

**FACTORS AFFECTING WATER PRODUCTIVITY IN FARMER-MANAGED
IRRIGATION SCHEMES: A CASE OF RUANDA-MAJENJE
IN MBARALI DISTRICT**

**BY
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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN RURAL
DEVELOPMENT OF SOKOINE UNIVERSITY OF AGRICULTURE.
MOROGORO, TANZANIA.**




2008

ABSTRACT

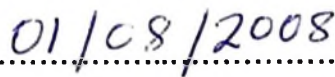
Irrigation Department and other sectors have been improving irrigated agriculture to overcome problems associated with vagaries of the weather. However, despite these efforts the growing competition in water use between sectors, make the sustainability of irrigation schemes and people's livelihoods questionable. Improving water productivity (WP) from the reported 0.22-0.32 kg/m³ for cereals in Mkoji sub-Catchment towards 2.0 kg/m³ recorded in Asia and World wide at large under irrigation has been found to be the key answers. Several researches have been conducted on WP in the Mkoji sub-Catchment but none assessed factors affecting WP in farmer-managed irrigation schemes (FMIS). Therefore, the overall objective of the study was to investigate factors affecting WP in FMIS in order to suggest strategies for WP enhancement. The study was carried out in Ruanda-Majenje irrigation scheme in Majenje village, in Mbarali District in Mbeya region. The study adopted a cross-sectional research design for household data collection. Also the study involved field experiment and on farmers' plots observation. Questionnaires, checklists and direct observations were used in data collection. Data were analysed by using the Statistical Package for Social Sciences (SPSS 11.5) and Statistical Analysis System (SAS) computer software in which descriptive statistics such as frequencies, percentages, means, Analysis of Variance (ANOVA) and separation of means were computed. Findings indicated that WP in farmers' field is still low (0.26-0.76 kg/m³ for maize). Results from the experimental plots show that there are still potentials for improving WP by improving factors affecting WP. The low WP is influenced by socio-economic, institutional and technical factors such as lack of capital, knowledge, extension services and poor agronomic practices to mention a few. The study recommends that there is a need for the Government and other stakeholders to develop strategies that aim in improving WP since water use competition is growing within agriculture and between other sectors.

DECLARATION

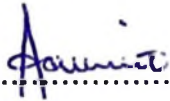
I, JOHN WILLIAM KADUMA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work, and has not been submitted for a higher degree in any other University.



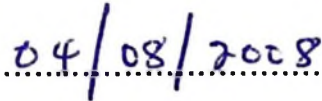
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ACKNOWLEDGEMENT

I thank God for his help in my studies. I am also thanking him for giving my parents, wife and children strength and their daily means of living all over the period I was undertaking my study. Special thanks should go to my lovely wife Mrs. Martha J. Kaduma whom I am greatly indebted for her financial, moral, material support, love, advice and who also kept on supporting our family in my absence. Also thanks goes to my lovely brother Donald W. Kaduma together with my parents who laid down my education foundation. May God bless them always.

My immense thanks also go to my Supervisors, Professor A. K. P. R. Tarimo and Professor N. I. Kihupi for their financial support, tireless guidance, constructive criticisms and moral support from the initial stage of writing the research proposal up to the time of production of this dissertation.

Furthermore, I thank Mbarali District and Zonal Irrigation unit for allowing me to collect data from their irrigation schemes and offices and for their support during the data collection process. I also thank my research assistant Mr. Sydney Kasele from MATI Igurusi for the support and assistance during data collection.

I am greatly indebted to Mr. K. A. Kayunze, Mr. J. S. Mbwambo, from Development Studies Institute; Mr. Kossa Rajabu and Henry Egbadun from Department of Agricultural Engineering and land Planning and Mr. W. Kayombo from MATI Igurusi for their constructive comments, which helped me to improve this work.

So long as it is not possible to express gratitude to every one individually; then I wish to express my great thanks to my colleagues and all friends who helped me in one-way or another at different stages of my studies and dissertation preparation. Their assistance and contribution is highly accredited. Last but not the least, I would like to thank all my respondents and my casual labourers and any one who in one way or another made my study successful. However, all shortcomings that may be observed out of this study are my own weaknesses and should not be directed to anyone who is acknowledged in this study.

DEDICATION

This work is dedicated to my parents Mr. and Mrs. William Aaron Kaduma, and my late brother Mr. Donald William Kaduma who assisted me in my struggle towards my education program. May God bless them.

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LIST OF ABBREVIATIONS AND SYMBOLS

CAN	Calcium ammonium nitrate
cm	Centimetre
DAIPESA	Development Alternative Incorporated Private Enterprise Support Activity
DALDO	District Agricultural and Livestock Development Officer
DAP	Diammonium Phosphate
DED	District Executive Director
DIO	District Irrigation Officer
EDC	Enterprise Development Centre
FGDs	Focus Group Discussions
FMIS	Farmer managed irrigation schemes
GDP	Gross Domestic Product
GWP	Gross Water Productivity
lirr	Amount of water applied by irrigation
IWMI	International Water Management Institute
KATC	Kilimanjaro Agricultural Training Institute
kg/m ³	kilogram per cubic metre
MAC	Ministry of Agriculture and Cooperative
MAFC	Ministry of Agriculture, Food security and Cooperatives
MATI	Ministry of Agriculture Training Institute
MBZIU	Mbeya Zonal Irrigation Unit

mm	Millimetre
MWLD	Ministry of Water and Livestock Development
NSGRP	National Strategy for Growth and Reduction of Poverty
PANTIL	Programme of Agricultural and Natural resource Transformation for Improved Livelihoods
Pr	Water productivity under rainfed condition
PWAIS	Productivity of Water in Agriculture and Interacting System
RELMA	Regional Land Management
RBMSIIP	River Basin Management and Smallholder Irrigation Improvement Project
RIPARWIN	Raising Irrigation Productivity and Releasing Water for Inter-sectoral Needs
RW	Amount of water supplied by rain
SA	Sulphate of Ammonia
SACCOS	Savings and Credit Cooperative Society
SAS	Statistical Analysis System
SMUWC	Sustainable Management of Usangu Water Management and Catchment
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan African Africa
\$/m ³	Dollar per cubic metre
SUA	Sokoine University of Agriculture
SWMRG	Soil Water Management Research Group
TAS	Tanzanian shillings
TAS/m ³	Tanzanian shillings per cubic metre

URT	United Republic of Tanzania
UAC	Uyole Agricultural Centre
WALEO	Ward Agricultural and Livestock Extension Officer
WANA	West Asia and North Africa
WP	Water Productivity
Wsup	Water productivity under supplemental irrigation
WUG	Water User Group
Y	Crop yield
ZIE	Zonal Irrigation Engineer

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In sub-Saharan Africa (SSA), only 4% of arable land is under irrigation, compared to 40% in South Asia (Commission for Africa, 2005; FAO, 2005a; Mkapa, 2005). In SSA, more than 67% of the population relies on agriculture for their livelihood, contributing more than 30% of the gross domestic product (GDP) (Commission for Africa, 2005; FAO, 2005a; IWMI, 2006). Agriculture is the main source of employment, food security and survival for the majority of the population. While agricultural production is steadily increasing, the population is growing faster than food production. This inevitably results in net decline in per capita food production, contributing to increased food deficits and poverty (Straaten, 2002).

In Tanzania, agriculture accounts for 45% of gross domestic product, about 60% of export earnings and provides livelihood to about 82% of the population (URT, 2005). Out of one million hectares suitable for irrigated agriculture only 0.2 million hectares are under irrigation (URT, 2002a; TARP II-SUA, 2005). The main constraints facing irrigated agriculture include low productivity of land, underdeveloped irrigation potentials and effects of environmental degradation (URT, 2005). However, water productivity (WP) in most of irrigation schemes, is low requiring enhancement to allow the excess water to be used in expansion of areas under irrigation or to be used by other sectors.

1.2 Problem statement and justification

Over the years the Government of the United Republic of Tanzania (URT) has invested in irrigated agriculture to overcome the problems associated with the vagaries of the weather especially rainfall unreliability. However, despite these efforts, the growing need for water

for irrigation and other sectoral uses put the sustainability of irrigation schemes and people's livelihoods in question. According to Raising Irrigation Productivity and Releasing Water for Inter-sectoral Needs (RIPARWIN) project, improving water productivity in irrigation is one of the key answers to the question, since irrigation is the major water user (SMUWC, 2000).

The water productivity in the Usangu Plains which is in the range 0.22-0.32 kg/m³ for cereals (SMUWC, 2001) is lower than the 2.0 kg/m³ WP for cereals under irrigation in Asia (IWMI, 2006) and the water productivity of maize that ranges between 1.2 and 1.3 kg/m³ (Droogers *et al.*, 2000). A number of studies have been conducted on water productivity in the Mkoji sub-Catchment (SMUWC, 2000; Kasele, 2004; RIPARWIN, 2004) but none has assessed factors that affect water productivity in farmer managed irrigation schemes (FMIS). The aim of this study was thus to find out factors that affect water productivity in FMIS in the sub-catchment. This is in line with the National Strategy for Growth and Reduction of Poverty (NSGRP), which among other things advocates on increasing area under irrigation as well as and promoting efficient use of irrigation water (URT, 2005).

1.3 Objectives

1.3.1 General objective

To investigate factors that affect water productivity in FMIS with a view to identifying strategies for enhancing water use efficiency in agriculture.

1.3.2 Specific objectives

- (i) To investigate current levels of water productivity in FMIS.
- (ii) To identify factors affecting water productivity in FMIS.
- (iii) To suggest strategies for enhancing water productivity in FMIS.

1.3.3 Research questions

- (i) What is the current level of water productivity in FMIS?
- (ii) What are the socio-economic factors that affect water productivity in FMIS?
- (iii) What are the institutional factors that affect water productivity in FMIS?
- (iv) What are the technical factors that affect water productivity in FMIS?

1.4 Conceptual framework

The conceptual framework is an outline presentation of variables studied and the relationships that exist between them (Fig. 1). Socio-economic variables included sex, age, marital status, ethnicity, education level, occupation, household economic status, farm size and household size. Technical variables included agronomic practices and water management. Institutional variables included social networks (effectiveness of farmers' organization), credit services and policies. The dependent variable was water productivity which is a function of crop yield and the amount of water used to produce a crop.

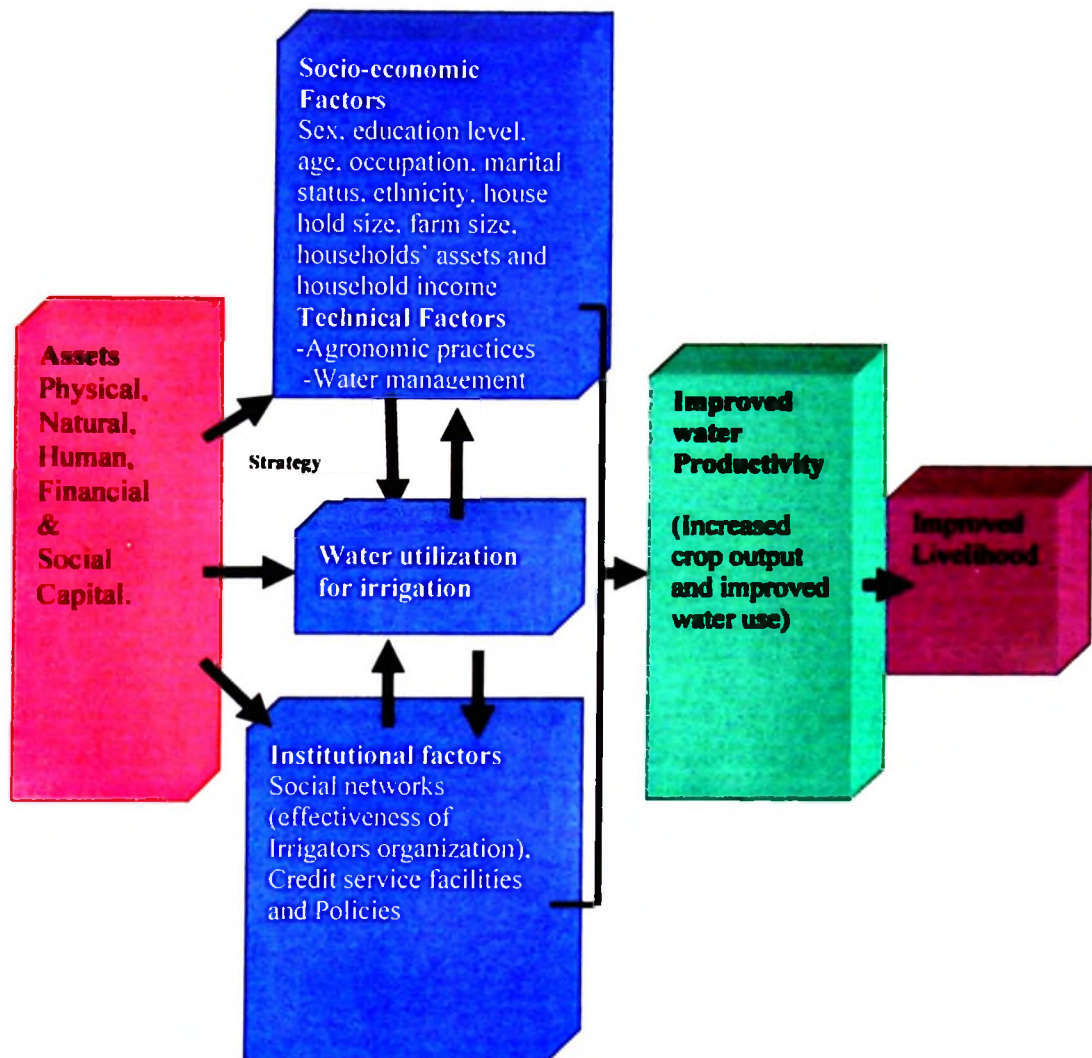


Figure 1: Modified DFID's Sustainable Livelihoods Framework

Source: Montagu (1999)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

In this chapter, a review of what is known on factors that affect water productivity issues is discussed. A review of related literature brings clarity and focus to the research problem, improves methodology and broadens the knowledge base on the subject (Kumar and Casley, 1988). This chapter begins by defining water productivity and FMIS. It further discusses current levels of water productivity attained world wide, in Tanzania and finally in the Mkoji sub-Catchment. Methods commonly used to evaluate water productivity and factors affecting water productivity are also discussed. The later are discussed under three sub-sections namely socio-economic, institutional and technical factors.

2.2 Water productivity

Water productivity in irrigation is the amount of crop produced or gross value of output per unit volume of water used (Barker *et al.*, 2000). Maro (2005) defines water productivity as the physical mass of production or the economic value of production measured against gross, net inflow, depleted water or available water. Water productivity is becoming popular since it links water consumed with the outputs produced (Barker *et al.*, 2003). The concept is replacing the most famous irrigation efficiency which measures the efficiency of irrigation in given boundaries.

Water productivity is usually measured as kilograms of a crop per cubic meter of water used (Barker *et al.*, 2000; Ahamad *et al.*, 2004). It can also be expressed in monetary units such as \$/m³ or TAS/m³ (Barker *et al.*, 2000). This approach is replacing the effeciency concept which has been seen to give little information about the amount of food that can

be produced with the amount of water available (Barker *et al.*, 2000). Assessment of water productivity involves estimation of physical mass of production or the economic value of produce and the unit volume of water depleted in the process (PWAIS, 2004).

According to RIPARWIN (2004), water productivity portrays the product obtained from the irrigated crop that the water delivered was planned for. Here we just consider irrigated production but do so in ways that boundaries are carefully defined and capture the whole system of water use and re-use. Improvement of water productivity is a function of three actions (a) reducing gross water demand by reducing losses that are not usefully recaptured (b) lowering net usage where 'deficit irrigation' cuts water required in greater proportion than yield lost (maximizing returns to water) and (c) boosting the crop growth or response to water by managing crop husbandry, inputs, including the timely scheduling of water. Improving water productivity is a better strategy for improved agricultural productivity in water scarce areas which requires a better matching of water application to crop needs in terms of both timing and quantity (Howell, 2001; Oweis and Hachum, 2004).

2.3 Farmer managed irrigation schemes

FMIS are schemes where farmers make most of the decisions and manage their activities while Government provides technical or logistical support whenever necessary. At least 70 % of today's existing area under irrigation worldwide constitutes formal irrigation schemes built by governments in the middle decades of the twentieth century; through local, national or most likely international funding (FAO, 2005b). By the 1980s most of infrastructure of these irrigation schemes had decayed and users were reluctant to contribute to their maintenance, which resulted in poor water deliveries performance. This subsequently lowered the agricultural profits (FAO, 2005b). The antecedent condition coupled with the far reaching economic crisis of the latter years of the century, gave way to a "devolution" process on the part of governments to transfer responsibility of the

management of the irrigation systems to its users. Currently, more than 40 countries have transfer management to users (FAO, 2005b). Tanzania being one of the countries which transferred management of irrigation schemes to users. This has resulted in greater participation of water users in the decision making process to operate and maintain their irrigation schemes (FAO, 2005b).

Over 80% of the schemes in the Rufiji basin in Tanzania are farmer-managed under irrigation water committees, cooperatives and water user organizations (SMUWC, 2001). Farmers have developed some of these schemes themselves while others have been developed or rehabilitated jointly by the Government and farmers or also in support from external donors.

Most farmer managed irrigation schemes are gravity irrigation systems. In these schemes water user groups (WUGs) seldom practice recording the amount of water abstracted (PWAIS, 2004). In most of them flow measurement devices are absent. They are installed in few improved irrigation systems along the main canals only, and very seldom in secondary and tertiary canals. Even in the improved systems, intake flows are not regularly recorded by WUGs, because there is no regular monitoring of volume of abstraction for water user fee estimation, which would motivate WUG's to keep flow records (PWAIS, 2004).

In practice in farmer managed irrigation schemes, water is allocated among farmers in terms of duration and frequencies of irrigation and not in specific volume of flow. Frequent data kept by WUGs; include a list of farmers in the scheme, designated acreages, irrigation turns and yield that each farmer gets (Tarimo *et al.*, 2004). This set of data is essential for estimation of quota of water user fee each farmer is supposed to pay, of which is remotely related to actual water use.

2.4 Current levels of water productivity

With the increasing water scarcity, water productivity becomes a global concern due to the argument that less water will be available for agriculture because of increasing water demands for domestic, municipal, industrial and environmental purposes (Guerra *et al.*, 1998). Despite its scarcity, water continues to be misused (Oweis and Hachum, 2004). The

current water productivity which has been attained in rice and wheat under irrigation in Asia is between 0.5 to 2.0 kg/m³ (IWMI, 2006). According to Droogers *et al.* (2000) the attained water productivity for maize ranges between 1.2 and 1.3 kg/m³. Zwart and Bastiaanssen (2004) have reported a global water productivity of maize of up to 1.8 kg/m³ while water productivity of rice in Tanzania is 0.1-0.14 kg/m³ and that of other cereals is 0.22-0.32 kg/m³ (PWAIS, 2003). Water productivity for rice in the Usangu Plains is estimated to range between 0.2 and 0.35 kg/m³ (SMUWC, 2001). Igbadun *et al.* (2006) reported that the water productivity of maize in terms of crop water use in Mkoji sub-Catchment ranged between 0.40 and 0.70 kg/m³ among the treatments, while the crop water productivity in terms of water applied varied from 0.40 to 0.55 kg/m³. The national and the Usangu Plains water productivities are low compared to the global ones (Table 1). A Land Management Project in Babati reported that rainwater utilization efficiency increased maize yield from 0.15 to 0.41 kg/m³ due to land management interventions (Hatibu and Mahoo, 2000).

Table 1: Water productivities from different areas

Crop	Location	Water productivity (WP) kg/m ³	Source:
Maize	Global	Up to 1.80	(Zwart and Bastiaanssen, 2004)
	Mkoji sub-Catchment (treatments)	0.40 - 0.70	(Igbadun <i>et al.</i> , 2006)
	Mkoji sub-Catchment (Water applied)	0.40 - 0.55	(Igbadun <i>et al.</i> , 2006)
	Land Management Project (Babati)	0.15 – 0.41	(Hatibu and Mahoo, 2000)
Cereals	Tanzania	0.22 - 0.32	(PWAIS, 2003)
Rice and wheat	Asia	0.50 - 2.00	(IWMI, 2006)
Rice	Tanzania	0.10 - 0.14	(PWAIS, 2003)
	Usangu Plains	0.20 - 0.35	(SMUWC, 2001)

2.5 Methods used to evaluate water productivity

Pure physical water productivity is determined by the quantity of the product divided by the quantity of water depleted or diverted (Barker *et al.*, 2003; Maro, 2005). The combined physical and economic water productivity is determined by the economic value of either the gross or net present value of the product divided by the amount of water diverted or depleted. The economic water productivity implies gross or net present value of the product divided by the value of water diverted or depleted.

In water productivity assessment, the key problem lies in measuring the numerator and denominator of water productivity. Quantity of water used in producing benefit is measured directly in the field. Flows across boundaries should be measured during the irrigation time (Kasele, 2005). Little understanding exists among different stakeholders on how to assess water productivity in irrigation. Irrigation water allocation to farmers is in hours of access and according to frequencies, which are decided by water users associations (Tarimo *et al.*, 2004). Due to this it is difficult to get the actual amount of water used by the farmers to produce their crop.

2.6 Factors affecting water productivity

Bartle (2005) explains that a "factor" and a "cause" are not quite the same thing. A "cause" can be seen as something that contributes to the origin of a problem like poverty, while a "factor" can be seen as something that contributes to its continuance after it already exists. Basing on this translation on factor, therefore we can define factors that affect water productivity as everything which contributes to perpetual of current water productivity (this might be low or high level).

It shows that substantial and sustainable improvements in water productivity can only be achieved through integrated farm resources management (Oweis, 1997; Kirda, 2000; Kumar, 2003; Oweis *et al.*, 2006). On farm water productivity techniques if coupled with improved irrigation management options, better crop selection and appropriate cultural practices, improved genetic make up, and timely socio-economic interventions will help to achieve this objective (Oweis *et al.*, 2006). Therefore, to promote water productivity in the existing systems, conventional water management guidelines should be revised to ensure maximum water productivity instead of land productivity (Oweis *et al.*, 2006).

2.6.1 Socio-economic factors affecting water productivity

Water productivity mainly depends on effective water management and proper agronomic practices (Oweis, 1997; Kirda, 2000; Kumar, 2003; Oweis *et al.*, 2006). For example, improved farm water management could have the greatest impact on water availability in dry areas (Oweis, 1997; Kirda, 2000). This involves social, economic, organizational, policy issues and technical factors. For instance research has demonstrated that proper management can more than double the return from water (Oweis, 1997). As stress on water resources increases, competitions grow between agriculture fighting to retain its water allocations and cities needing to satisfy the rapidly growing population (FAO, 2005a). Water stress and the pressing need to renegotiate inter-sectoral allocation are usually factors that force changes in the way water is managed in agriculture. Indulging in improving water productivity is an inevitable action in order to maintain crop production with an increasing water scramble within the sector and between different sectors.

Despite the fact that water is scarce and an extremely valuable economic input, it is generally supplied free or at low and highly subsidized cost in West Asia and North Africa (WANA) (El Beltagy, 2000) and outside of this area. It is widely accepted that water

pricing would improve water use efficiency (Kumar, 2003; Luquet *et al.*, 2005). For example, China had a plan of five years to raise water prices each year to reduce water shortages (Brown, 2001). Therefore, innovative solutions are needed to put a real value on water for improving its efficiency in use (El Beltagy, 2000). In achieving this, consideration in determining the price of water used in irrigation should be based on its extreme value. Pricing of water should be fixed in such a way that it discourages uses that are economically inefficient. However, water pricing is complex due to concerns relating to public policy apart from those which are purely economic in nature (Rao, 2000).

Price support for farm commodities that encouraged farmers to increase yield through inputs use, land improvement, investment in agricultural research, and building public institutions to support efforts from agricultural extension services to farm credit banks doubled land productivity between 1950 and 1984 in China (Brown, 2001). Therefore, this kind of improvement has effects in improving water productivity whether under rain fed or irrigated agriculture.

Sustainable income and profitability are among the most important incentives for investing in any technology (Hatibu, 2002). To improve effectiveness and profitable use of rainwater and other resources such as irrigation water, these incentives should be emphasized. Reduction of risks and shocks in an area are important too. Improvement of the management of rainwater and irrigation water has a vital role in the reduction of livelihood and enterprise risks caused by climate vagaries (Hatibu, 2002).

Absence of well defined property right regimes is a major source of uncertainty about the negative environmental impacts of resource use, leading to inefficient and unsustainable use. Individuals should be given opportunities and incentives to develop and use the

resource efficiently, or transfer it for more efficient use (Kumar, 2003). In this regard all water users should be educated on their rights to use the resource and their responsibilities in terms promotion of its sustainable availability.

2.6.2 Institutional factors affecting water productivity

For successful improvement in irrigation water management, public and private sector should be involved in decision making pertaining its management. To achieve this objective appropriate policies are needed (Oweis and Hachum, 2003; Sharma and Minhas, 2005). Tanzania amended its water policy in 2002 to suit different stakeholders in its use. The policy among others emphasizes on efficient use of water resource in an attempt to reduce poverty since the resource is key to development and conservation of biodiversity (MWLD, 2002). All sectors are called upon to use the resource carefully and sustainably as the resource is decreasing in its availability due to environmental degradation while its demand is increasing. In implementing policies for maximizing yield, careful consideration should be made before they are applied under water scarcity conditions as at some high level of yield; incremental yield increase requires higher amounts of water to achieve it (Oweis and Hachum, 2006).

Formal institutions such as policy and legislation on water resources management should assign more room for the other side of the coin the informal side, as it has a lot to offer for achieving today's water management imperatives. Water managers at different levels should appreciate formal-informal interfaces and encourage the better coexistence of the two arms at various tiers and prefectures of water resources management (Sokile *et al.*, 2005).

There is need to build capacity of water managers, users and other stakeholders on the importance of both formal and informal institutions at the catchment and grassroots level specifically, where the formal-informal linkages are clearer (Sokile *et al.*, 2005).

Good planning exercised by irrigation institutions in China has enabled the country to tackle food security problem through better water use in irrigation, in spite of the lesser availability of irrigation water, while India produces much less with a high level of irrigation water use (Kumar, 2003). Therefore, poor water allocation and management associated with weak functioning of farmers' organizations contributes in low water productivity.

Water productivity mainly depends on how effective water is managed by the farmers and their organizations (Oweis, 1997; Kirda, 2000; Kumar, 2003; Oweis *et al.*, 2006). A strong water users' organization promotes better water use, if it goes hand in hand with the extension workers.

2.6.3 Technical factors affecting water productivity

Adoption of improved water conservation technologies in the central Great Plains in the United States of America have increased wheat yields by 45% on average (Hatibu, 2002). This was significantly higher than improved varieties (30%) and fertilizer practices (5%). Technologies for overcoming loss of water in rain-fed agriculture include well known soil and water conservation techniques. The principal requirement is the improvement of infiltration, water holding capacity and water uptake by plants. For example, it has been shown that sub-soiling coupled with manure can lead to four fold increases in yields of maize per unit of land in dry areas of Tanzania (Hatibu, 2002). In order to increase water productivity in agriculture the primary productivity of land needs to be increased. This

requires nutrients to be proportionally increased to raise the efficiency of utilization of irrigation water. In order to increase the overall productivity of land, the moisture retention capacity of soil needs to be enhanced along with increasing the biomass inputs. Thus there is a need to manage land, water and biomass in an integrated manner (Kumar, 2000).

Poor access to water is among the leading factors hindering sustainable development in semi-arid and arid regions (Hatibu, 2002). This problem can be overcome through efficient use of available innovations in rain-fed production; rainwater harvesting and precision irrigation (Kirda, 2000; Hatibu, 2002).

Kirda (2000) suggested that innovations were needed to improve the efficient use of available water based on existing approaches. Different irrigation approaches could be used for more effective and rational uses of limited supplies of water. Drip and sprinkler irrigation methods are preferred to less efficient traditional surface methods. For example farmers in India, Israel, Jordan, Spain and the United States have shown that use of improved technology such as drip irrigation systems minimize water use by 30 to 70 % and raise crop yields by 20 to 90 % (World Watch Institute, 1999; Brown, 2001). In China water productivity almost tripled between 1966-78 and 1989-2001 due to the adoption of deficit water irrigation practices, changing cropping pattern, volumetric pricing of water and the recapture and reuse of water (Future Water Project, 2006).

How irrigation is practised at farm level has an influence in water productivity (Mintesinot *et al.*, 2004). New irrigation scheduling approaches which are not necessarily based on full crop water requirement, but ones designed to ensure the optimal use of allocated water such as deficit (regulated deficit) irrigation are needed to be developed and adopted (Kirda, 2000). The main objective of deficit irrigation is to increase water use efficiency of

a crop by eliminating irrigations which have little impact on yield (Kirda, 2000; Hatibu, 2002; Mintesinot *et al.*, 2004). Supplemental irrigation with a limited amount of water applied to rain-fed crops during critical stages, improves yield and water productivity substantially (Oweis and Hachum, 2003, 2004; Oweis *et al.*, 2004a; Li QuSheng *et al.*, 2005; Fox and Rockstrom, 2003). It has been found that one cubic meter of water applied as supplemental irrigation at the proper time might produce more than 2.0 kg of wheat grain over that of rain-fed (Oweis and Hachum, 2004). Application of water to satisfy less than the full water requirement of crops was found to increase water productivity and spare water for irrigating new lands. It is now recognized that optimum water productivity can be achieved by under irrigation (Oweis and Hachum, 2003).

Water productivity can be improved by introducing precision irrigation which involves the application of only the required quantity of water in the root zone (Hatibu, 2002). This will include application of a small amount of water to overcome stress due to dry spell within the growing period. Technologies for achieving high levels of control such as micro-drip techniques for high frequency, low volume and partial-areas application of water and nutrients to crop fields are available. The technologies involve applying water directly to the root zone, increases transpiration by plants due to improved contact between water and roots while soil evaporation and deep percolation are reduced.

In irrigation, storage losses are very high for surface reservoirs. The potential for saving this water is very high. The conveyance or the network losses are very high for surface irrigation systems. It is believed to be in the order of 45-55 percent for many of the large surface irrigation systems with extensive distribution networks consisting of unlined channels. This is due to very high field evaporation, evapo-transpiration, percolation, and runoff losses due to flood irrigation and the poor on-farm water management practices

being adopted by farmers. It was found that 70 % of water was lost due to percolation through sand loam soils of Delhi and only 480 mm out of 1200 mm of water was actually used consumptively by rice (Kumar, 2003).

Management factors for more productive farming systems include use of suitable crop varieties, improved crop rotation, planting dates, crop density, soil fertility management, weed control, pests and diseases control, water conservation measures (Oweis and Hachum, 2004). Poor management of the above management factors results in reduction of water productivity. Therefore, optimizing agronomic practices and inputs, such as appropriate cropping patterns and fertilization, can increase water productivity (Oweis and Hachum, 2003). Use of improved crop varieties that can increase water use efficiency while maintaining or even increasing yield levels and water productivity need to be developed (Barker *et al.*, 2000; Brown, 2001; Oweis and Hachum, 2003; Tyagi *et al.*, 2005). This is also supported by Oweis (1997), Kirda (2000), Kumar (2003) and Oweis *et al.* (2006) that water productivity mainly depends on effective water management and proper agronomic practices. Improved farm water management has proved to have the greatest impact on water availability in dry areas (Oweis, 1997; Kirda, 2000).

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Overview

This chapter presents the methods used to collect and analyse data on factors affecting water productivity in FMIS. The chapter is divided into six sections. Section one presents the study location and justification of its selection. Section two presents research design, which describes how the study was carried out. Section three presents the sampling procedures involved. Section four describes data collection. Data processing and analysis are presented in section five and lastly limitations of the study are presented in section six.

3.2 Study area and justification for its selection

3.2.1 Description of the study area

The study was conducted in Ruanda-Majenje irrigation scheme in Middle Mkoji sub-Catchment in Mbarali District in Mbeya Region (Fig. 2). Mkoji su-Catchment is drained by the Mkoji River and is located in the Southwest of Tanzania, between latitude 7^o48' and 9^o25' South, and longitudes 33^o40' and 34^o09' East (SWMRG, 2004). This zone is in the transitions between the highlands and the flat plains of Usangu. This zone is located at an average altitude of 1100 m above sea level. It has mean annual rainfall of about 800 ranging between 700 and 1100 mm (SMUWC, 2000). The rainy season normally commences between the third or fourth decade of November and April. The zone is characterized by perennial and seasonal streams and rivers, which run from the Poroto Mountains. The presence of perennial water flows in the zone has led to a proliferation of irrigation schemes in this area. The schemes are both traditional and improved traditional irrigation systems.

Initially, the study was planned to be done in two areas namely Majenje and Mahango-Mswiswi, but due to unavailability of water in Mahango-Mswiswi irrigation scheme, the study was only done in Majenje. Ruanda-Majenje irrigation scheme which is the biggest area under irrigation in the village covers an area of 371 ha with a total of 240 farmers. The scheme is subdivided into two areas. The upper part with light soils is used for crops such as maize, cassava, beans, and vegetables; to mention a few, while the lower part an area with heavy soils is used for paddy production. The scheme gets water from Lwanyo River. The river originates from Poroto mountain ranges and discharges its water into Great Ruaha River.

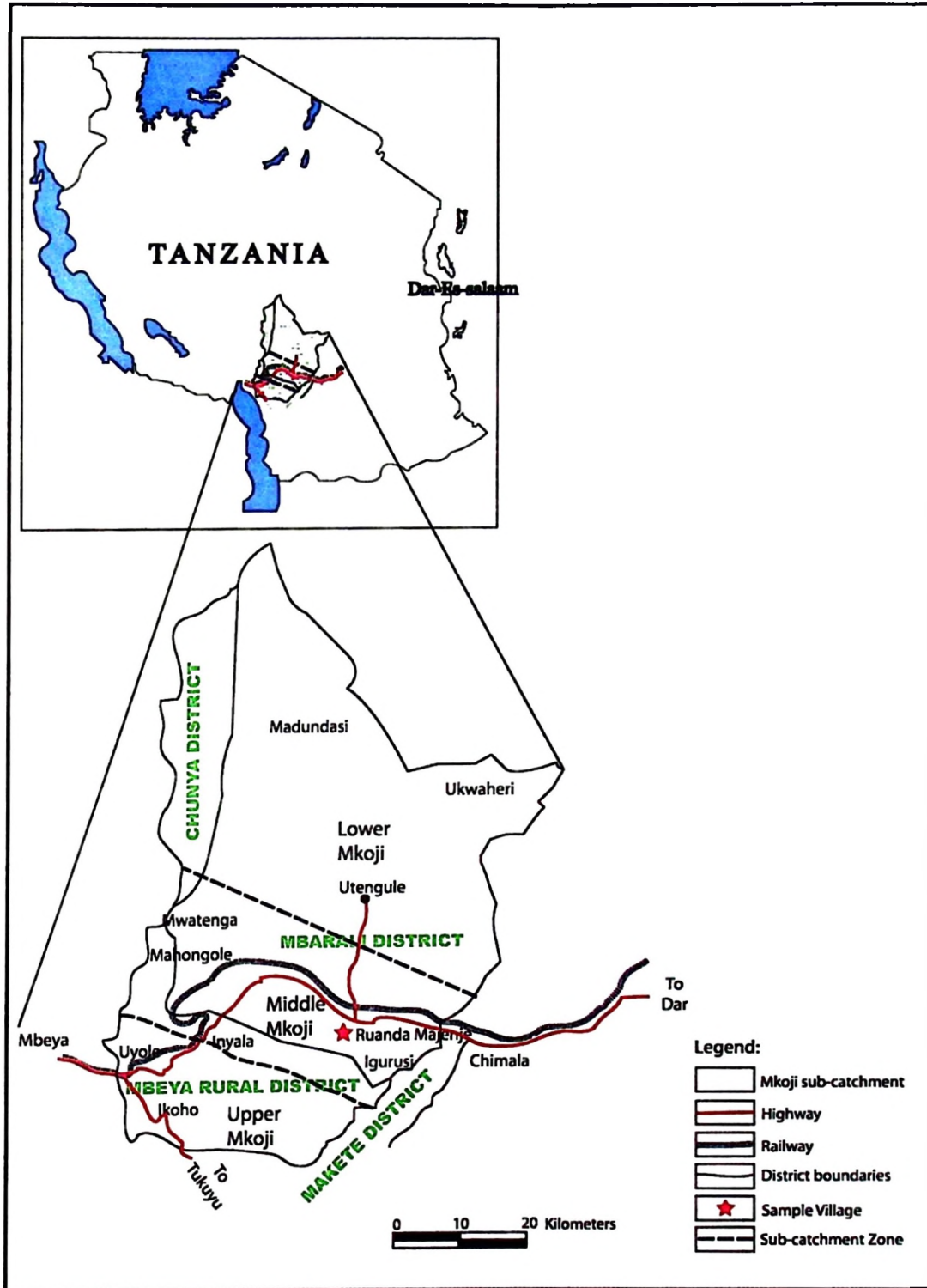


Figure 2: A map of Mkoji sub-Catchment showing the study area

Source: SWMRG (2004)

3.2.2 Justification for its selection

Mbarali District was selected for the study by considering certain peculiar characteristics of the area. The District is endowed with a large number of irrigation schemes in the country. Ruanda-Majenje irrigation scheme is one of the irrigation schemes in the area. Since irrigation schemes which are located upstream of Mtera and Kidatu power stations have been blamed to be the cause of water scarcity to the two power generation stations; therefore, it was important this study was done on them in order to see if the results could be used to minimize the discrepancies between irrigators and other water users.

3.3 Research design

The cross-sectional research design was used in this study ((Bailey, 1998). This method allows data to be collected at one point in time and establishes relationships between variables for the purpose of testing the hypotheses (Bailey, 1998). This method was considered to be useful because of time limitation and resources constraints.

3.4 Sampling procedures

The scheme was selected purposively to study typical cases of factors affecting water productivity in farmer managed irrigation scheme. Respondents were selected randomly from a group of farmers under the Programme of Agricultural and Natural Resource Transformation for Improved Livelihoods (PANTIL) project and some additional number of farmers outside the project who grow maize and beans in the area. Plots for crop yield and water measurement in the field were selected randomly from a list of few farmers who had maize crop at establishment stage.

3.4.1 The population and sample size

The sample population for study was taken from a population of people involved in agricultural production in the area. The sampling unit consisted of households which are directly concerned in agricultural activities mainly irrigated agriculture.

A sample of 40 respondents was taken out of 240 farmers in the scheme. This sample size is above the minimum suggested sample size of 30 cases (Bailey, 1994). A sample of 4 plots was taken out of a list of 6 plots which had maize crop at establishment stage at the commencement of the study.

3.4.2 Sampling technique

Purposive sampling and simple random sampling techniques were employed for selection of the respondents. The selection of the village was done purposively to cover the village under PANTIL project. Simple random sampling technique was used to select respondents from the village. The researcher listed the names of respondents then wrote them in small pieces of paper, folded, mixed them, and eventually picked the pieces of paper randomly to select the respondents. Farmers to participate in on-farm water productivity were selected randomly from farmers who were in the process to grow maize under irrigation. Only few farmers grew maize under irrigation at that time due to water scarcity in the area.

3.5 Data collection methods

3.5.1 Primary data

(i) Household data Collection

Qualitative and quantitative data collection methods were used to get primary data. Structured questionnaire with open and closed ended questions were used (Appendix 1). This tool was used to collect socio-economic, technical, institutional and demographic

factors which affect water productivity in irrigated agriculture. Data collection began in October 2006 and ended in March 2007. Data collection was preceded by pilot study which was done to pre-test the questionnaire for its consistency, clarity of questions and estimate time taken to administer each questionnaire. A team consisting of principal researcher and one trained research assistant administered the questionnaires. The same team was also involved in conducting focus group discussions (FGDs). After every data collection, the team went through the filled questionnaires to check for its consistency, clarity and immediately cleared doubts that were observed.

(ii) Focus Group Discussion

Focus group discussion was conducted to get information on crop production, scheme and water management in order to complement information obtained from the field and as well to verify it. The information was collected from two groups consisting seven discussants each. The first group consisted women while the second involved men. The two groups were expected to involve 12 discussants each but due to unavoidable limitations only seven discussants attended the discussion in each of the two groups. With the help of a check list, the discussions were guided by the principal investigator together with the research assistant in order to capture the information expected to be obtained. The information was jotted down by the recorder then the information was summarized.

(iii) Key informant approach

Other information was collected from six key informants through discussion guided by check list (Appendix 2). The information was collected from District Irrigation Office (1), Rufiji Basin Water Office in Mbarali (1), Majenje Village Office (1), Ruanda-Majenje irrigation scheme office (2) and Mbeya Zonal irrigation Office (1). This was done to complement and get clarification of some of information gathered in field.

(iv) Field data**(a) Water productivity**

Current water productivities were determined practically in farmers' fields and in the experimental plots. Water productivities were computed from the obtained field data.

Data for water productivity in farmer managed farms were collected from four farmers' plots by measuring the amount of water irrigated whenever the irrigation was done. In order to achieve this, irrigation water supplied in plots was measured by using a calibrated cutthroat flume. Rainfall was also measured by a rain gauge which was installed within the study area. After maturity the crop was harvested, dried, threshed, cleaned and eventually its yield determined at 13% moisture content. Water productivity was computed from the data by dividing the crop yield by the volume of water used to produce it as follows:

$$W_{sup} = \frac{Y}{I_{irr} + RW} \dots\dots\dots(1)$$

Where:

- WP_{sup} = water productivity under supplemental irrigation (kg/m^3)
- Y = crop yield (kg/m^3)
- I_{irr} = amount of water applied by irrigation (m^3)
- RW = amount of water supplied by rain (m^3)

This was done in order to get the current water productivity at farm level under farmers' management conditions.

(b) Water productivity in experimental plot

Based on varying frequency and moisture depletion level, water productivity in the experimental plots was studied. The aim of conducting experimentally this study was to determine if there was still some potentiality of raising water productivity and eventually to demonstrate to farmers how water productivity can be improved. Two types of approaches were used, the first one based on irrigation interval while the other was based on moisture depletion level.

(i) Determination of water productivity based on irrigation frequency

In determining water productivity basing on varying irrigation intervals, 24 basins for maize and beans were well prepared. Each basin had a size of 3.0 m by 3.5 m. The first twelve (12) basins were planted maize at a spacing of 60 cm by 90 cm. Each hole was planted with two seeds. The remaining 12 basins were planted beans at a spacing of 10 cm by 50 cm. Two seeds of beans were planted per hole.

These basins (maize and beans) were supplied with the irrigation water at irrigation intervals of 7 days, 8 days, 9 days and 10 days. The experimental treatments were laid in a randomized complete block design and each treatment was replicated thrice. The 7 days irrigation interval commonly used by many farmers in the irrigation scheme was used as a control while the rest were used to subject the crops to deficit irrigation condition in order to determine the possibility of reducing the amount of water use in order to promote water productivity and if possible save water for other uses.

The irrigation interval for maize and beans were determined basing on the crop water requirement and soil moisture retention characteristics of the study area. As mentioned earlier, amounts of irrigation water supplied in the basins were measured by using a

calibrated cutthroat flume. This was achieved by reading the water stages on a gauge mounted on the flume accompanied by recording the time each irrigation took. Since the study continued even after the onset of rainfall, the amount of rain was measured by a rain gauge which was installed within the experimental area. After maturity, crops (maize and beans) were harvested, dried, threshed and yield for each basin separately determined in kilograms. Using the information obtained, water productivity for each basin was computed by dividing yield in kilogram by the respective amount of water used in its production in cubic meters (Equation 1).

(ii) Moisture depletion

Gypsum blocks were molded of gypsum powder (Calcium sulphate) $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ in match boxes. Lead wires were inserted in the gypsum mixture at equ-distant from the edges for all blocks. The blocks were left to dry for two days.

Then the match boxes covers were removed during the time of their installation in field. The blocks were installed in all basins meant for deficit irrigation at a depth of 20 cm (important soil layer for maize and beans). The installation was done basing on gypsum installation protocol (Washburne, 1997). Then water was applied to allow the calibration of the blocks. Each block was calibrated individually due to the existence of variation in performance of the blocks which was experienced when few of them were installed. The variation in performance was based on accuracy in workmanship and variation in quality of the gypsum powder.

The blocks were installed in the basins followed by water application under irrigation. Time of one day was provided after the irrigation to allow the equilibrium point between the saturated soil and the blocks to be attained. In the second day after irrigation to 9th day,

soils were sampled about 30 cm away from position of the blocks everyday by the use of core rings at a depth of 20 cm for moisture content determination. Also, resistance of blocks in ohms was measured by the using resistance meter. Moisture content was determined using the gravimetric method.

Resistances of gypsum blocks at 40%, 50% and 60% by weight moisture depletion level of available soil moisture were pre-established then used to monitor moisture depletion in beans and maize plots after planting. Since only few of the blocks worked properly, then the blocks were assigned to monitor moisture depletion level in several basins assuming soil to be homogeneous. Due to early onset of rainfall the blocks were used to monitor the need for supplemental irrigation. Plots under beans received enough moisture from rain water making irrigation not necessary until crop maturity. In maize plots irrigation was done only once in 40% and 50% by weight moisture depletion level basins until when the crop had tasseled. Only 21 mm (equivalent to 0.2205 m³) of water was supplied to each of 40% and 50% moisture depletion level maize basins at vegetative stage. Maize basins at 60% moisture depletion level were not irrigated because it rained before reaching the moisture content level for replenishment. After the tassling stage of the maize, full supply of water to meet crop water requirement during moisture sensitive period was required. Water productivity under supplemental irrigation was calculated (Equation 1). Water productivity under rainfed condition was computed from the data by dividing the crop yield by the amount of rain water used to produce it as follows:

$$WPr = \frac{Y}{RW} \dots\dots\dots(2)$$

Where:

- WPr = water productivity under rainfed condition (kg/m³)
- Y = crop yield (kg/m³)
- RW = amount of water supplied by rain (m³)

Agronomic practices in water productivity under experimental plots

(a) Irrigation interval

(i) Maize

Staha was the variety of maize (*Zea mays L.*) which was used in the experimental plots. The variety took about 135 days to full maturity. Planting was done on 17 October 2006. It was planted in basins of 3.0 m by 3.5 m. Two seeds per hole were planted at a spacing of 0.6 m by 0.9 m. After seven days all maize had germinated. Diammonium phosphate (DAP) fertilizer was applied during planting by placing it in holes made for planting. It was buried with some amount of soil before putting seeds in those holes then finally the holes were covered with soil. DAP was applied at a rate of 57.5 kg P₂O₅ /ha. Top dressing was done into two equal rates of split application. The first dose of urea was applied 4 weeks after planting. The second dose of urea was applied after 8 weeks after planting (few days before tasseling of maize). This was at a rate of 60 kg N/ha the fertilizer rate recommended for the district. Weeding was done three times due to high infestation of weeds. Carbosulfun insecticide was applied twice to control stalk borers. Maize after 125 days was at a stage which they did not need additional of moisture any more. The crop was left in the farm to continue drying up until when it was 135 days old when it was harvested. The crop was dried in sun for 3 days, then was threshed, weighed after authenticating in laboratory that its moisture content was 13%.

(ii) Beans

Wanja was the variety of common beans (*Phaseolus vulgaris*) used in the experiment under irrigation interval. The variety took about 77 days to full maturity. Planting was done on 17 October 2006 and were planted in basins of 3.0 m by 3.5 m. Two seeds of beans per hole were planted at a spacing of 0.1m by 0.5 m. After 7 days all beans had germinated. Diammonium phosphate (DAP) fertilizer was applied during planting. It was

placed in holes made for planting then covered with some amount of soil before putting seeds then covered with soil. DAP was applied at a rate of 46 kg P₂O₅/ha. No top dressing was done basing on the fact that beans tend to fix nitrogen themselves. The only nitrogen supplied to the crop was that which was supplied in DAP. This was at a rate of 18 kg N/ha. Weeding was done twice. Insecticides were applied three times to control insects. The first insecticide application was done four days after beans germination to control bean fly (*Melanagromyza spp*). Ridomil an antifungal was applied every week after the onset of rainfall to control fungal infection since the crop is highly susceptible. Beans after 67 days were at a stage which they did not need additional supply of moisture. Then, the crop was left in the farm to mature. It was harvested 77 days after the planting date. The crop was dried in sun for four days. Then it was threshed and weighed at moisture content of 13%.

(b) Moisture depletion level

(i) Maize

Most agronomic practices used in moisture depletion level and irrigation interval experimental plots were the same. The differences were on how to determine when to apply water and planting was done on 27 November 2006. Under this, irrigation was done basing on moisture depletion level.

(ii) Beans

Most of agronomic practices used in irrigation interval experimental plots for beans were used in moisture depletion level. Planting of beans was done on 27 November 2006. The difference was on water application. Under this, irrigation was done basing on moisture depletion level.

3.5.2 Secondary data

Secondary data necessary for enriching the primary data were obtained from different sources such as Mbeya Zonal Irrigation Unit (MBZIU), Sokoine University of Agriculture Library and internet. Different research reports from various sources were used as source of information.

3.6 Data processing and analysis

Socio economic data from field survey was coded and analysed using the Statistical Package for Social Sciences (SPSS 11.5) computer software. Descriptive statistics such as frequencies, percentages, means. Focus group discussions (FGDs) and key informants' data were summarized and used. Experimental results were analysed using Statistical Analysis System (SAS). Analysis of Variance (ANOVA) was run in which treatment means were separated using Duncan's Multiple Range. The significance was based on a p-value of 0.05. Graph and tables were used in data presentation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

In this chapter, the results of the study are presented and discussed in line with the study objectives and research questions. The main purpose of this chapter is to provide a detailed discussion on the factors that affect water productivity in FMIS.

4.2 Current level of water productivity in FMIS

4.2.1 Water productivity of maize in farmers' farms

Results obtained from 4 farmers who grew maize, under supplementary irrigation, in Ruanda-Majenje irrigation scheme show that the gross water productivity was 0.26 to 0.76 kg/m³. This suggests the average gross water productivity for maize in farmers' farms was 0.45 kg/m³. Igbadun *et al.* (2005) reported almost similar water productivity for maize under rainfed condition under farmers' managed farms of between 0.19 kg/m³ and 0.49kg/m³. It was observed that yields were higher for farmers who used improved seeds than those who used local varieties. However, these farmers differed in other aspects such as in plant spacing, number of seeds per hole, amount of water applied, fertilizer rates and timing of application. In Table 2 for instance, the first and the second farmer used improved maize seed varieties while the last two farmers used local seed varieties. Results suggest that water productivity in the scheme is still low. These results are compared to 2 kg/m³ for cereals under irrigation that was recorded in Asia (IWMI, 2006) and that of maize which ranges between 1.2 and 1.3 kg/m³ (Droogers *et al.*, 2000).

Table 2: Water productivity of maize in farmers plots

Farmer no.	Plot size (m ²)	Yield (kg)	Yield (t/ha)	Amount of water irrigated (m ³)	Amount of water supplied by rain (m ³)	Total amount of moisture supplied (m ³)	Gross WP (kg/m ³)
1 ^a	88.02	45.84	5.21	47.72	47.85	95.57	0.48
2 ^a	566.93	392.59	6.92	78.95	434.55	513.50	0.76
3 ^b	162.80	45.00	2.76	21.03	131.64	152.67	0.29
4 ^b	168.60	39.11	2.32	16.65	136.33	152.98	0.26
Average			4.30				0.45

^a Farmer who used improved seeds^b Farmers who used local seeds

4.2.2 Water productivity in experimental plots

(i) Gross water productivity of maize production

Table 3 shows the gross water productivity between 10 and 9 days, and 8 and 7 days irrigation intervals did not differ significantly ($P < 0.05$). On the other hand, there was a significant difference ($P < 0.05$) in gross water productivity between the two groups (Appendix 3). The results suggest that experimental plots had higher values than those reported by other researchers in the Mkoji sub-Catchment. For example, SMUWC (2001) reported that water productivity in the Usangu Plains for cereals ranged between 0.22-0.32 kg/m³. Igbadun *et al.* (2006) reported from a study done in the sub-Catchment values of crop water productivity ranging from 0.40 to 0.55 kg/m³.

Table 3: Gross water productivity in kg/cubic meter of maize crop

Duncan separation of means	GWP mean (kg/m ³)	N	Irrigation interval (days)
A	0.70	3	10
A	0.69	3	9
B	0.62	3	7
B	0.61	3	8

Means with the same letter are not significantly different at 0.05 level

This happened during the period when monitoring of moisture deficit had already ceased. Comparing these results with the results obtained under irrigation interval (Table 3) it can be observed that the gross water productivity under irrigation interval is higher than the results obtained under moisture depletion level. The main reason for the variation might be due to smaller amount of water supplied without affecting much yield decline under irrigation interval contrary to over supplied water by torrential rainfall under moisture depletion level irrigation treatments (Appendix 6). This additional water above the amount that could be stored in soil the rest was lost by runoff and deep percolation which could have been harvested and stored for future use.

Table 5: Gross water productivity in maize production

Duncan separation of means	GWP mean (kg/m ³)	N	Moisture depletion level (%)
A	0.63	4	60
A	0.63	4	50
A	0.60	4	40

Means with the same letter are not significantly different at 0.05 level

(iv) Beans yield and gross water productivity under rain-fed condition

Table 6 shows that the average gross water productivity for beans under rain-fed condition was 0.25 kg/m³. These plots were meant for moisture depletion level especially during crop development stage, but due to early rainfall onset the plots were fully supplied with rain water for the whole crop growth period altering the previous plan. Instead, these have been treated as rain-fed. This average gross water productivity (0.25 kg/m³) obtained under rain-fed condition is lower than the averages of gross water productivities (0.38, 0.41, 0.32 and 0.35 kg/m³ under irrigation intervals (Table 4) despite the higher yields obtained per hectare of 1.6 t/ha. The low water productivity under rain-fed condition might be attributed to excessive water supplied by torrential rainfall which rained during its

production cycle. This implies that some of the amount of moisture supplied by rain was not useful in beans production. This also can be confirmed by the fact that the general water requirement of beans lies between 250 to 500 mm (FAO, 1977) which is equivalent to 2.63 to 5.25 m³ for a basin of 10.5 m² of water for the whole period of its production cycle contrary to 6.64 m³ supplied by rain to the same size of basins. This is typically an indication that over supplying of water which is not recoverable downstream for reuse affected water productivity.

Table 6: Beans yield and gross water productivity under rain-fed condition

Category	Basin size (m ²)	Yield (kg/10.5m ²)	Yield (t/ha)	Water supplied (m ³)	WP (kg/m ³)
gross water productivity	10.5	1.68	1.6	6.636	0.25

4.3 Socio-economic factors affecting water productivity

4.3.1 Gender

Table 7 shows that about 70% of the respondents involved in the study were male. The remaining portion consisted of women. According to the results obtained, almost all women respondents reported to get maize yields of between 0 and 3.0 t/ha while men reported to obtain up to above 5.1 t/ha (Table 8). This may have similar effects in water productivity. This could be due to the exposure availed to male farmers through seminars which are mostly attended by men. Mwangi *et al.* (1999) in their study in gender differential in adoption of improved maize production technologies in Mbeya region found that female household heads were less educated and had less access to extension services and information on the improved technologies. A typical example is observed under RBMSIIP where among 1674 farmers who were trained under the program, 1052 were men while only 622 were women. These women who received training consisted only

37% of all the trainees (MAFC, 2006). On the other hand, many household chores done by women such as water fetching, firewood collection and children care limit women to concentrate on farm works and attend different trainings. This shows that gender has influence in crop production and water productivity.

Table 7: Gender of respondents

Gender of respondent	Frequency	Frequency
male	28	70.0
female	12	30.0
Total	40	100

Table 8: Maize yield in relation to gender

Gender of respondent	Maize yield (t/ha)						Total
	0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	above 5.1	
male	2	5	6	8	1	1	23
female	3	7	2	0	0	0	12
Total	5	12	8	8	1	1	35

4.3.2 Influence of age in crop production

The average age of farmers was 44 years (Table 9). Bisanda *et al.* (1998) found the similar average age of farmers of 44 years in the intermediate zone (900-1500 masl) including the study area. About 52.5% of the respondents were at an age group of 36-45 years (Fig. 3). Only 12.5% were at an age group less than this. This entails that more than 87.5% of farmers are at an age of more than 36 years old. This suggests that only a small number of people with less than 36 years of age are engaged in agricultural production. Therefore, in some years to come it is believable that there will be a decline in agricultural production due to older farmers phasing out of the agricultural sector. Results show weak positive influence of age on crop production and water productivity basing on proxy from yield

data (Fig. 4 and Appendix 8). Therefore, the current study suggests more studies to be done to investigate the influence of age on crop production and water productivity.

Table 9: Age of respondents

Age of respondent (N=40)	Minimum	Maximum	Mean
Age	25	68	44.

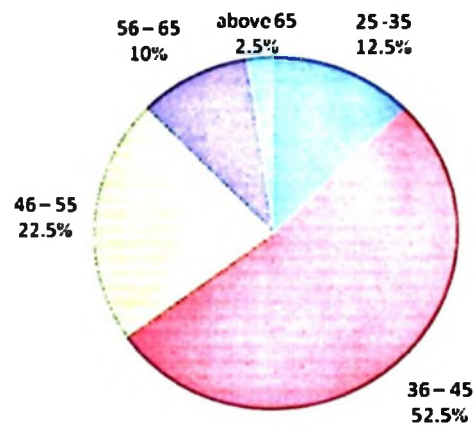


Figure 3: Age of respondents in groups

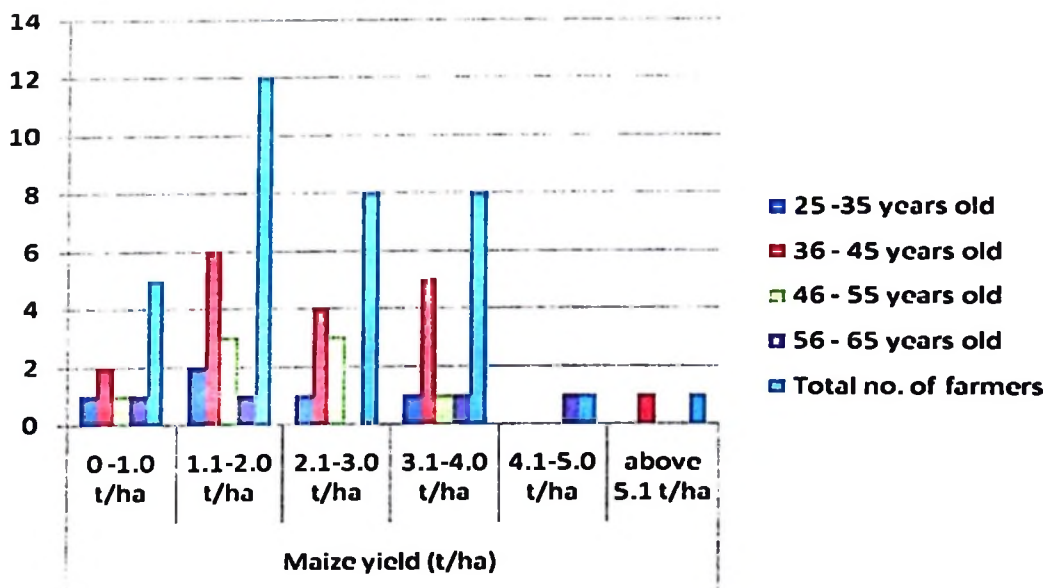


Figure 4: Influence of age (in groups) and amount of maize produced

4.3.3 Marital status

About 92.5% of respondents were married (Table 10). Their family size ranged from 2 to 11 members. On average the family size was 5 members. Being married is associated with having different parental roles such as search for household food, school fees, meeting medical cost, to mention a few. These responsibilities force the head of a household to be more responsible, but on the other side being over burdened than the unmarried one. Therefore, being married makes an individual responsible for many things, which can reduce the effectiveness of whatever one does. There is no clear picture on how this affects crop production and water productivity as there was limited number of respondents who were single to allow comparison to be made. Therefore, the effect of marital status in crop production and water productivity calls for more research.

Table 10: Marital status of respondents

Marital status of respondent	Frequency	Percentage
married	37	92.5
single	1	2.5
separated	2	5.0
Total	40	100

4.3.4 Education level

The general education levels of respondents were, no formal education, standard four, standard seven, standard eight and ordinary level education. Eighty percent of them had primary education level (seven years in school) while those with no formal education consisted of 12.5%. Only a very small portion of respondents were form four leavers indicating that agricultural production is mainly carried out by people with education levels lower than secondary school education (Fig. 5 and Appendix 9). Bisanda *et al.*

(1998) reported the average education level of farmers to be 5 years of formal training for intermediate and highland zones.

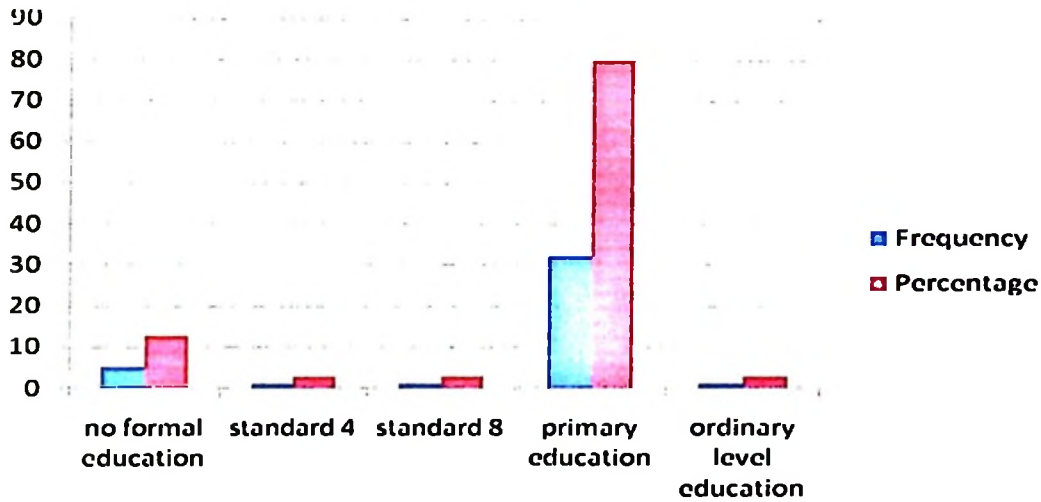


Figure 5: Education level of respondents

Education is likely to have a strong influence on household poverty status through enhancement of productivity. This is supported by Lawson *et al.* (2005) that higher education levels are crucial for sustained poverty reduction and enhanced productivity which may have influence in acquisition of necessary agricultural inputs and good agricultural skills that ultimately may have some impact in water productivity. Mwangi *et al.* (1999) reported that various studies have shown that, improvements in agriculture and the likelihood of adoption of improved technologies are strongly linked to access to education. Results under this study did not show vividly the influence of education level on water productivity due to unproportional number of respondents, based on education, to allow comparison. Therefore, this requires more research to be carried out.

4.3.5 Ethnicity

The current study showed that Nyakyusa and Safwa were the dominant ethnic groups in the study area. Results in Table 11 show that Nyakyusa and Safwa tribes consisted about 22.5% each while the rest of the tribes were distributed as follows: Bena (15%), Wanji

(10%) and Kinga (7.5%). The remaining 22.5% consisted of other small tribes in the area. Basically Safwa were found to occupy this area much earlier than the rest of tribes. According to the results, Bena were found to get relatively higher yields per hectare (a proxy for water productivity) than the rest. They managed to get yield of more than 5.1 t/ha of maize crop while the rest got up to 4.0 t/ha (Table 12). Probably this too might have similar impacts in water productivity. Therefore, ethnicity may have some influence in crop production and water productivity. This might be due to commitment put on agricultural activities given by different farmers of different origin.

Table 11: Ethnicity of respondents

Ethnicity of the respondents	Frequency	Percentage
Kinga	3	7.5
Wanji	4	10.0
Bena	6	15.0
Nyakyusa	9	22.5
Safwa	9	22.5
others	9	22.5
Total	40	100

Table 12: Maize yield based on ethnicity of the respondents

Ethnicity of respondents	Maize yield (t/ha)						Total
	0-1.0 t/ha	1.1-2.0 t/ha	2.1-3.0 t/ha	3.1-4.0 t/ha	4.1-5.0 t/ha	Above 5.1 t/ha	
Kinga	0	1	0	2	0	0	3
Wanji	0	1	0	2	0	0	3
Bena	0	1	2	1	1	1	6
Nyakyusa	4	0	3	2	0	0	9
Safwa	0	5	1	1	0	0	7
others	1	4	2	0	0	0	7
Total	5	12	8	8	1	1	35

4.3.6 Occupation

Table 13 shows that majority of respondents (90%) essentially depended solely on farming in attaining their livelihood. The rest combined farming with other activities for their livelihood such as farming with livestock keeping and farming with employment. Table 14 shows that about 90% of respondents depend on food crop production as their main sources of income while about 7.5% depended on vegetable production. The remaining portion depended on production of other crops. Those who relied on single activity were very susceptible to among others bad weather, unsuitable crop market and pest attack subsequently disturbing their capital. Farmers with multiple activities were found to have high opportunities in soliciting funds from other ventures to buy the required agricultural inputs for irrigated agriculture whenever they are required to do so. Farmers who also keep animals for instance, have been found to have opportunities of using animal manure, in place of chemical fertilizers, in their farms (Bisanda *et al.*, 1998). Therefore, dependence on single occupation may have some negative effects in crop production and hence water productivity.

Table 13: Main occupation of respondents

Main occupation	Frequency	Percentage
only a farming	36	90.0
a farmer and petty business person	1	2.5
a farmer and livestock keeper	2	5.0
a farmer and worker	1	2.5
Total	40	100

Table 14: Main sources of income of respondents

Main sources of income	Frequency	Percentage
food crop production	36	90.0
vegetable production	3	7.5
others	1	2.5
Total	40	100

4.3.7 Ownership of assets

The current study determined ownership of assets such as ox carts, ox-ploughs, radio, refrigerator, bicycle, iron sheet roofed houses, television set, sewing machine, motor cycle and tractor. These assets are considered to be indicators of socio-economic status of a household. A household with a radio or television has an access to mass media communication; refrigerators allow storage of perishable food for a long period to promote food security in a household, while bicycles, ox carts and motor cycles provide assurance of good transportation of farm products, inputs and as well as facilitating movement of farmers to and from the field and other areas of interest during production processes. Tractors and ox-ploughs assure easy and early land preparation (Bisanda *et al.*, 1998). Use of tractors and ox-plough is an indicator of redemption of a farmer from the dependence on hand hoe a tool which is associated with perpetual poverty as it is linked with small scale farming.

The findings show that radios, bicycles and houses roofed with corrugated iron sheets were the most common household assets owned by most of respondents (Table 15). Ox-ploughs and television sets were owned only by few households. All households were found not to possess refrigerators, sewing machines, tractors and motor cycle probably due to the fact that these items are too expensive for them to buy. Some household assets have direct effects on crop production. These include those used in land preparation,

transportation of inputs and communication media to mention a few. Households owning different types of assets are potentially liable to produce more than those without. For instance, a family with ox plough can prepare land earlier and nicely than those depending on hand hoe or hired labour. Also, such families when faced with problems can hire or mortgage some of their assets to solve their problems. Therefore, household assets may have influence in crop production and water productivity.

Table 15: Household assets

Household assets	Frequency	Percentage
ox-carts	0	0.0
ox plough	9	22.5
bicycle	31	77.5
radio	38	95.0
iron sheet roofed house	31	77.5
television set	2	5.0
refrigerator	0	0.0
sewing machine	0	0.0
motorbike	0	0.0
tractor	0	0.0

4.3.8 Housing conditions

In order to assess housing conditions in which respondent live, house ownership and kind of material used for building the walls, roofing and flooring were identified. Information on these characteristics is useful as they reflect the household socio-economic status. Results in Table 16 indicate that about 95% of the respondents lived in their own houses. Only 5% of respondents lived in rented houses.

Table 16: House ownership

House ownership	Frequency	Percentage
yes	38	95.0
no	2	5.0
Total	40	100

About 73.7% of houses owned by the respondents, had walls made up of burnt bricks (Table 17). About 78.9% of the houses had roofs covered by corrugated iron sheets while grass thatched houses were only few (Table 18).

Table 17: Materials used in wall making

Materials used in walls	Frequency	Percentage
burnt bricks wall	28	73.7
un burnt bricks	9	23.7
mud wall	1	2.6
cement bricks wall	0	0.0
Total	38	100

Table 18: Materials used in roofing

Type of roof	Frequency	Percentage
tin	0	0.0
corrugated iron sheets roof	30	78.9
grasses roof	8	21.1
Total	38	100

Table 19 shows that mud was the main material used (57.9%) for flooring of the houses. These depict the quality of housing. The study showed that only 42.1% of respondents'

houses' floors were made of cement. Poor housing condition requires family labour and resources to be used almost every year to maintain it hence denying time and money to be used in promotion of crop production, water productivity and other household development activities. Poor housing condition also has some effects on health of the household's members. Thus solving this problem requires diverging some of the resources envisaged to be used in agricultural production. Therefore, this too might have some effects on crop production and water productivity.

Table 19: Materials used in floor making

Type of floor	Frequency	Percentage
cemented floor	16	42.1
mud floor	22	57.9
floor tiles	0	0.0
Total	38	100

4.3.9 Source of energy for cooking

The study shows that 97% of respondents rely on firewood as the main source of energy for cooking (Table 20). Use of firewood and charcoal has some implications on tree cutting from our forests. This might have some impact on land cover that causes land degradation; hence affect water availability in the sub-catchment. Only 2.5% of respondents used charcoal as a source of energy for cooking. None of the respondents used kerosene, electricity or gas as source of energy for cooking in their households. According to the researcher's observation, there were no woodlots grown by the households for domestic wood supply indicating that firewood was obtained from a nearby natural forest. URT (2005) argues that the use of firewood for domestic purposes in rural areas is associated with consuming women's and children's time in its search hence reducing their time in participating in agricultural production and other economic activities and attending

school. Lack of sufficient labour, due to most women being engaged in collection of firewood, results in low household income, inefficient water application, and improper agronomic practices. Therefore, this affects crop production and water productivity.

Table 20: Source of energy for cooking

Source of energy for cooking	Frequency	Percentage
firewood	39	97.5
charcoal	1	2.5
kerosene	0	0.0
electricity	0	0.0
gas	0	0.0
Total	40	100

4.3.10 Source of water for domestic use

Fig. 6 and Appendix 10 show that majority (50%) of households depended on public water taps while 20% depended on running water within their homesteads. About 17.5% got water from irrigation canal. The rest 12.5% used water from other sources such as spring for domestic purposes. SMUWC (2000) reported that about 65% of Mbarali District residents are saved by piped or well water. Economic factors might be the main reason which had limited majority of the community members to install their own water taps in their own houses as there is no limitation on this. Dependence on irrigation canals as source of domestic water has some impact on water productivity of the irrigation scheme as it forces water to flow in the canal throughout the day and night to meet this demand (Lankford, 2001; Maro, 2005). Type of water source used for domestic purposes by the community is linked with prevalence of water borne, water based and water washed diseases, which have negative effect on community labour and income availability (SMUWC, 2000). Further, domestic water availability has some effects in labour

availability to other activities such as agricultural production. Where water is fetched from a distance it entails heavy workload on women and children (URT, 2005) and they spend a lot of time in getting water resulting in reduced women's contribution to agricultural production, while children lose time to attend school programmes. The deficits in water and sanitation are trapping households in cycles of poverty (Earth Policy Institute, 2003). Therefore; sources of water for domestic use have some influence in household economic status, crop production and water productivity.

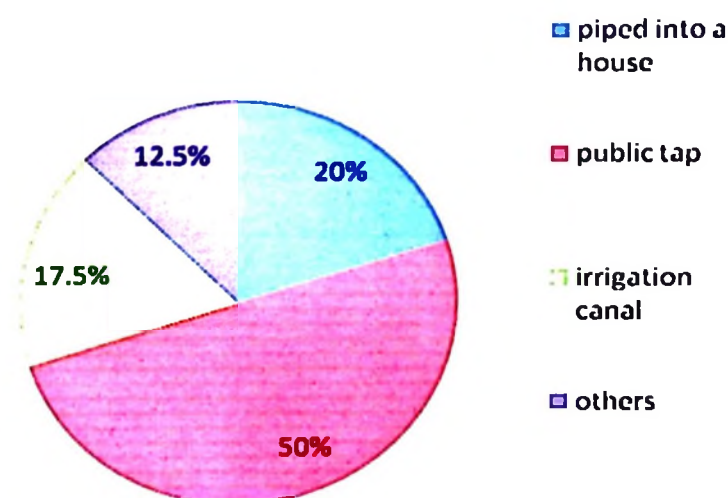


Figure 6: Sources of water for domestic use

4.3.11 Household size

The respondents' households had an average size of 5 members (Table 21). According to URT (2002b) this household size is above the regional level household size of 4.2 members. The minimum household size found was 2 while the maximum was 11.

Table 21: Household size

Household size (N=40)	Minimum	Maximum	Mean
number of members in household	2.00	11.00	5.

About 58.3% of the households comprised between 2 to 5 members (Table 22). Families with 6 to 10 members covered about 38.9% while those with more than 10 members consisted 2.8%. Considering this high family size in relation with their low income, these families live in difficulty life. Also most of their income produced is used to settle family requirements and very little is made available for input acquisition for agricultural production. This may have some influence on poor crop production and hence perpetuate poverty and hence low water productivity.

Table 22: Household size in group

Household size in group	Frequency	Percentage
2-5	21	58.3
6-10	14	38.9
above 10	1	2.8
Total	36	100

4.3.12 Household income

The average household income of respondents was found to be about TAS 50 277 per month (Table 23). The minimum household income per month being TAS 8 333, while the maximum was TAS 200 000. Table 24 shows that about 62.5% of respondents reported to have an income of TAS 50 000 per month or less. The second group consisted 28.1% of farmers with an income of between TAS 50 000 and TAS 100 000 per month. Only 9.4% of respondents had an income of more than TAS 100 000 per month. In accordance with the National Strategy for Growth and Reduction of Poverty, majority of these farmers are living below poverty line. This is due to the fact that the average family size of 5 members per household with an average income of about TAS 50 000 per month implies that on average, these families used about TAS 1676 per day, which is roughly about TAS 335 per

head. According to URT (2005) people who use less than a dollar per day per head are considered to be income poor. McNicoll (1999) defines income poverty as a condition of per capita income below a fixed poverty line that is typically set at a purchasing power equivalent to US\$ 1 per day. Therefore, low household income has negative influence in input use, which ultimately affects crop production and water productivity.

Table 23: Monthly household income

Monthly household income	Minimum	Maximum	Mean
average household income (TAS)	8 333	200 000	50 277

Table 24: Monthly household income in groups

Household income (TAS)	Frequency	Percentage
0 - 50 000	20	62.5
50 001 - 100 000	9	28.1
100 001 - 150 000	1	3.1
150 001 - 200 000	2	6.3
Total	32	100

4.3.13 Crop yield

The average yield of maize for 2005/06 season was 2.4 t/ha (Table 25). In the FGDs the same average yield of 2.4 t/ha was reported. The reported yields ranged from 0.06 to 6.9 t/ha. Table 26 shows that majority (34.3%) of farmers realized production of between 1.1 and 2.0 t/ha. In beans production, average yield obtained was 0.8 t/ha while that reported by FGDs was 0.9 t/ha. Beans yields in study area ranged from 0.3 to 1.6 t/ha (Table 25). The difference in yield for crops between the minimum and maximum levels attained by the farmers indicates the potentiality in yield that can be attained if all farmers equally fulfil some basic requirements in crop production and moisture utilization in irrigation.

The big variations in yield might be caused by different agronomic practices such as initial land preparation, type of seeds used, plant spacing, planting time, weeding, fertilizer rate and types applied and pest control done by the different farmers. Oweis and Hachum (2003) explained that optimization of agronomic practices and inputs, such as appropriate cropping patterns and fertilization, had an influence on crop yields and water productivity. Low crop yields have a negative effect on water productivity as they represent the numerator in determination of water productivity (Igbadun *et al.*, 2005).

On the other hand, amount of rainfall or irrigation water applied to the crop might be the other factor, which contributes to yield variation as it affects the denominator in computing water productivity (Igbadun *et al.*, 2005). Also if excessive amount of water is applied it causes leaching of nutrients hence lowering crop yields. Therefore, the low crop yield associated with excessive use of irrigation or rainfall water lowers tremendously water productivity.

Table 25: Maize and beans yields

Category (N=35)	N	Minimum	Maximum	Mean
maize production (t/ha)	35	0.06	6.90	2.38
beans production (t / ha)	18	0.30	1.60	0.82

Table 26: Maize yields (grouped)

Maize production (t/ha)	Frequency	Percentage
0 -1.0	5	14.3
1.1-2.0	12	34.3
2.1-3.0	8	22.8
3.1-4.0	8	22.8
4.1-5.0	1	2.9
above 5.1	1	2.9
Total	35	100

4.3.14 Critical labour demand in crop production

About 85% of respondents indicated that they usually experience critical labour demand in some of the months in an area (Table 27). Majority (28.6%) of them said that high labour demand is mostly experienced in December (Table 28). This is a major labour constraint especially when the rain season is delayed and labour demands of the rainfed maize and the paddy overlap (SMUWC, 2000). Maize and paddy are the most common crops grown in this area.

Table 27: Critical labour demand

Is there any critical labour demand?	Frequency	Percent
yes	34	85.0
no	6	15.0
Total	40	100

Table 28: Months with critical labour demand

Months with critical labour demand	Frequency	Percentage
September	6	21.4
November	1	3.6
December	8	28.6
January	4	14.3
February	6	21.4
April	3	10.7
Total	28	100

About 61.5% indicates that family labour does not suffice labour requirements in irrigated agriculture (Table 29). While 73.1% of respondents reported that hired labour is the most common coping strategy to curb this problem (Table 30). Few (15.4%) solved this problem by using communal labour in which a farmer asks neighbours for support to accomplish the envisaged activities, but this technique is becoming less popular with time.

About 7.7% of farmers reported that due to labour shortage some farmers sometimes leave planted areas unattended. This kind of situation contributes to reducing water productivity as during the initial stages, these crops had used water for irrigation.

Table 29: Availability of family labour in irrigated farming

Is family labour enough for irrigated farming activities?	Frequency	Percentage
yes	15	38.5
no	24	61.5
Total	39	100

Table 30: Strategies used to supplement labour shortages

Strategies used to supplement family labour shortages	Frequency	Percentage
hire labour	19	73.1
use communal labour	4	15.4
leave some planted farms unattended	2	7.7
others	1	3.8
Total	26	100

Ninety percent of respondents reported about the existence of effects of labour shortage in crop water application (Table 31). When there is labour shortage during water application in the field, the most experienced problem is how to make follow up of more water or reduce the amount of water when found to be important to do so. The respondents (41.7%) reported that, whenever a canal or furrow leaked or wants to stop water flow in the canal farmer go to attend the matter leaving water for irrigation to flow in the field uncontrolled thus causing over irrigation. Subsequently water breaks furrows or basins and finally gets lost through over irrigation or flows outside the intended area (Table 32). Oweis and Hachum (2003) have found that over supplying water to crops lower water productivity through leaching of nutrients and impeding soil aeration.

Over irrigation as result of labour shortage contributes to significant water loss and hence lowering of water productivity. Therefore, labour shortage in water application in irrigated agriculture contributes much in lowering crop production and water productivity.

Table 31: Existence of effect of labour shortage in water application in field

Is there any effect of labour shortage in water application?	Frequency	Percentage
yes	36	90.0
no	4	10.0
Total	40	100

Table 32: Effect of labour shortage in water application in field

Effect of labour shortage in water application to crops	Frequency	Percentage
bund destruction	16	44.4
over irrigation	15	41.7
irrigate non intended area	4	11.1
delayed completion of irrigation	1	2.8
Total	36	100

4.3.15 Scheme's land utilization

It was observed that low land use in the scheme was due to among others a few farmers owning large farms. These farmers were not using the whole area possessed for agricultural production. On the other hand, water which is enough to irrigate the whole scheme is usually diverted from the river especially during rain season (Rajabu *et al.*, 2005). Low cooperation between scheme leaders and the village Government made follow-ups on bad performance of the irrigation scheme difficult. FGDs exposed that there was under utilization of land, while the amount of water diverted at the source was as per

allocation (water right) for irrigating the whole area. This lowered scheme water productivity as this water got lost in fallow land. In addition, FGDs revealed that those farmers who had big farms did not like to hire their land to others. If they did so, it is for one or two seasons, a situation which does not give incentive to those who hired it to undertake proper land preparation. As a result they end up practising irrigation in poorly prepared land resulting in uneven water distribution in the field which ultimately negatively affects water productivity.

4.3.16 Land used for irrigated agriculture own by the household

Table 33 shows that the average land for irrigated agriculture owned by the household was 0.9 ha. Land ownership ranges from 0 to 3.2 ha per household. Similarly, (SMUWC, 2000) reported that an average land own by household for maize production is 0.8 ha. About 50% of respondents reported that between 2004 and 2006 land kept under irrigation had been unchanged while only 29% said it had decreased (Fig. 7 and Appendix 11). The rest reported that their land for irrigation had increased.

Table 33: Ownership of land for irrigated agriculture

Category (N=34)	N	Minimum.	Maximum	Mean
total land for irrigated agriculture (ha)	38	0.0	3.20	0.9

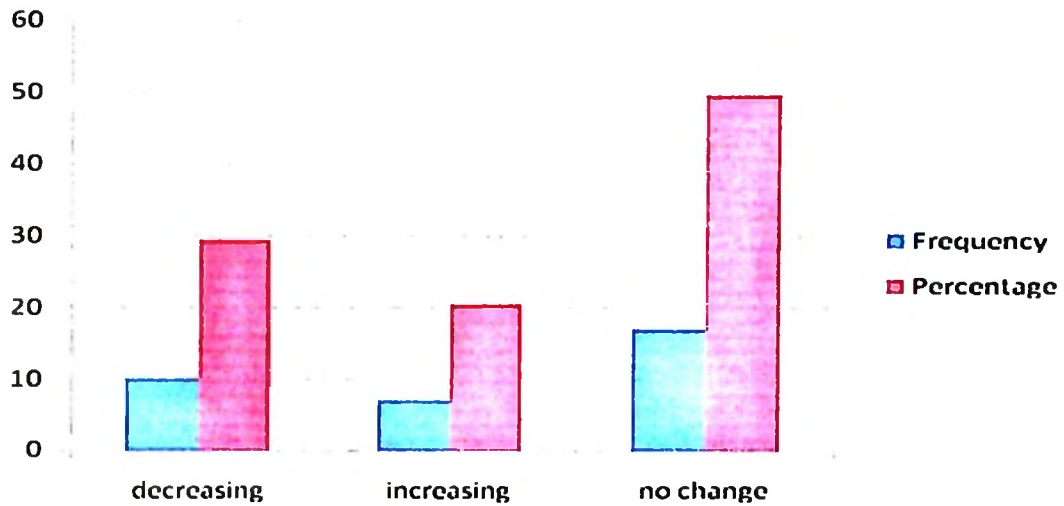


Figure 7: Tendency of irrigated agriculture

In regard to the main reason for land being unchanged for the past three years, 55.6% of respondents said that it was because of water shortage while 44.4% said it was due to lack of capital (Fig. 8 and Appendix 12). For the past three years water shortage and lack of capital were explained by the respondents to be the major reasons of decreasing and/or not changing land under irrigation. These might be the major limiting factors in crop production and water productivity as some farmers lose or get low yield due to water shortage and/or lack of capital to buy necessary inputs for crop production. Consequently, the above different aspects cause low yield and low water productivity.

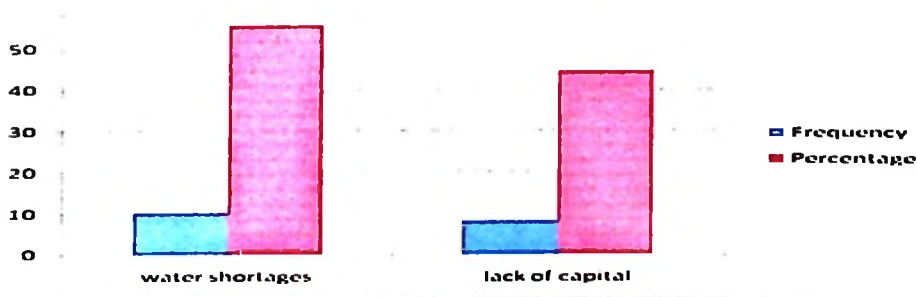


Figure 8: Reasons for no change in area under irrigation

4.3.17 Household food security

Table 34 shows that about 65% of respondents' experienced food shortage in some months of the year. The main cause of food shortages was unavailability of water for irrigation, in the scheme (Table 35). In this aspect shortage of land and lack of knowledge were ranked second in importance. Despite being of least importance lack of capital, low soil fertility, and shortage of labour were also pointed out. November to February period was mentioned by 46% of the respondents to be the months with most food shortages (Table 36). Few of them extended the period of food shortage to March. According to the experience in this area, in February to March farmers started harvesting crops grown in lowland which are basically wetlands "vinyungu" and sometimes crops grown under irrigation and finally supplemented with moisture from rain. In April onwards maize and paddy under rain-fed and or irrigation matured especially from those farms which were planted early thus reduced the problem of food shortage.

Table 34: Food security in the household

Do you produce enough food for a household?	Frequency	Percentage
yes	14	35.0
no	26	65.0
Total	40	100

Table 35: Causes of food insecurity

Causes of food shortage	Frequency	Percentage
shortage of land	3	12.0
insufficient irrigation water	16	64.0
shortage of labour	1	4.0
lack of knowledge in crop production	3	12.0
low soil fertility	1	4.0
lack of capital to buy inputs	1	4.0
Total	25	100

Table 36: Months with food security in the household

Months with food shortages	Frequency	Percentage
January up to march	4	14.3
January up to February	5	17.9
January up to April	2	7.1
September up to November	1	3.6
November up to February	13	46.4
December up to April	1	3.6
February up to April	2	7.1
Total	28	100

Table 47 shows that selling labour to other farmers was mentioned to be the main coping strategy against food shortage for majority of the respondents (39.3%). Few of the respondents pointed out that previous money savings was used to overcome food shortages (28.6%). Minority (10.7%) do sell livestock or other assets while others (7.1%) get involved in petty businesses or get assistance (7.1%) from relatives as remittances. Selling labour to other farmers and using money from previous savings have negative effects in labour and capital availability for household agricultural production. This suggests that food insecurity in a household may have a negative effect in crop production and water productivity.

Table 37: Coping strategies employed to solve food shortage

Coping strategies employed to solve food shortages	Frequency	Percentage
use previous own money savings	8	28.6
sell livestock or other assets	3	10.7
do petty business	2	7.1
sell labour to other farmers	11	39.3
get assistance from relatives (remittance)	2	7.1
others	2	7.1
Total	28	100

4.4 Institutional factors affecting water productivity

Institutional framework within the irrigation scheme has an impact in water productivity. For example, well organised irrigation water users groups, which are well supported by Government policies perform better because they are motivated to accomplish their roles accordingly. When there is a good institutional framework, different matters, which ultimately may negatively affect water productivity, can be rectified. In case it happens that the institutional framework is not conducive the performance of these irrigation schemes becomes questionable.

4.4.1 Extension services

Majority (37.5%) of the respondents pointed out that they had never met with any extension worker for the past three years (Table 38). About 22.5% of the respondents said they had met with extension worker only once. The remaining small portion of respondents pointed out that they met extension workers several times.

Table 38: How often farmers met with extension worker(s) for advices

How often farmers met with extension worker(s) for advices	Frequency	Percentage
0	15	37.5
1	9	22.5
2	6	15.0
3	4	10.0
4	1	2.5
5	3	7.5
8	2	5.0
Total	40	100

Majority (80%) of those who managed to meet with the extension worker pointed out that the extension workers taught them about proper crop production (Table 39). Eight percent of the respondents were taught about proper water management. Farmers individually and

in FGDs were lamenting on the lack of extension workers. They showed that they really need extension workers to provide them with the service. This is an indication that farmers miss extension services which could have contributed positively in enhancement of crop production and water productivity.

Table 39: Knowledge provided to farmers

Knowledge provided to farmers	Frequency	Percentage
proper crop production	20	80.0
proper water management	2	8.0
others	3	12.0
Total	25	100

In response to the above situation, Ward Agricultural and Livestock Extension Officer (WALEO) (Magomela, R. personal communication, 2006) pointed out that the coverage of extension workers in an area is extensive in relation to number of available extension workers in an area. WALEO revealed that the ward had only two Agricultural extension officers including himself covering an extensive area. The ward covers seven villages namely Igurusi, Majenje, Chamoto, Uhambule, Mambi, Kongolo-Mswiswi and Azimio-Mswiswi. WALEO on the other hand, have other responsibilities of attending administrative duties in the ward, making the only extension worker solely available fully for agricultural extension works in the ward to be merely one. Apart from rain-fed agricultural production, in the ward, there are about eight irrigation schemes (Ruanda-Majenje, Maendeleo, WIA, Njalalila, Matunda, Kilombero, Meta/Lunwa and Majengo) attended by these two extension workers.

Sosovele *et al.* (2002) pointed out that Districts including Mbarali are constrained by inadequate technical staffs due to limited financial capacity to employ more staff. Such

constraints are felt more in extension services that are inadequate, lack of means of transport and cannot move out of stations easily to offer services.

Low knowledge in proper use of fertilizer, improper plant population, use of local varieties and late weeding were found to be among extension issues affecting crop production in an area. It was admitted by respondents in FGDs that crop production in the irrigation scheme is not impressive. This is an indication that either extension services provided to farmers are low or the rate of adoption of new knowledge by the farmers is low. Therefore, lack of adequate extension services may have effects on crop production and water productivity in the area.

4.4.2 Farmers' organization performance

About 71% of respondents said that the irrigators' organization accomplishes its responsibilities (Fig. 9 and Appendix.13). In respect Officer in charge of Zonal Irrigation Unit (Kweka, P.F. personal communication, 2007) differed saying that the farmers' organization does not accomplish its responsibilities accordingly. He further pointed out that the main reason of low performance of the schemes was basically due to inefficient leadership, and poor implementation of bylaws. This was different with the way other irrigation schemes, such as Ipatagwa and Igomelo which were constructed by River Basin Management Smallholder Irrigation Project (RBMSIIP). It was pointed out that all irrigation schemes constructed under (RBMSIIP) all got same types of training, study tours to both leaders and farmers. But unfortunately the impact of the training and study tours on the part of Ruanda-Majenje irrigation scheme's leaders and farmers seemed to be low. This is shown by the poor performance of their irrigation scheme. This was supported by the low yields obtained, poor contribution for operation and maintenance, lack of farmers' lists, lack of farm ownership list and most of farms being left fallow for most of

time of years even during rainy season without any measure being taken by the leaders and farmers. Tarimo *et al.* (2004) found that the frequent data kept by most WUG's include list of farmers in the schemes, designated acreages, irrigation turns and yield that each farmer gets.

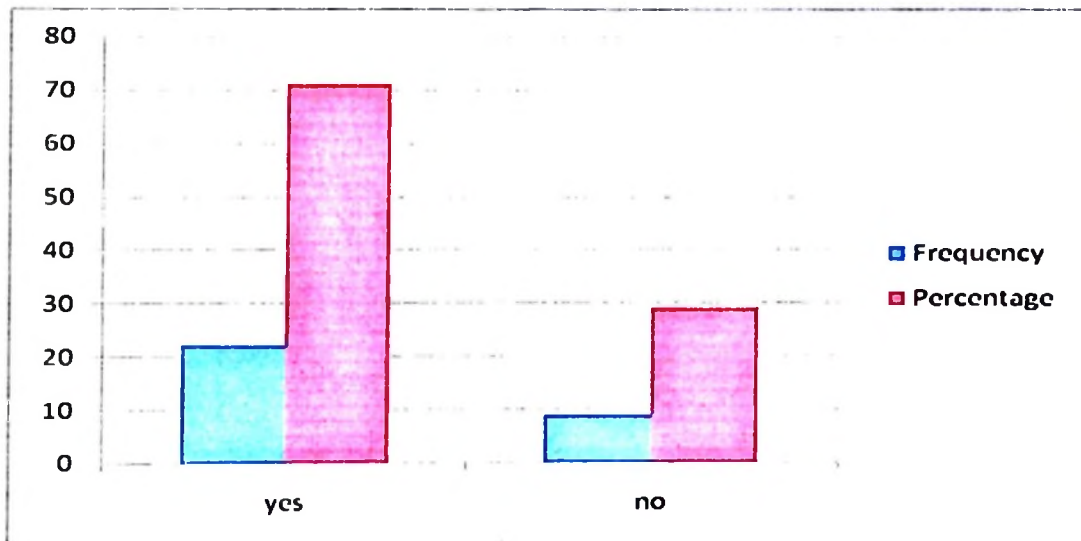


Figure 9: Farmers' organization accomplishment of its responsibilities

Water productivity mainly depends on how effectively water is managed by the farmers and their organizations (Oweis, 1997; Kirda, 2000; Kumar, 2003; Oweis *et al.*, 2006). Unfortunately, water in agriculture is indeed too often misused and mismanaged due to lack of know-how of people and weakness of the institutions. Strong water users' organization can promote better water use, if it works hand in hand with the extension workers. Therefore, the performance of farmers' organization has effects on crop production and water productivity of scheme as whole.

4.4.3 Credit service facilities

Table 40 shows that only 37.5% of the respondents had access to different credit service providers. It was further learnt that farmers from Ruanda-Majenje did not use SACCOS to

get loans to solve their problems like what Igurusi farmers did. Mostly, only business people joined the Majenje SACCOS. Credit service providers who operated in the area include formal and informal ones. Formal credit service providers include SACCOS and NMB while informal involve Mkombozi, Mshikamano and Punda Afe groups. Out of 37.5% of respondents who were involved with credit service providers, 57% were under SACCOS scheme while 14.3%, 14.3%, 7.1% and 7.1% were indulged with NMB, Mkombozi, Mshikamano, and Punda Afe groups respectively (Table 41).

Table 40: Farmers credit facilities services

Household member belonging to any credit facilities?	Frequency	Percentage
yes	15	37.5
no	25	62.5
Total	40	100

Table 41: Farmers credit facilities services

Credit facilities	Frequency	Percentage
SACCOS	8	57.1
NMB	2	14.3
Mkombozi group	2	14.3
Mshikamano group	1	7.1
Punda Afe Group	1	7.1
Total	14	100

Field observation showed that only a small number of members had managed to get loans from the SACCOS and NMB. Reasons given by the respondents were that leaders of these formal institutions are stubborn and reluctant in providing loans to farmers. Lack of knowledge in loans procedures together with lack of collaterals hinder some of them from applying for loans. Similarly, Bisanda *et al.* (1998) reported this too to be the main

limitation facing farmers in credit acquisition for agricultural production in intermediate and highland zones. On the other hand, the SACCOS which were operating in the Majenje had limited amount of money to meet the demand. It was also claimed that leaders of that SACCOS were biased in providing credit. It was explained that SACCOS' leaders were easily providing loans to business people than to farmers due to fear of risks associated with agricultural production. Due to unavailability of credit service providers supporting farmers, these farmers were found to be left helpless and subjected to farming without using the basic farm inputs. In most cases, these farmers are forced to get loans from local money lenders who charge high interest rates (SMUWC, 2000). Similarly, Nkonya *et al.* (1998) reported that in Northern Tanzania for instance, there were no formal credit services supporting maize farmers with rising input prices. This subsequently, led farmers into getting low yield and hence affecting water productivity negatively as they did not follow the recommended farming practices due to lack of capital.

4.4.4 Role of District and Zonal Irrigation Unit in promoting production

There is little pressure exerted to irrigation schemes leaders and farmers to play their role in irrigation matters. This is due to the existence of insufficient collaboration between District and Zonal Irrigation Unit teams in crop promoting production and water management. Scheme's leaders and farmers need to be pushed intermittently to accomplish their duties. These two parties are required to put much effort to induce farmers in the irrigation scheme to perform better than the way they are doing now. Only technical staffs appointed to work with these farmers are left to accomplish those duties with little back up by the higher authorities.

If district leaders could put on efforts such as those used in other sectors such as that used in controlling grazing cattle in Ihefu or mobilizing building schools then production and

water productivity could have been enhanced a great deal. It should be understood that in developing these irrigation schemes, the Government invested a lot of money, which needs to be recovered indirectly through farmers' contribution in production of food to meet country's requirements.

Sokile *et al.* (2005) indicated that formal institutions such as policy and legislation on water resources management should assign more room for the other side of the coin the informal side, as it has a lot to offer for achieving today's water management imperatives. Water managers at different levels should appreciate formal-informal interfaces and encourage the better coexistence of the two arms at various tiers and prefectures of water resources management. Therefore, there is a need to build the capacity of water managers, users and other stakeholders on the importance of both formal and informal institutions at the catchment and grassroots level specifically, where the formal-informal linkages are clearer (Sokile *et al.*, 2005). Therefore, efficient water use will be attained only if there will be strong collaboration among the stakeholder in the sector. Every one should work tirelessly to promote crop production, efficient water use which subsequently will lead into improved water productivity and livelihood of the community.

4.4.5 Policies related with enhancement of water productivity

The Government policy for controlling crop market outlets to neighbourhood countries has a negative effect on farmers' crop prices, which subsequently hinders the number of people entering the agricultural industry because its has a low return. FEWS NET (2002) explains that maize export together with other food crops from Southern Highlands increased cash income to traders and farmers thus improving their welfare and ability to purchase more farm inputs such as improved seed and fertilizers. Lack of processing industries of agricultural crops to add value affects crop prices that eventually affect

promotion of production activities. Farmers in FGDs aired their grievances on the common tendency of the Government, to protect few consumers at their expense.

Despite good export prices of crops in the neighbouring countries such as Zambia, Malawi and Democratic Republic of Congo the Government in most cases does not allow exportation of food crops. This tendency usually limits farmers' economic growth. FGDs emphasized that contrary to farmers' plans, sometimes the Government tends to prevent farmers to sell locally their maize as green maize "*gobo*" whenever the country is faced with food shortages despite good prices, which farmers had targeted during crop production plans. This limits farmers from getting good income subsequently discouraging farmers and probably causing withdrawal of some of them from the industry or perpetuation of poverty to most of rural people. Despite exportation of food crops being a threat to the country's food security, it is suggested that limiting flow of food crop outside the country might limit farmers from getting good prices consequently limiting the entry of new small scale investors in the sector of food crop production.

Apart from this, lack of good policy that supports ways of getting resources limited farmers in the supply of farm input trade; it is plausible that farmers are subjected to buy inputs at very high prices. Field observations revealed that containers such as '*sados*', which are a four litre paint container, and a one litre container are commonly used for this purpose. Prices charged are relatively exorbitant compared to prices charged per 50 kg bag of fertilizer. This is just one side of the coin in regard to the effect of policy and how it affects agricultural production and subsequently water productivity.

4.5 Technical factors affecting water productivity

Water productivity as stated earlier is a ratio of amount of yield of a crop divided by the amount of water diverted or applied to the crop. In this regard therefore water productivity is a function of different factors. These factors include those which affect land productivity of crops such as land preparation, type of seeds used, plant population, time of planting, weeding, time of harvesting, etc. Water management has an influence in water productivity. Manipulation of water use in the field to attain the optimum level also improves water productivity. In manipulating these factors there is a certain level of combination where water productivity will be maximized.

4.5.1 Experience in irrigated agriculture

It is believed that practices makes perfect. According to this study, the average experience of respondents was 12 years (Table 42). About 25.6% of respondents had an experience in irrigated agriculture of between one to five years. Those with experience of six to ten years comprised of about 23.1%. The rest had an experience of more than 10 years (Table 43). There was a low relationship between experiences in irrigated agriculture and amount of yield per hectare (Table 44). The yield per hectare is a numerator (a proxy for water productivity) in the equation for determining water productivity. In this regard therefore, number of years practising irrigated agriculture has low positive influence in water productivity.

Table 42: Experience of respondents on irrigated agriculture

Category	Minimum	Maximum	Mean
average years of experience in irrigated agriculture	2	30	12.

Table 43: Experience of respondents on irrigated agriculture (grouped)

Respondents' years of experience in irrigated agriculture (years)	Frequency	Percentage
1 -5	10	25.6
6-10	9	23.1
11-15	7	17.9
16-20	7	17.9
over 20	6	15.4
Total	39	100

Table 44: Linkage of crop yield with experience of respondents on irrigated agriculture

Maize production (t/ha)	Number of years undertaking irrigated agriculture					Total
	1-5	6-10	11-15	16-20	Over 20	
0.0 -1.0	3	1	0	1	0	5
1.1-2.0	2	3	2	3	1	11
2.1-3.0	2	2	2	1	1	8
3.1-4.0	1	2	1	2	2	8
4.1-5.0	0	0	0	0	1	1
above 5.1	0	0	1	0	0	1
Total	8	8	6	7	5	34

4.5.2 Training in irrigated agriculture

Table 45 shows that 79.5% of respondents had some training related with irrigated agriculture and that water management was the key issue that they were taught. Other training mentioned was on crop production, water harvesting and budgeting. In regard to knowledge they have in irrigated agriculture, 97.5% said that it was not satisfactory (Table 46). Hundred percent of respondents suggested the need for having training (Table 47). Even during FGDs session albeit farmers admitted to get training on different matters, yet

they insisted the need for extension services, so that they can get more knowledge on irrigated agriculture.

Table 45: Training attended by farmers

Attending training in irrigated agriculture	Frequency	Percentage
yes	31	79.5
no	8	20.5
Total	39	100

Table 46: Knowledge in irrigated agriculture

Knowledge has in irrigated agriculture satisfactory?	Frequency	Percentage
it is satisfactory	1	2.5
it is not satisfactory	39	97.5
Total	40	100

Table 47: Suggestions related in knowledge

Suggestion if knowledge not satisfactory	Frequency	Percentage
need more education/training	38	100.0

Farmers of Ruanda-Majenje irrigation scheme like those of Ipatagwa, Igomelo, Nyamahana, Luganga, Mangalali and Mapogoro irrigation schemes which were under RBMSIIP received same training and were sent for study tours in various areas, but their performance in crop production is still low (Masha, R. personal communication, 2006). Training was conducted by River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP), Kilimanjaro Agricultural Training Institute (KATC) and

Development Alternative Incorporated Private Enterprise Support Activity (DAIPESA) in collaboration with Enterprise Development Centre (EDC). The training included cash management, budgeting, crop production and leadership and formation of SACCOS. These indicate that training in irrigated agriculture are not the only factor affecting crop production and water productivity in this area. Therefore, suggesting more study to be done to establish the main cause of this.

4.5.3 Sources of seeds for crop production

As illustrated in Table 48 most farmers used maize seeds, which they sorted from their previous harvest while some got seeds from their friends' harvests. About 62.5% of farmers sorted seeds from previous harvests. Only 37.5% of farmers used seeds from input dealers. This shows that only 37.5% of farmers used improved seeds for crop production. Even in FGDs it was revealed that majority of farmers do not use improved seeds. The main reasons provided were that improved seeds were sold at very high prices (TAS 2500/kg for maize) and their germination rate was poor. The use of seeds of poor quality or low yield potential usually leads to low crop yields and water productivity. This is reported by Oweis and Hachum (2003) that using both Mendelian breeding techniques and modern genetic engineering, for new crop varieties can increase water-use efficiency and yield.

Table 48: Sources of seeds for crop production

Sources of seeds (maize) for crop production	Frequency	Percentage
input dealers	15	37.5
sort seeds from previous harvest	21	52.5
get from friend's harvest	4	10.0
Total	40	100

Staha, *SC 403*, *Kilima*, *SC 407*, unspecified local and hybrids varieties are the commonly used maize varieties in the study area (Table 49). *Staha* was used by about 57.5% of respondents followed by the unspecified local varieties. Farmers who reported to use *Staha* as improved seeds; most sort them from previous yields. Due to lack of seed technology it is plausible that these seeds were of low quality due to cross pollination that might have resulted into low water productivity. Due to low knowledge in seed technology, as mention above, farmers tend to sort seeds even from hybrid maize to be used in the subsequent season a situation which is not acceptable under seed production. Bisanda *et al.* (1998) and Nkonya *et al.* (1998) noted that it was common for farmers to practice seed sorting from previous harvest including hybrid maize, for several years without buying new seeds from seed dealers in Southern Highlands and Northern Tanzania. It is recommended that composites can be recycled for a maximum of three years or seasons, and hybrids should not be recycled (Nkonya *et al.*, 1998).

Table 49: Varieties of maize used in production

Maize varieties used in crop production	Frequency	Percentage
<i>Staha</i>	22	57.9
<i>local varieties</i>	8	21.1
<i>SC 403</i>	3	7.9
<i>high breed</i>	3	7.9
<i>Kilima</i>	1	2.6
<i>SC 407</i>	1	2.6
Total	38	100

In regard to beans production, *Mwasipenjele* variety was found to be the dominant variety among the four commonly used bean varieties (Table 50). Others are *Msafiri*, *Msukanywele* and *Kablanketi* in that order of importance. Majority of input dealers do not sell bean seeds in their shops. Most improved bean seeds were usually obtained directly

from researchers such as Uyo research centre and others. Almost all farmers in the scheme used local varieties. Unreliable market of improved varieties was spelt out by the respondents and through FGDs to be the foremost problem, which limited the use of improved varieties of beans in production. Most consumers preferred local varieties such as *Kablanket*, *Msukanywele* etc. The productivity and quality also can be differentiated within the local varieties themselves. For instance, *Kablanketi* fetches good price but has relatively low yield. These results suggest that the use of local varieties with low yielding potential under irrigation and rain-fed condition results in low production and hence low physical water productivity.

Table 50: Varieties of beans used in production

Beans varieties used in crop production	Frequency	Percentage
<i>Mwasipenjele</i>	12	60.0
<i>Msafiri</i>	4	20.0
<i>Msukanywele</i>	2	10.0
<i>Kablanketi</i>	2	10.0
Total	20	100

4.5.4 Plant population

About 95% of farmers plant maize in rows (Table 51). However, adoption of appropriate maize spacing and number of seeds per hole are still critical problems that affect plant population in production of maize (Table 52). Most farmers estimate the distances, a situation that causes most of them to plant their maize either too close or too wide. Both cases affect plant population.

Some farmers measured the distances between and within rows while others just estimated the distances. Some farmers mixed plant spacing required to be used for one seed with

what is supposed to be for two seeds. FGDs revealed that it was common to find farmers planting many seeds per hole with an intention of thinning the seedlings. However, it was as well uncommon to find farmers thinning healthy and vigorous seedlings/young plants. Consequently this causes over population of crops with subsequent low yields.

Table 51: Type of planting (maize)

Type of planting	Frequency	Percentage
random planting	2	5.0
row planting	38	95.0
Total	40	100

Table 52: Number of seeds planted per hole (maize)

Number of seeds planted per hole	Frequency	Percentage
1	9	23.7
2	24	63.2
3	5	13.1
Total	38	100

Table 53 shows different plant populations which were used by the farmers in maize production. The recommended plant spacing for maize with plant population per hectare in brackets are 30 cm x 75 cm one seed/hole (44 444), 60 cm x 75 cm two seeds/hole (44 444) (KATC, 2003; Acland, 1977; Bisanda *et al.*, 1998; Nkonya *et al.*, 1998), 30 cm x 90 cm one seed/hole (37 037) and 60 cm x 90 cm two seeds/hole (37 037) (Acland, 1977; Nkonya *et al.*, 1998). In drier areas such as Western Tanzania a spacing of 30 cm x 90 cm (37 037) is recommended (Acland, 1977). According to the above plant spacing, the recommended plant population for maize ranges from 37 037 to 44 444 plants per hectare. Farmers in the study area over populate their farms up to 166 667 plants per hectare. Results show that some farmers plant maize more than four folds of the recommended

plant population. Also, Mwangi *et al.* (1999) found that none of the sampled farmers in their study followed the exact recommendations for spacing between and within hoes. Oweis and Hachum (2004) reported that crop density is among the management factors for more productive farming systems. In this regard therefore, improper plant spacing in this area has negative effects in crop production and water productivity. These results also, indicate that knowledge in proper crop production, to most farmers, is still low.

Table 53: Maize plant population used by farmers

Plant population (plants/ha)	Frequency	Percentage
37 037	2	5.4
44 444	5	13.5
53 333	2	5.4
55 556	2	5.4
74 074	8	21.6
88 889	3	8.1
111 111	13	35.1
148 148	1	2.7
166 667	1	2.7
Total	37	100

The study shows that 77.8% of the farmers planted beans in their farms randomly (Table 54). Majority of them planted one seed per hole while few planted two seeds per hole (Table 55). Field observations revealed that most farmers' bean fields were over populated. Only 25% of farmers planted beans correctly at a spacing of 10 cm by 50 cm, and used one or two seed(s) per hole (Table 56). The spacing of 10 cm by 50 cm is recommended for beans production (UAC, 2002). Over plant population in beans production makes lower leaves to act as sinks as they are denied the ability to produce

their own food due to lack of exposure to sunlight. There are chances that this tendency may lower crop yields and consequently water productivity.

Table 54: Type of planting (beans)

Type of planting	Frequency	Percentage
randomly	14	77.8
rows	4	22.2
Total	18	100

Table 55: Number of seeds per hole (beans)

Number of seeds planted per hole	Frequency	Percentage
1	3	60.0
2	2	40.0
Total	5	100

Table 56: Plant spacing (beans)

Plant spacing	Frequency	Percentage
20×20	1	25.0
10×40	1	25.0
15×15	1	25.0
10×50	1	25.0
Total	4	100

4.5.5 Weeding

The current study showed that weeding was a common practice in the area. However, differences in timing of weeding of maize or beans were apparent. Results show that most of the farmers who weeded their farms did so after three weeks for maize and after four weeks for beans. This suggests that weeding in beans fields was done later than in maize fields. Table 57 shows that, 47.5% of weeding in maize was done after three weeks, while

32.0% of weeding in beans was done after four weeks (Table 58). Apart from these results, majority of the farmers who grew beans did not weed their farms. Bisanda *et al.* (1998); Nkonya *et al.* (1998) reported farmers to weed maize farms for instance twice. The first weeding is usually done between second and third week depending on level of grasses in farm and time availability. Farmers weed their farms to reduce competition between crops and weeds for moisture, nutrients and light.

Majority of respondents (36%) and FGDs reported that they did not weed bean farms. The main reason provided was that there are low or no infestation of weeds. This normally involved beans, which were planted between March and May, and were irrigated. Usually, beans grown around this period did not face excessive weed infestation. Those farmers, who faced weed problems, weeded their beans farms once after two to four weeks.

Table 57: Maize weeding

When do you weed maize	Frequency	Percentage
after two weeks	10	25.0
after three weeks	19	47.5
after four weeks	11	27.5
Total	40	100

Table 58: Beans weeding

When do you weed beans	Frequency	Percentage
after two weeks	4	16.0
after three weeks	4	16.0
after four weeks	8	32.0
no weeding	9	36.0
Total	25	100

Weed infestation if not controlled, may cause significant reduction in crop yields and water productivity. Weeding is one of the important agronomic practices in maize and beans production as inefficient weed control causes low average yields in East Africa (Acland, 1977). Weed can cause yield reduction of up to 30 to 100% (Bisanda *et al.*, (1998)). Some farmers due to different reasons fail to control weeds in their farms in time or completely leading to lowering of yields. Some farmers due to having different commitments in other agricultural activities fail to weed their crops. Since the crop had already spent some amount of water during its early stages of its growth, then this lead into failure in getting the targeted yield resulting into low crop and water productivity.

4.5.6 Fertilizer application

About 97.4% of respondents used fertilizers in crop production (Table 59). Only a small percentage indicated not to use fertilizer in maize production. This suggests that most farmers know the importance of applying fertilizers in their farms. The common types of fertilizers used for maize production were mentioned to be Urea, CAN and SA. Others were TSP, DAP and organic manures. Farmers mainly top dressed their maize but they commonly did not use TSP and DAP even though MAC (1998) recommended 46 kg P_2O_5 /ha to be used in this area. The average rate of fertilizers used in maize production by these farmers is 43.9 kg N/ha ranging from 11.75 to 115 kg N/ha (Table 60). This rate is lower than 65 kg N/ha recommended to be used in the scheme (MAC, 1998).

Table 59: Application of fertilizer in maize

Do you apply fertilizer to your crops?	Frequency	Percentage
yes	38	97.4
no	1	2.6
Total	40	100

Table 60: Amount of fertilizer applied as top dressing

Amount of fertilizers applied as top dressing	Minimum	Maximum	Mean
Fertilizer rate (kg of N / ha)	11.75	115.00	43.9

The main reason for not using the required rates from farmers' point of view was mainly due to exorbitant prices of the fertilizers. It was also observed that some farmers applied these fertilizers at a wrong time. Lack of knowledge in fertilizer use was another problem farmers faced in agricultural production. In regard to time of fertilizers application into their farms, there was no consistency in their responses. Table 61 and 62 show different responses given by the respondents on time they apply fertilizer in their farms. This implies that farmers did not have enough knowledge on the proper use of fertilizer in their farms. Improper fertilizer utilization has a negative effect in crop production and in water productivity. Oweis and Hachum (2003) reported that optimizing fertilizer use increases water productivity. Right fertilizer application was found to increase yields significantly in a study carried in Machakos Kenya (Rao and Okwach, 2005).

Table 61: Time of fertilizer application in maize (top dressing)

Time of fertilizer top dressing	Frequency	Percentage
after one week	1	2.9
after three weeks	7	20.6
after four weeks	10	29.4
after five weeks	5	14.7
after six weeks	1	2.9
after seven weeks	8	23.5
near tasseling stage	1	2.9
after eight weeks	1	2.9
Total	34	100

Table 62: Time of fertilizers application in maize (basal application)

Time of application of DAP and TSP	Frequency	Percentage
during planting	4	57.1
two weeks after planting	2	28.6
during tasseling stage	1	14.3
Total	7	100

Most farmers did not even know that Urea, CAN and SA have different nutrient contents. Poor economic status facing farmers affects their use of fertilizers in their crop production. Bisanda *et al.* (1998) also, reported that fertilizer use is positively related to wealth. Mwangi *et al.* (1999) reported that most farmers use low level of fertilizers while others do not use it at all due to lack of capital. Therefore, low level use of fertilizers due to different reasons has effect on lowering land and water productivity.

4.5.7 Effect of pests and diseases in crop production

Stalk borers (*Busseola fusca*) have been mentioned to be the main insect pest attacking maize in this area. About 72.7% of respondents reported stalk borers to be the major pest in their maize farms (Table 63). Similarly, Acland (1977) and Mwangi *et al.* (1999) explained stalk borers to be the main pest of maize crop in Western Tanzania. Bisanda *et al.* (1998) also reported that stalk borers were the most serious pests of maize in intermediate and highland zones. Other insect pests reported by the respondents were army worms (*Spodoptera exempta*), cutworms and termites. Army worms, cutworms and termites have been reported to have little effects than stalk borers. However, the majority (90.4) of the farmers do apply insecticides to control maize pests (Table 64).

Table 63: Common pests of maize

Common insect pest of maize	Frequency	Percentage
stalk borer	24	72.7
cutworms	2	6.1
army worm	6	18.2
termites	1	3.0
Total	33	100

Table 64: Remedial measures taken against maize insect pest

Remedial measures taken against maize insect pest	Frequency	Percentage
apply chemicals	19	90.4
killing mechanically	1	4.8
no measures taken	1	4.8
Total	21	100

Maize streak (a viral disease) was reported by all respondents to be the main disease, which attacks their maize, especially during dry season (Table 65). Similarly, Bisanda *et al.* (1998) found maize streak to be the main maize disease in the intermediate and highland zones. The disease causes big losses to farmers. Some farmers have reported to get a total crop failure. In FGDs farmers reported the disease to be critical in Igomelo irrigation scheme in Igawa where its infection was found to be more critical than that faced in Majenje area. Some (45.4%) farmers reported to use resistant varieties while others (27.3%) uprooted the infected plants to manage the disease (Table 66). About 27.3% of respondents reported not to take any remedial measure on the problem due to lack of knowledge.

Table 65: Common diseases of maize

Common diseases of maize	Frequency	Percentage
maize streak	21	100.0

Table 66: Remedial measures taken against maize diseases

Remedial measures taken against maize diseases	Frequency	Percentage
rogging of infected plants	3	27.3
plant resistant seeds	5	45.4
no measure taken	3	27.3
Total	11	100

Aphids (*Aphis fabae*) were reported by 85.7% of respondents to be the main pests of beans (Table 67). Similarly, Acland (1977) mentioned aphids to be one of the major pests of beans in East Africa. FGDs revealed that late planted beans were mostly affected. Beans in this area were said to be commonly planted between March and May. Between August and October beans were planted on small scale. During this period the effects of aphids was minimal. Under irrigation farmers can plant beans at any time provided they are prepared to use pesticide to control aphids. About 100% of farmers reported that the main remedial measure to the problem is to apply insecticides (Table 68).

Crop pests seem to have big effects on crop yield (Bisanda *et al.*, 1998) and as well as water productivity. In order to get good yield and high water productivity, crop protection against insect pests and diseases is a prerequisite.

Table 67: Common pests of beans

Common pest of beans	Frequency	Percentage
aphids	6	85.7
bean beetles	1	14.3
Total	7	100

Table 68: Remedial measures taken against beans insect pest

Remedial measures taken against beans insect pest	Frequency	Percentage
apply chemical	6	100.0

4.5.8 Farmers' knowledge in water productivity

About 66.7% reported that they had heard about water productivity, while the rest (33.3%) said they had never heard about water productivity (Table 69). However, majority defined water productivity as “use of the right amount of water to crops without wastage”. This definition does not directly associate the amount of yield obtained with the amount of water used to produce it. Kasele (2004) reported that about 87.7% of the smallholder farmers indicated low awareness on the concept of water productivity as universally defined. This implies that these farmers have little knowledge on water productivity.

Table 69: Understanding of water productivity

Have you ever heard anything about water productivity?	Frequency	Percentage
yes	26	66.7
no	13	33.3
Total	39	100

About 92.5% of farmers reported that they did not measure water when they irrigated their crops (Table 70). Few farmers who claimed to measure irrigation water, failed to mention the types of instruments they used to measure water, and instead they revealed that estimation of amount of water used was the common practice. This suggests that there were no formal water measurements done by the farmers, when applying water in their farms. Tarimo *et al.* (2004) and Mkoga *et al.* (2005) too explained that no formal irrigation water measurements were done by farmers. Water measurement is not done even at the scheme level. FGDs showed that water levels were just controlled at a specified level for the purpose of coping up with the maximum limit of water withdraws governed by the water right. It was learnt that, even the flume constructed at the abstraction point in the irrigation scheme was not calibrated for use. Lack of data of water used in crop production hindered the direct determination of water productivity.

Table 70: Measurement of volume of water used for irrigation

Do you measure volume of water when irrigating?	Frequency	Percentage
yes	3	7.5
no	37	92.5
Total	40	100

4.5.9 Irrigation and irrigation interval (maize and beans)

Majority of farmers (92%) showed that they practised irrigation water scheduling in their irrigation scheme (Table 71). Most respondents (87.5%) irrigated maize once a week (Table 72). Others irrigated everyday (6.3%), after two weeks (3.1%) and after ten days (3.1%).

Table 71: Irrigation schedules used by farmers

Do you have irrigation schedule in your irrigation scheme?	Frequency	Percentage
yes	36	92
no	3	8.0
Total	39	100

Table 72: Irrigation interval used in maize production

Irrigation interval of maize	Frequency	Percentage
once per week	28	87.5
once in two weeks	1	3.1
every day	2	6.3
once in ten days	1	3.1
Total	32	100

About 40% of bean growers irrigated once a week, 20% every two weeks, 13.3% after 4 days, and 13.3% each day, 6.7% after 3 days and 6.7% after 5 days (Table 73). This shows that there is no uniform irrigation interval. This means that some of the farmers were over irrigating while others probably subjected their crops to moisture stress. For both case may have some effects on crop yield and thus, water productivity. During data collection, one farmer said that he had changed the irrigation interval for maize from seven days commonly used to ten days irrigation interval. This farmer further pointed out that the use of ten days irrigation interval had increased maize yield even though it was not specified by how much. Apart from over supplying water to the crop and lowering water productivity through leaching of nutrients also impedes soil aeration (Oweis and Hachum, 2003). Short irrigation intervals apart from over supplying water also, consume farmers' time that could otherwise be used for other beneficial activities. It is plausible that application of water to satisfy less than the full water requirement through manipulation of

irrigation intervals might increase water productivity and spare some amount of water for irrigating new land or for other uses.

Table 73: Irrigation interval used in beans production

Irrigation interval used in beans production	Frequency	Percentage
once per week	6	40.0
once in two weeks	3	20.0
after four days	2	13.3
after three days	1	6.7
each day	2	13.3
five days	1	6.7
Total	15	100

4.5.10 Causes of over irrigation

About 54.1% of respondents pointed out that the major causes of over use of irrigation water was the habit of farmers, especially those at the upstream of the irrigation canal or river to divert water for irrigation beyond their need (Table 74). This tendency was said to be due to greediness in Swahili "*Uchoyo*" resulting in over irrigating their farms. About 21.6% of respondent's made small furrows or small basin bunds, which, broke and lose a lot of water. Other causes mentioned were making small size of field supply canals, seepage losses in conveyance canals, lack of knowledge in water use and shortage of labour during water application in the field. Most of the above reasons resulted in over use of water. Oweis and Hachum (2003) have reported that applying too much water to land causes a host of adverse effects such as building up of salinity if drainage is poor, decline in crop yield due to aeration problems, loss of nutrients, energy and water wastage.

Table 74: Causes of over use of water for irrigation

Common cause of over use of water for irrigation	Frequency	Percentage
breaking of small furrows and basins (due to poor furrow and basin preparation in field)	8	21.6
breaking of small size of supply canals in field	2	5.4
diverting too much water beyond their controlled	20	54.1
labour shortages during water application	1	2.7
conveyance losses	2	5.4
lack of knowledge in water use	2	5.4
others	2	5.4
Total	37	100

4.5.11 Availability of water for irrigation

Table 75 shows that about 89.7% of respondents experienced critical water shortages in their area. Majority (47.4%) of them commonly experienced water shortage between September and December (Table 76). During this period of water shortages farmers reduced irrigated farm size to minimize risk of losing their crops (Table 77). Key informant interviews showed that coping strategies taken by the farmers included, extending irrigation intervals, practising irrigation water rotation and sometimes doing other activities outside irrigation. Respondents and FGDs members indicated that water shortages in a certain period of time caused total crop loss or reduction of irrigated area. It has been explained that moisture availability to the growing crops is the most significant single factor limiting crop production (Oweis and Hachum, 2003). Oweis and Hachum (2003) suggested that the use of technologies, which improve yields and water productivity can double the amount of crops produced from the present water resource. To cope with low availability of water for irrigation in the scheme, farmers were advised by District Irrigation Officer to use one area to reduce water movement and reduce area under irrigation especially during dry season to match with the available amount of water, but

farmers did not accept to do so. This was reported in FGDs. It was observed that growing crops in scattered plots during dry period caused high delivery water losses which eventually affected crop yields and water productivity. For instance, field observations revealed that, some farmers totally lost their crops due to water scarcity. Water scarcity influences reduction in yield and water productivity if moisture stress surpasses crop tolerable level. Poor access to water for irrigation has been found to be among the leading factors hindering sustainable development in semi-arid and arid regions (Hatibu, 2002). Therefore, availability of water for irrigation has some influence on crop production and water productivity.

Table 75: Availability of water for irrigation

Do you experience critical irrigation water shortages?	Frequency	Percentage
yes	35	89.7
no	4	10.3
Total	39	100

Table 76: Months with critical water for irrigation shortage

Months with critical water for irrigation shortage?	Frequency	Percentage
November-December	2	5.3
August-November	2	5.3
November-January	1	2.6
October-November	6	15.8
August-October	2	5.3
September-December	18	47.4
July-December	1	2.6
August-December	1	2.6
September-November	3	7.8
July-November	2	5.3
Total	38	100

Table 77: Remedial measures taken against water shortage

What do you do when there is water shortage?	Frequency	Percentage
extend irrigation interval	4	10.6
reduce area under irrigation	20	52.6
do other activities	3	7.9
water rotation	1	2.6
others	10	26.3
Total	38	100

4.5.12 Farmers' perception on water use

Farmers were tested for their perception on matters related to water use. They were required to respond whether they agree, are neutral or disagree with the four statements (Table 78). About 85% of respondents disagreed with the statement “when water is plenty in the river a farmer can apply any amount of water in his/her farm”. Majority (92.5%) of respondents disagreed with the second statement “water is a gift from God so therefore, it can be used anyhow without taking any conservation measures”. In regard to the statement “applying a lot of water to the crop gives more yield than applying just what is required by the crop”, majority (90%) disagreed with the statement. In the last statement, 100% disagreed with the statement saying “canal dirtiness has no effect on water availability to the farmer”.

Basing on the index (Table 78), it can be generalized that 91.9% of respondents disagreed with all the statements which were designed to test farmers' perception on water misuse. The high percentage of disagreement with the four statements suggests that farmers have positive perception on proper water utilization and canal cleanliness. It is therefore plausible that farmers upon close follow up can attain efficient water utilization.

Table 78: Farmers' perception on water use

Variable: Farmers' perception on water use (N =40)	Agree		Uncertain		Disagree	
	Freq.	%	Freq.	%	Freq.	%
when water is plenty in the river a farmer can apply any amount of water in his/her farm	3	7.5	3	7.5	34	85.0
water is a gift from God so therefore it can be used anyhow without taking any conservation measures	3	7.5	0	0	37	92.5
applying a lot of water to the crop gives more yield than applying just what is required by the crop.	2	5	2	5	36	90.0
canal dirtiness have no effect on water availability to the farmer	0	0	0	0	40	100.0
Overall: index		5		3.1		91.9

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Overview

The main objective of the study was to investigate factors affecting water productivity in FMIS in order to suggest strategies for enhancing water productivity in agriculture. This chapter presents conclusion, and recommendations for policy formulation, community livelihood improvement and suggestions for further research.

5.2 Conclusions

Findings indicated that, water productivity in farmers' field is still low for maize (0.26-0.76 kg/m³). In this study, factors that affected water productivity in farmer managed irrigation schemes were investigated and several socio-economic, institutional, and technical factors have been found to have contributed to this.

- i. Under socio-economic factors, low income, low crop yield, food insecurity, source of energy for cooking, ownership of assets, quality of houses owned by farmers, gender division of labour, poor accessibility to domestic water and low yields were found to contribute to low water productivity in farmer managed irrigation schemes.
- ii. The technical factors together with other things included, lack of technical knowledge associated with limited accessibility to extension services.
- iii. In regard to institutional factors, insufficient collaboration between District and Zonal Irrigation Unit in enhancement of crop production, low market of agricultural products accompanied with lack of processing industries to add value of crops also contributes to low water productivity.

- iv. However, results from the experimental plots show that there is still a high potential for improving water productivity in farmer managed irrigation schemes.

5.3 Recommendations

The study recommends the following:

- i. Emphasis should be made on the use of improved seed varieties, promote good crop markets (an incentive to farmer) and to promote efficient water use;
- ii. Government and other stakeholders should assist food crop producers to get good crop prices an incentive to enhance crop production and water productivity.
- iii. Policies which promote price support on farm commodities should be formulated and implemented to encourage farmers to increase yield and water productivity through inputs use and land improvement;
- iv. Investment in agricultural research aimed at promotion of improved crop production and water productivity should be advocated;
- v. Government and its partners should ensure availability of extension services in irrigation schemes and rain-fed agriculture in order to impart knowledge to farmers for enhancement of both crop yield and water productivity;
- vi. Irrigators' associations should be further strengthened and closely supervised in order to promote efficient use of water for irrigation and make sure that all land for irrigation is used properly by the farmers in crop production to avoid unnecessary water losses and other losses which influence yield and water productivity;
- vii. Districts in collaboration with Zonal Irrigation Unit on behalf of the Ministry of Water and Irrigation should work closely with all irrigation schemes to make sure that farmers produce accordingly and use water efficiently in order for

these irrigation schemes to contribute significantly in improving farmers' livelihoods, poverty alleviation, promotion of food security at household level and nation at large;

- viii. Promotion of use of available water saving technologies in irrigation should be emphasised in order to use water efficiently whenever possible as the competition for this resource among different sectors is increasing daily;
- ix. Investment in storage dams and exploration of other water sources are prerequisite to improve food production, enhancement of community livelihood and poverty reduction as well as rendering water availability to other sectors; and
- x. More studies on the subject are required to be done in other parts of the sub-catchment and country at large to allow more precise generalization of the observations.

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APPENDICES

Appendix 1: Household questionnaire

SOKOINE UNIVERSITY OF AGRICULTURE

**QUESTIONNAIRE FOR RESEARCH ON WATER PRODUCTIVITY IN
FARMER-MANAGED IRRIGATION SCHEMES: A CASE STUDY OF RUANDA-
MAJENJE IRRIGATION SCHEMES**

Good morning/afternoon,

My name is....., from Sokoine University of Agriculture, Morogoro. In collaboration with Mbarali District Council, we are carrying out a study in the district to determine factors affecting water productivity in farmer-managed irrigation schemes in the district; your household has been selected randomly among others from which data will be collected. All the information will be treated confidentially and therefore you are requested to be free to give any information that will be requested.

Section a: Questionnaire identification

Date of interview.
 Name of respondent.....
 Name of ward.....
 Name of village.....
 Name of irrigation scheme.....
 Name of interviewer.....

Section b: Background and socio-economic information

1. Sex of head of household

1. Male.....2. Female.....[]

2. How old are you?

3. In which ethnic group do you belong?
 1=Kinga 2=Wanji 3=Bena 4=Nyakyusa.....[.....]
 5=Others (Specify).....
4. What is your marital status?
 1=Single.....2=Married.....3=Widower.....4=Separated.....[]
5. What is your highest level of formal education attained?
 1= Primary education 2= Ordinary level education
 3=A level education.....[]
 4=others (specify).....
6. What is your main occupation?
 1= Only a farmer.....[]
 2= A farmer and businessperson.....[]
 3= A farmer and animal keeper.....[]
 4= A farmer and a worker.....[]
 5= Others (Specify).....[]
7. What is your main source of income and means of living?
 1=Food crop production.....[]
 2=Livestock production.....[]
 3=Vegetable production.....[]
 4=Others (Specify).....[]
8. What is your average household income per month? Tshs.....
9. Does this house belong to you?
 1=Yes.....2=No.....[]
10. What kind of material has been used for walls of your house?
 1=Burnt bricks.....[]
 2=Unburnt bricks.....[]

- 3=Cement bricks.....[]
- 4=Mud.....[]
- 5=Others (specify).....[]
11. What kind of materials used for roofing?
- 1=Tin.....[]
- 2=Corrugated iron sheets.....[]
- 3=Grasses.....[]
- 4=Others (specify).....[]
12. What kind of material used for floor of your main house?
- 1=Cement[]
- 2=Mud.....[]
- 3=Floor tiles.....[]
- 4=Others (specify).....[]
13. What is the main source of energy for cooking used by your household?
- 1=Firewood 2=Charcoal 3=Kerosene
- 4=Electricity 5=Gas.....[]
- 6=Others (specify).....
14. What is the main source of water for domestic purpose in your household?
- 1=Piped into a household 2=Piped into a yard of a house.....[]
- 3=Public tap 4=Irrigation canal
- 6=Others (specify).....

Number of Livestock

Livestock Type	Number Now	Number Years ago	Number Bom	Number Bought	Number Sold	Number Gift In	Number Gift Out	Number Eaten (at home)	Current Price
Cattle									
Goats									
Pigs									
Sheep									
Chicken									

Section c: Labour availability

17. Provide numbers of the following age groups in your household

S/No.	Household group	Total number	Number of those who provide labour at the HH
1	Infants 0-4 years old		
2	Children 5-14 years old		
3	Adult male 15-64 years old		
4	Age of a farther		
5	Adult female 15-64 years old (excluding a mother)		
6	Age of a mother		
7	Over 64 years old		
6	Total household size		

18. Is there any period with critical labour demand in crop production under irrigation?

1=Yes.....2=No.....[]

19. If yes, mention month(s) with critical labour demand

(1).....(2).....(3).....(4).....

20. Is your family labour able to accomplish all your irrigated farming activities during critical labour period?

1=Yes.....2=No.....[]

21. If no, indicate strategies used to solve this problem of labour.
- 1= Hire labour.....[]
- 2= Use communal labour.....[]
- 3=Leave some planted area unattended.....[]
- 4=Increase working hours (give number of working hours increased)
- 5=Others (Specify).....
22. Do you think labour deficit have effect in proper water application in field?
- 1=Yes.....2=No.....[]
23. If yes, what are the effects?
- 1.....

Section d: Land use and land ownership

24. For how long have you been practicing irrigated agriculture?..... (years).
25. What is the total land for irrigation owned by your household?.....(acres)
26. What size of land your household has been able to put under irrigation (during dry season) in past three years 2004.....(acre) 2005.....(acre)
- 2006.....(acre).
27. Is your area under irrigation has increased over the past 3 years?
- 1= Increased from.....acres to.....acres
28. If area under irrigation has increased give reasons that have influenced your household to increase acreages.
-
29. If area under irrigation has decreased, what are the reasons that have influenced your household to decrease the acreage?
- (1) Water shortages.....[]
- (2) Lack of capital.....[]
- (3) Low crop prices.....[]
- (4) Unavailability of inputs.....[]

(4) Lack of good crop market.....[]

Section c: Household food security

30. Do you produce enough food to sustain the household for the whole year?

1=Yes.....2=No.....[]

31. If not, what is the main reason for not producing enough food to meet your household needs for the whole year? (Only one answer is needed).

1= Shortage of land.....[]

2= Insufficient irrigation water.....[]

3= Shortage of labour.....[]

4=Lack of knowledge in crop production.....[]

6=Low soil fertility.....[]

7= Lack of capital to buy inputs.....[]

8= Unaffordable high prices of inputs (e.g. fertilizers)..... []

9=Low product prices.....[]

10=Others (Specify).....

32. In which months in a year, your household commonly faces food shortages?

(from)(to).....

33. What are the coping strategies usually taken on food shortages?

No.	Strategies for solving seasonal food shortages	Rank the strategy 1=most important
1	Use previous own money savings	
2	Sell livestock or other assets	
3	Do petty business	
4	Sell labour to other farmers	
5	Get assistance from relatives (remittance)	
6	Reduce number of meals from two to one meal per day	
7	Go to other areas (e.g. towns) to seek for employment	
8	Others (Specify)	

Section f: Agronomic practices and extension services

34. How many times have you managed to meet with an agricultural extension worker(s) for advise in 2005/2006 season?.....times.
35. What new message did he/she give you?
- 1= Proper crop production.....[]
- 2= Proper water management.....[]
- 3= Proper operation and maintenance of irrigation scheme.....[]
- 4= Participation in irrigation scheme leadership.....[]
- 5= Others (Specify).....
36. Have you ever attended any training related with your irrigation scheme's activities?
- 1= Yes.....2= No.....[]
37. If yes, the training was about what?.....
38. If no, what do you suggest should be done in future?
.....
39. Is the knowledge you have in irrigated agriculture satisfactory?
- 1= It is satisfactory.....[]
- 2= It is not satisfactory.....[]
40. If not satisfactory, what is your suggestion on this?
.....
41. Where do you get seeds for your crop production?
- 1= Input dealers.....[]
- 2= Sort seeds from my previous harvest.....[]
- 3= From my friend's harvest.....[]
- 4= Others (specify).....

42. What are the varieties of seeds you used in this season?

1. Maize.....2. Beans.....

43. How did you plant your crops?

Crop	Type of planting (Randomly or in row)	Spacing (cm)	Seeds per hole
Maize	X.....	
Beans	X.....	

44. When do you weed your maize crop after planting?

1= after one week.....[]

2= after two weeks.....[]

3= after three weeks..... []

4= after four weeks.....[]

5= others (specify).....

45. When do you weed your beans crop after planting?

1= after one week.....[]

2= after two weeks.....[]

3= after three weeks.....[]

4= after four weeks.....[]

5= Others (specify).....

46. Do you apply fertilizer in your crop production?

1=Yes.....2= No.....[]

47. If yes, what type and fertilizer rates you used this season?

Crop	DAP (kg/ha)	TSP (kg/ha)	SA (kg/ha)	UREA (kg/ha)	CAN (kg/ha)	Organic Manure (ton/ha)
Maize						
Beans						

48. When do you apply fertilizers to your crops (after planting)?

Crop	Basal application	Top dressing	
		First application	Second application
Maize			
Beans			

49. What are common major pests that affect your crop production?

Crop	Kind of a pest		Remedial measure taken by a farmer
Maize	Insect(s)		
	Disease(s)		
Beans	Insect(s)		
	Disease(s)		

Section g: Farmers' organization

50. Does your irrigation scheme have farmer's organization?

1= Yes.....2= No.....[]

51. If yes, what kind of farmers' organization operates your irrigation scheme?

1= Water users association.....[]

2= Cooperative society.....[]

3= Irrigation committee.....[]

4=others (Specify).....

52. Are you a member of the farmers' organization?

1= Yes.....2=No.....[]

53. If yes, what made you to be a member?

1= willingly joined.....[]

2= it is compulsory once you have a farm in the scheme.....[]

- 54. What are the major roles of your farmers' organization?.....[]
(a).....
(b).....
- 55. Do you think your farmer's organization accomplishes its duty accordingly?
1= Yes.....2= No.....[]
- 56. If no, what do you think is the main reasons of failure to do so?
.....
- 57. Are there any by-laws governing your irrigation scheme?
1=Yes.....2=No.....[]
- 58. If ycs, are the bylaws followed by all scheme members?
1= Yes.....2= No.....[]
- 59. If no, what do you think is the major reason that makes them not to be followed?
.....
- 60. Do you think the bylaws are strong enough to maintain discipline in all aspects of scheme operation and maintenance (i.e. water sharing, canal cleaning, following cropping calendars etc.) in your irrigation scheme?
1= Yes.....2= No.....[]
- 61. If no, what are your suggestions on what should be done to improve the situation?
.....

Section h: Irrigation water utilization

- 62. Have you ever heard anything about water productivity?
1=Yes.....2=No.....[]
- 63. If yes, can you define it?
.....

64 Do you practice irrigation water scheduling in your irrigation scheme?
 1= Yes2= No.....[]

65. After how many days do you irrigate the following crops?
 1= Maize.....days 2= Beans.....days.

66. Please for each of the following statement say whether you strongly agree (SA), agree (A), undecided (U), disagree (D) or strongly disagree (SD).

	Statement: Farmers perception on water use	SA	A	U	D	SD
1.	When water is plenty in the river a farmer can apply any amount of water in his farm	1	2	3	4	5
2.	Water is a gift from God so therefore it can be used anyhow without taking any conservation measures.	1	2	3	4	5
3.	Applying a lot of water to the crop gives more yield than applying just what is required by the crop	1	2	3	4	5
4.	Canal dirtiness have no effect on water availability to the farms	1	2	3	4	5

67. Do you measure the volume of water you use for irrigation?
 1= Yes.....2= No.....[]

68. If yes, what method do you use to measure the volume of water?
 1= Cutthroat flume.....2= Float method.....Others (Specify).....[]

69. What is the common cause of overuse of irrigation water in your field?
 1= breaking of small furrows and bunds.....[]
 2= Small size of supply canals in field.....[]
 3= Diverting too much water to be controlled.....[]
 4= Labour shortage during water application in field.....[]
 5= Conveyance losses.....[]

70. During your production cycle do you experience critical water shortage?
1= Yes.....2= No.....[]

71. If yes, what are the effects to your crop production?
.....

72. In which months do you experience critical water shortages?.....

73. What coping strategies do you use during this period of water scarcity?
1= extend irrigation intervals.....[]
2= reduce area under irrigation.....[]
3= do other activities which do not involve use of water..... []
4= Others (specify).....

Section I: Credit services

74. Does anyone in this household belong to any credit provider group?
1=Yes.....2=No.....[]

75. If yes, in what credit scheme?.....

76. What was the last amount borrowed?.....

77. What was the purpose of borrowing it?.....

78. If no one has borrowed money what is the main reason that hinder you from borrowing?
.....

Appendix 2: Checklist for key informants

(Farmers' leaders, Extension officers, ZIE, DALDO and DIO)

The following are general questions for key informants. Each key informant will be only asked the relevant questions. Some of questions will emanate from the dialogue and from respondents questionnaires' responses requiring clarification from key informants.

1. For how long have you been in this irrigation scheme?
2. Do you know when this scheme started?
3. Who first initiated the scheme?
4. What was the aim of initiation of this scheme?
5. What was its general performance before improvement?
6. Was the area used for irrigation before intervention?
7. What were the major problems faced before the rehabilitation?
8. What were the aims of undertaking the scheme rehabilitation?
9. When the rehabilitation started and ended?
10. What kind of extension services have (you) been providing to the farmers in the scheme?
11. Who else have provided extension services to farmers within 3 years?
12. What are your views on the way farmers apply the knowledge provided?
13. What is the trend of irrigation water availability?
14. What do you think are factors, which affect water productivity in the scheme?
Examine: (i) Socio-economic factors, (ii) Institutional factors (iii) Technical factors and others if any.
15. What do you suggest should be done to improve the situation? (For Qn. 14)
16. What is your opinion on the current crop production and its trends? (Whether yield is increasing or declining).
17. What is your opinion on the current water use and its trends?

Appendix 3: Gross water productivity in kg/cubic meter of maize (irrigation interval)

ANOVA table					
Source	df	SS	MS	F-Value	P>F
Model	3	0.018 691 67	0.006 230 56	19.17	0.000 5
Error	8	0.002 600 00	0.000 325 00		
Corrected total	11	0.021 291 67			

Appendix 4: Gross water productivity and maize yield separation of means (irrigation interval)

Irrigation interval (days)	Yield (kg/10.5m ²)	Gross water productivity			
		IWA (m ³)	RWA (m ³)	WA (m ³)	GWP (kg/ m ³)
7	6.15 ^B	1.47	8.45	9.92	0.62 ^B
8	5.90 ^B	1.25	8.45	9.70	0.61 ^B
9	6.70 ^A	1.25	8.45	9.70	0.69 ^A
10	6.54 ^A	0.96	8.45	9.40	0.70 ^A

Means with the same letter are not significantly different at 0.05 levels

IWA=Irrigation water applied

RWA-Rain water applied

WA= Water applied

GWP=Gross water productivity

Appendix 5: Gross water productivity and beans yield separation of means (irrigation interval)

Irrigation interval (days)	Yield (kg/10.5m ²)	Gross water productivity			
		IWA (m ³)	RWA (m ³)	WA (m ³)	GWP (kg/ m ³)
7	1.48 ^A	1.69	2.20	3.89	0.38 ^A
8	1.52 ^A	1.47	2.20	3.67	0.41 ^A
9	1.17 ^A	1.47	2.20	3.67	0.32 ^A
10	1.13 ^A	1.029	2.20	3.23	0.35 ^A

Means with the same letter are not significantly different at 0.05 levels

IWA=Irrigation water applied

RWA=Rain water applied

WA= Water applied

GWP=Gross water productivity

Appendix 6: Gross water productivity and maize yield separation of means (moisture depletion level)

Moisture depletion level (%)	Yield (kg/10.5)	N	Irrigation water applied (m ³)	Water applied by rain (m ³)	Total water supplied (m ³)	GWP (kg/ m)
40%	6.19 ^A	4	1.10	9.23	10.34	0.60 ^A
50%	6.52 ^A	4	1.10	9.23	10.34	0.63 ^A
60%	6.40 ^A	4	0.88	9.23	10.11	0.63 ^A

Means with the same letter are not significantly different at 0.05 level

Appendix 7: Age of respondents in group

Age of respondents in group (in years)	Frequency	Percentage
25 -35	5	12.5
36 – 45	21	52.5
46 – 55	9	22.5
56 – 65	4	10.0
above 65	1	2.5
Total	40	100

Appendix 8: Influence of age (in groups) in amount of maize produced

Age of respondents in group	Maize yield (t/ha)					
	0 -1.0 t/ha	1.1-2.0 t/ha	2.1-3.0 t/ha	3.1-4.0 t/ha	4.1-5.0 t/ha	above 5.1 t/ha
25 -35 years old	1	2	1	1	0	0
36 - 45 years old	2	6	4	5	0	1
46 - 55 years old	1	3	3	1	0	0
56 - 65 years old	1	1	0	1	1	0
Total no. of farmers	5	12	8	8	1	1

Appendix 9: Education level of respondents

Education level	Frequency	Percentage
no formal education	5	12.5
standard 4	1	2.5
standard 8	1	2.5
primary education	32	80.0
ordinary level education	1	2.5
Total	40	100

Appendix 10: Source of water for domestic use

Source of water	Frequency	Percentage
piped into a house	8	20.0
public tap	20	50.0
irrigation canal	7	17.5
others	5	12.5
Total	40	100

Appendix 11: Tendency of irrigated agriculture and its reasons

Tendency of irrigated agriculture	Frequency	Percentage
decreasing	10	29.4
increasing	7	20.6
no change	17	50.0
Total	34	100

Appendix 12: Reasons for no change in area under irrigation

Reason for no change in irrigated area	Frequency	Percentage
water shortages	10	55.6
lack of capital	8	44.4
Total	18	100

Appendix 13: Farmers' organization accomplishment of its responsibilities

Does your farmers' organization accomplish its duties?	Frequency	Percentage
yes	22	71.0
no	9	29.0
Total	31	100