	0.837022
Tomatoes	327.58	551.20	1.682633
Onions	267.29	441.75	1.65269
Maize	170.79	44.45	0.260261
Tomatoes	149.79	1005.53	6.712931
Maize	204.65	159.12	0.777513
Tomatoes	175.88	1409.09	8.011656
Onions	275.68	853.26	3.095094
Maize	158.26	68.04	0.429925

Appendix 9.3 Output per water consumed by ET

Location	ET volme (m^3)	SGVP	Output per water consumed
Head	533.46	135.45	0.25
Middle	258.84	141.62	0.55
Tail	545.73	242.39	0.44

Appendix : Guide to general evaluation of some soil chemical and physical properties

Appendix 10.1 Organic matter and total nitrogen

	Very low	Low	Medium	High	Very High
Organic matter %	<1.0	1.0-2.0	2.1-4.2	4.3-6.0	>6.0
Organic C %	<0.6	0.60-1.25	1.26-2.50	2.51-3.50	>3.5
Total N %	<0.10	0.10-0.20	0.21-0.50	>0.50	

Appendix 10.2 Available phosphorus

Mg/kg	Low	Medium	High
Available (Bray-Kurtz I)	<7	7-20	>20
Available . (Olsen)	<5	5-10	>10

Appendix 10.3 Cation exchange capacity (CEC)

	Very low	Low	Medium	High	Very high
CEC	<6	6.0-12.0	12.1-25.0	25.0-40.0	>40.0

Appendix 10.4 Exchangeable Calcium

me/100g	Very low	Low	Medium	High	Very high
Ca (Loamy)	<0.5	0.5-2.0	2.1-4.0	4.1-6.0	>6.0

Appendix 10.5 Exchangeable Magnesium

me/100g	Very low	Low	Medium	High	Very high
Mg (loamy soils)	<0.25	0.25-0.75	0.75-2.0	2.1-4.0	>4.1

Appendix 10.6 Exchangeable K

Me/100g	Very low	Low	Medium	High	Very high
K(Loamy soils)	<0.13	0.13-0.25	0.26-0.80	2.1-4.0	>4.1

Appendix 10.7 Exchangeable Sodium

me/100g	Very low	Low	Medium	High	Very high
Na	<0.10	0.10-0.30	0.31-0.70	0.71-2.00	>2.00

Appendix : Variation in RWS in the plots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Canal	2	2.9956	1.4978	3.22	0.112
Residual	6	2.7928	0.4655		
Total	8	5.7884			

***** Tables of means *****

Variate: RWS

Grand mean 1.90

Canal	2.00	4.00	10.00
	1.79	2.65	1.25

*** Standard errors of differences of means ***

Table	Canal
rep.	3
d.f.	6
s.e.d.	0.557

*** Least significant differences of means (5% level) ***

Table	Canal
rep.	3
d.f.	6
l.s.d.	1.363

***** Stratum standard errors and coefficients of variation *****

Variate: RWS

d.f.	s.e.	cv%
6	0.682	36.0

Appendix : Expenditures at the scheme

Appendix 12.1 Expenditure 2007/2008

Allowances	1 996 600
Maintenance of the Main canal	500 000
Emergence	300000
Training	300 000
Administration	137 500
Water fees	180 000

Appendix 12.2 Expenditure 2006/2007

Allowances	1 305 650
Training	52 000
Emergence	191 000
Administration	838 000
Water fees	363 128

Appendix 12.3 Expenditure 2008/2009

Allowance	912 000
Maintenance	500000
Administration	740 000
Water fees	533 000
Construction of a toilet	611 000

Appendix : Field application efficiency

Plot	Volume furnished to the fields (m^3)	Volume of irrigation water needed and made available (m^3)	Application efficiency (ea)
1	341.36	120	0.35
2	388.58	120	0.31
3	356.08	120	0.34
4	277.81	120	0.43
5	210	120	0.57
6	213.42	120	0.56
7	278.4	120	0.43
8	303.19	120	0.40
9	300.36	120	0.40

Appendix : Lined Lengths of the Canals

Canal	Total length (M)	Lined Length (M) on the canal side	Total Structures
Main Canal	5000	116	15
1	539	93	4
2	454	156	6
3	306	306	168
4	4028	0	21
5	1490	0	4
6	265	15	7
7	420	0	3
8	986	0	5
9	794	15	5
10	1344	0	5
11	434	0	3

Appendix : Questionnaire

TITTLE:PERFORMANCE OF REHABILITATED IRRIGATION SYSTEMS:

A CASE STUDY OF IGOMELO IRRIGATION SCHEME IN TANZANIA.

Name/No…………………………………………

Date of Interview………………………………………………..

District: ………………………………………

Division…………………………………………………..

Ward……………………………………………………

Village……………………………………………………

Hamlet: ………………………………………………

1. BACKGROUND INFORMATION

1.1 Respondent's Number…………………..

1.2 Age…………………years

1.3 Gender …………… 1 Male 2 Female

1.4 **Marital Status**

1. Married,
2. Single,
3. Divorced
4. Widowed

1.5 Level of education

1. No formal education,
2. Primary education,
3. Secondary education,

4. Technical education
5. University/Diploma level
6. Others

1.6 Ethnic group…………….

1.7 Religion

1. Christian
2. Muslim
3. Pagan
4. Others

1.8 Occupation

1. Farming
2. Employment (public sector)
3. Employment (private sector)
4. Own business
5. Others

1.9 Annual income

1. Less than TAS 100,000
2. Between TAS 100,000 – 500,000
3. Between TAS 500,000 – 1,000,000
4. Between TAS 1,000,000 – 3,000,000
5. Above TAS 3,000,000

2. Period that you have been a member of the irrigation scheme

1. Less than 2 years
2 Between 2 and 5 years
3. More than 5 years

3. Irrigation agriculture experience

1. Practicing irrigated agriculture for less 5 years
2. Practicing irrigated agriculture for 5 – 10 years
3. Practicing irrigated agriculture for more than 10 years

2.0 LAND USE

2.1 How many farm plots do you cultivate under irrigation?

1. One
2. Two
3. Three
4. Four
5. More than five

2.2 How big are the farm plots?

1. 0.5 acres
2. 1 acre
3. 2 acres
4. 3 acres
5. 4 acres
6. More than 5 acres

2.3 What is the location of your farm plots in relation to your scheme?

1. Head
2. Middle
3. Tail

2.4 Crops grown

1. Paddy
2. Maize
3. Beans
4. Sunflower
5. Onions
6. Vegetables
7. Tomatoes
8. Others

2.5 Crops yield

S/No	Name of crop	Size of farm plot (ha)	Crop yield (kg)	Yield (kg/ha)	Price per kg	Amount of money (TAS)
1	Paddy					
2	Maize					
3	Beans					
4	Sunflower					
5	Onions					
6	Tomatoes					
7	Vegetables					

3. BASELINE DATA ON IRRIGATION

3.1 Type of irrigation practiced

1. Furrow
2. Check basin
3. Check Border strips
4. Wild/uncontrolled flooding
5. Others (specify)

3.2 Factor(s) that influence the choice crop grown under irrigation

1. High value crop
2. Low irrigation crop water need
3. Deficit irrigation can be practiced
4. Availability of water in the irrigation canals
5. Others (mention it)

3.4 Why do you grow these particular crops?

	Reason for growing the crop				
Crop	**Food security**	**Income**	**Income and Food**	**High yield**	**Non**
Maize					
Paddy					
Beans					
Onions					
Tomatoes					

4. Duties of irrigators' association

4.1 How did you form your irrigators association?

1. It was our own initiative
2. Through advice and technical assistance from the District
3. Through advice and technical assistance from an NGO
4. Forced to formulate it by the Government

4.3 Who is responsible for your irrigation schedule?

1. District Irrigation specialist
2. Ward Extension Officer
3. Water Distribution Committee
4. An individual appointed by the Association

4.4 How were you involved in the formulation of the irrigation schedules?

1. In a General Meeting of all irrigators
2 Informed by the Ward Extension Officer
3. Informed by the individual who distributes water
4. Informed by the Water Distribution Committee Members
5. Not involved at all

4.5 What factors do you think were considered in preparing the allocation schedule?

1. Type of crops grown in the area
2. Availability of water in the main canal
3. Reduction of conflicts among irrigators
4. Imposed by the executing agency
5. Nature of the soil in the area
6. Do not know

4.6 Do you have a fixed irrigation rotation?

1. Yes
2. No

If YES what is the rotation interval?

1. Seven days
2. Five days
3. Three days
4. Eight days
5. Others (Specify)

If NO how is it practiced?

1. According to water availability in the main canal
2. Depending on an individual request
3. Depending on the feeling of the water distribution person
4. Order of the Ward Extension Officer
5. Depending on the decision of the water distribution committee
6. Others (Specify)

4.7 Are you satisfied with the way irrigation scheduling is done?

1. Very Good
2. Good
3. Moderate
4. Bad
5. Very bad

4.8 How dependable is the irrigation scheduling?

1. Very High
2. High
3. Satisfactory

4. Low

5. Very Low

4.9 Are all crops given the same amount of water whenever irrigation water is applied?

1. YES

2. NO

If NO Why?

4.10 Are the crops given the same amount of water in all growth stages?

1. YES

2. NO

If NO at what stage do you give more irrigation water to your crop?

1. Germination stage

2. Vegetative (growing stage)

3. Flowering stage

4. Fruiting stage

5. Others (Specify)

4.11 How do you decide when to irrigate?

1. Looking at the dryness of the soil

2. Looking at the colour of the leaves

3. Measuring soil moisture

4. Advised by an Extension Officer

5. Other method (Specify)

4.12 Do you experience irrigation water scarcity during the rainy season?

1. YES
2. NO

If YES what is your coping strategy?

1. Do not irrigate the already planted crop
2. Irrigate once
3. Use whatever available water
4. Increase irrigation frequency
5. Others (Specify)

4.12 Do you experience irrigation water scarcity during the dry season?

1. YES
2. NO

If YES what is your coping strategy?

1. Do not irrigate the already planted crop
2. Irrigate once
3. Use whatever amount of available water
4. Increase irrigation frequency
5. Reduce the amount of irrigation water to be applied
6. Others (Specify)

4.13 How do you tell that you have supplied the right amount of water to the crop?

1. By having ponded water in the basin or furrow
2. Simply by guessing
3. Inserting a piece of stick into the ground

4. Seeking advice from friends who practise irrigation

5. Others (Specify)

4.15 How do you find the operations of the Irrigators' Association?

1. Very Good
2. Good
3. Moderate
4. Bad
5. Very bad

4.16 Are there problems in water distributions within the scheme?

1. YES
2. NO

If YES, What are the causes of the problem?

1. Favouritism caused by the Water Distribution Committee
2. Scarcity of irrigation water
3. The gate rider is not punctual
4. Individual farmers stealing water when it is not their turn
5. All the above
6. Others (Specify)

4.21 How often is the information communicated?

1. Daily
2. Weekly
3. Monthly
4. After three months
5. Yearly
6. Others (Specify)

4.24 Do you use fertilizers in your farms?

1. YES
2. NO

4.25 How much fertilizers do you use per season?

1. Less than 50kg per acre
2 Between 50 -100kg per acre
3. More than 100kg per acre

4.26 Do you know that fertilizers are harmful to the soil?

1. YES
2. NO

4.31 How often do you clean your canals and the distribution structures?

1. Daily
2. Weekly
3. Monthly
4. After three months
5. Yearly
6. Others (Specify)

4.37 Have you attended any irrigation water management training?

1. YES
2. NO

Appendix : A Checklist

1.0 Briefly can you explain the organization structure of the WUA and the way it is linked to the Local Government and the Central Government?

2.0 What are the roles of the Irrigators' Association?

Explain them in detail

3.0 How often do problem(s) occur? (how many cases per irrigation season)

3.1 How are the problems solved?

4.0 How is the communication system between you (farmers) and the Irrigators' Association?

4.1 What information is communicated?

4.2 Is the communication system reliable?

4.3 How is the information archieved?

5.0 What do you do to reduce accumulation of salts (from fertilizers) in thesoil? (Not necessarily from fertilizers)

5.1 Is there area within the scheme which has salinity problems?

6.0 Do you have drainage systems?

If YES how useful are they?

7.0 Is it necessary to maintain canal structures? why?

7.1 How should a well maintained canal look?

7.2 Do you have a maintenance schedule in the scheme?

i) Can you estimate the length of the canals that have been maintained this season? How do they compare with the total length of the canals.

ii) Are all the irrigation structures such as division boxes, turnouts etc in good working condition. If not how many structures that were repaired this season.

iii) How do they compare with the number of existing structures?

8.0 What indigenous practices do you have which are meant to conserve water?

9.0 What do you consider to be the main constraints/problems in irrigation?

9.1 What do you consider to be the most probable solutions to the problems mentioned above?

10.0 What do you do to make sure that no wastage of water occurs in your scheme?