INFLUENCE OF INSTITUTIONAL SET UP ON PERFORMANCE OF TRADITIONAL IRRIGATION SCHEMES. A CASE STUDY OF NYANDIRA WARDS, MVOMERO DISTRICT, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN IRRIGATION ENGINEERING AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

ABSTRACT

This study was conducted in Nyandira ward, Mvomero District, Tanzania to evaluate the influence of institutional set up on performance of traditional irrigation schemes. The study was envisaged to produce knowledge of institutional framework to guide performance of traditional irrigation schemes on efficient use of water resources. GPS reading to digitise the traditional canal, farmer's interview, focus group discussion and V-notch weir for canal flow measurements were used for data collection. Out of twelve traditional canals, four canals namely Fuku, Mbakana Kati, Mzinga and Nyamiseta No. 1 were purposively selected. The data were analysed using descriptive statistics, inferential statistical analysis and content analysis. Results showed that out of 93 interviewed farmers (91.4%) 85 people out of 93 were not aware of the National Water Policy of 2002 whereas only (8.6%) 8 people out 93 were aware of the National Water Policy of 2002. This shows that policies are formed and remain to the management (Decision and Policy makers) while people on the ground who are the actual implementers are not aware of what is going on. The results also showed that the majority of the respondents (93.5%) 87 people out of 93 in the study area were not aware of the Water Resources Management Act of 2009. This implies that the community members do not understand their role in water conservation and management in line with the Water Resources Management Act of 2009. The conveyance efficiency for the four canals, i.e. Fuku, Mbakana Kati, Mzinga and Nyamiseta No. 1 were calculated and found to be 63.05%, 62.74%, 60.89% and 60.5% respectively which is fairly good. But the overall efficiency of 34%, 32%, 33% and 37% for Fuku, Mbakana Kati, Mzinga and Nyamiseta respectively was low due to the fact that canals are unlined.

DECLARATION

I, **Philip Mathew Sumuni**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

13/04/2016

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DEDICATION

This dissertation is dedicated to my father, the late Mathew Sumuni, who laid the foundation of my education and could not live to reap the fruit of his good work. May Almighty God rest his soul in peace Amen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATION AND SYMBOLS

a.m.s.l	above mean sea level
BWB	Basin Water Board
BWO	Basin Water Office
CPR	Common Pool Resources
CWC	Catchment Water Committee
DAICO	District Agricultural, Irrigation and Cooperative Officer.
EWURA	Energy and Water Utility Regulatory Authority
FAO	Food and Agriculture Organisation
FGDs	Focus Group Discussions
FMIS	Farmer Managed Irrigation Scheme
GDP	Gross Domestic Product
GPS	Global Positioning System
GWP	Global Water Partnership
ICID	International Commission on Irrigation and Drainage
ILRI	International Institute for Land Reclamation Improvement
IMT	Irrigation Management Transfer
IO	Irrigators' Organisation
IWRM	Integration Water Resource Management
km	kilometres
LGA	Local Government Authority
MAFCs	Ministry of Agriculture, Food Security and Cooperatives
mm	millimetres
MoW	Ministry of Water
NAWAPO	National Water Policy

NIE	New Institution Economics
NWB	National Water Board
NWSDS	National Water Development Strategy
RB	River Basin
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SCWC	Sub Catchment Water Committee
SMS	Subject Matter Specialist
SPSS	Statistic Package for Social Science
UMADEP	Uluguru Mountain Agriculture Development Programme
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
URT	United Republic of Tanzania
US (SCS)	United States (Soil Conservation Section)
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
WAEO	Ward Agricultural Extension Officer
WEO	Ward Executive Officer
WRBO	Wami Ruvu Basin Office
WRBWB	Wami Ruvu Basin Water Board
WRM	Water Resource Management
WRMA	Water Resources Management Act
WSSD	World Summit and Sustainable Development
WUA	Water User's Association
WUG	Water User Groups
ZIU	Zonal Irrigation Unit

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Agriculture in Tanzania remains the most important economic sector: it contributes 45% of Tanzania's GDP and nearly 30% of its export earnings, while employing over 80% of the nation's work force (URT, 2010). Tanzanian agriculture, which is mostly rainfed, remains susceptible to drought as well as to the inadequate and erratic nature of rainfall. This kind of agriculture is severely constrained by drought, which drastically reduces crop yields (Boesen and Ravnborg, 1993). The Tanzanian Government has identified irrigation farming as one of the strategies for agricultural development (URT, 1997; URT, 2001). Irrigated agriculture protects crops against drought and ensures food security. The largest proportion of the irrigated area (85 000 - 100 000 of 450 000 ha) is farmed by smallholders using diversion furrows (Kaswamila and Masuruli, 2004).

The World Summit on Sustainable Development (WSSD) in 2002 recognized the need for promoting agriculture through Integrated Water Resource Management (IWRM) (Jönch-Clausen, 2004). River Basins (RB) are potential sources of water for human life. The water available is important for agricultural development, maintaining the ecology of the basin and use for domestic purposes. River Basins are also very fertile because flooding which occurs frequently is associated with soil nutrient enrichment due to deposition and nutrient transformation processes (Russell, 1973). Many people depend directly on irrigated agriculture to secure their livelihoods and it is therefore essential to understand local processes of water access and distribution (Johanna and Wirkus, 2010). Since 1980s to date, there have been a number of efforts in Tanzania to promote irrigation farming in River Basins in order to increase food security and alleviate poverty in the country. These efforts concentrated on large-scale irrigation schemes, which were often too mechanized and expensive for most Tanzanian farmers. There is ample evidence that most of these schemes or projects failed partly due to their high management costs, low capacity to manage them and due to related problems such as sedimentation and salinization (Majule and Mwalyosi, 2003).

The total potential area for irrigation development in Tanzania is estimated to be 29.4 million hectares, with varying potential levels. Of this total area, which includes over 450 000 hectares already under agricultural water management, 2.3 million hectares are under high potential, 4.8 million hectares are of medium potential and 22.3 million hectares are of low potential (URT, 2002). Eighty per cent of the irrigated area is under traditional irrigation schemes utilizing surface irrigation methods with low level water use efficiencies (Tarimo *et al.*, 2008). The traditional irrigation systems consists of numerous channels or ditches which convey water from rivers, streams and springs, employing simple and traditional methods (Omari, 1997). These systems have been built with little or no government support. However, a major problem faced by traditional irrigation scheme is that of inequity in water allocation caused by poor hydraulic performance and water management (Chambers, 1998).

In Tanzania irrigated agriculture continues to face increasing challenge to produce more food to feed the growing population in the face of water scarcity - erratic rainfall regimes, increasing competition for water. Literature indicated that the Government is giving increased responsibility to community-based organizations such as villages to manage irrigation schemes (Kadigi *et al.*, 2007). Although water management institutions are dynamic phenomena, particularly in irrigation schemes, they are less explored in Tanzania. Past analysis of irrigation management in Tanzania has focused mainly on assessing the efficiency or profitability of different schemes without much emphasis on institutional factors that guide households' cooperation in collective management (Sokile *et al.*, 2005; Kadigi *et al.*, 2007; Lein and Tagseth, 2009; Leucotere, 2010; Kashaigili *et al.*, 2012). Many scholars argue that institutions are very important to solve irrigation water management problems (North, 1990; Ostrom, 1990; Kramm and Wirkus, 2010).

However, neoclassical economics provided very little insight in understanding institutional development and how a wide diversity of institutional arrangements can be used to improve water allocation in different settings. How to incorporate and sustain institutional innovations to ensure efficient use and management of irrigation water under diverse ecological, economic, social and political constraints is an on-going debate on irrigation water resource development (Saleth and Dinar, 2004). Efficient use and management of irrigation water require clear understanding on how the actual management practices in both traditional and improved farmer managed irrigation schemes (FMIS) are operating. In order to achieve this, a clearer understanding of the dynamics of institutional change including the dynamic between individual choice, collective action in decision making, and how the formal institutions are included or modified or adopted in existing informal institutions is essential (Mehta *et al.*, 1999; Cleaver, 2001; Katani, 2010). Literature on development provides evidence of a continuing effort by economists to obtain a better understanding of the role of institutions in natural resources management including irrigation water (Lam, 1998). The New Institutional Economics paradigm (NIE) provides a flexible framework to understand a wide network of institutions that influence economic behaviour and performance (North, 1990; Lecoutere, 2010; Mbeyale, 2009; Katani, 2010; Msuya, 2010). Unlike neoclassical economics, NIE provides a finer theoretical focus that can be adopted to analyse governing institutions in traditional and FMIS in the study areas.

1.2 Problem Statement and Justification

1.2.1 Problem statement

In rural Tanzania, communities depend significantly on common property resources for irrigation water, fuel wood, grazing land and construction materials. However, most of these resources are exploited on a first come, first-served basis which results in the inefficient utilization of the resources and inequalities in the distribution of benefits to users (Gebremedhin *et al.*, 2002). Common property resources are defined as those resources that are owned and managed by a given community. They are contrasted with open access resource, which have no defined owner (Gebremedhin *et al.*, 2002). The solution to this problem in most developing countries depends not only on appropriate technologies and efficient market prices, but also on local level institutions of resource management and organizations that enforce them. This implies that just establishing the institutional set-up for the resource management is not a sufficient condition for sustainable use of the resources. Effectiveness in internal governance is needed for the effective application of community rules. Therefore, the need to identify factors that facilitate or hinder the development and effectiveness of local formal and informal institutions and organizations becomes important.

Because water as a liquid, is characterized as flowing, seeping, evaporating and transpiring. These attributes cause problems in identifying and measuring there source and also result in interdependencies among water users. Moreover, water supplies are often uncertain and variable. As a result of these attributes, the exclusive property rights which are the basis for an efficient exchange economy are difficult to establish and enforce. Relatively complex legal and administrative systems are needed in water allocation (Young *et al.*, 1986).

In Tanzania, with food production already lagging behind, population growth, inefficient allocation of water for agriculture may worsen the problem of current food insecurity despite the availability a large volume of water in the country. Since 1991, the role of local communities in resource management has been increasing in Tanzania. Locally there are different institutional arrangements for irrigation water management; examples include use of "water masters" and executives of water users' associations. These institutional arrangements and the monitoring and enforcement of the laws and regulations have two implications; production (efficiency) and distributional (equity) dimensions. Water distribution to farmers can be explained based on timeliness and volume. Water available at the wrong time during the production process may be of little value, while water available in time but in lesser volume than needed may not have the desired effect on productivity. Hence, the design of the appropriate water management institutions becomes critical. However, little evidence exists regarding local level institutions and organizations for irrigated water management in Tanzania. More generally, even if there is extensive literature on common property resource management (Bromley, 1987; Ostrom, 1990), further empirical research is required to analyse institutional aspect of the common pool resource and to identify factors associated with collective action effectiveness and failure.

1.2.2 Justification

In Tanzania the water sector is a resource-intensive sector, dominated by engineering concerns. The emphasis is mainly on the construction of physical facilities such as water distribution networks and treatment plants. There is little attention to the institutional and managerial aspects related to operating and using the facilities. Irrigation systems, for example, were often constructed and handed over without even an instruction manual being prepared, much less any training for the operators who then assumed the responsibility for it, nor was there institutional arrangements for their organisation. Throughout the 1990s and 2000s there was a growing concern that in many cases such projects had not been wholly successful, and that they had not often yielded the benefits that were intended for them.

Traditional Irrigation Schemes in Tanzania rely on the run-of-the river abstraction and gravity flows with the irrigation infrastructures in the state of temporal, poorly constructed and thus poses difficulty in water abstraction and overall water management, with low irrigation efficiencies. The schemes have informal institutions, weak and inefficient irrigators' organisations, inadequate skills on operation and maintenance resulting in low water use efficiency as well as inadequate environmental consideration during the planning and implementation stages. This contributes substantially to water losses and overall poor performance of these systems.

Establishing appropriate water management institutions and strengthening capacity of water management organizations could help for efficient and equitable distribution of irrigation water for beneficiaries, thus contributing to increased productivity. Water management institutions are also important to avoid and manage conflicts and ensure the participation of women and the poor.

In this regard, the findings of this study will contribute to narrowing the information gaps regarding the organizational and institutional context, management practices and collective action regarding irrigation water, and the major problems of irrigation development at the grass-root level. It will also shed some light on the problems of management and sustainability of agricultural water use in both areas. Therefore the purpose of this study is to evaluate the influence of institutional set on performance of traditional irrigation schemes in the Wami Ruvu Basin a case study of Nyandira traditional schemes in Morogoro region

1.3 Objectives

1.3.1 Main objective

The overall objective is to evaluate the influence of institutional set up on performance of traditional irrigation schemes. A case study of Nyandira traditional irrigation schemes in Nyandira ward in Mvomero District, Morogoro region – Tanzania.

1.3.2 Specific objectives

Specific objectives include to:

i. Evaluate the roles of Irrigators Association, Water Users Association and Water Basin Office and institutional arrangement underlying the management of the scheme

ii. Evaluate the adequacy of water allocation and water distribution to a small holder irrigation scheme in Nyandira

iii. Evaluate the irrigation scheme's performance in relation to institutional set up.

1.4 Conceptual Framework

The proposed study is conceptually framed based on the assumption that external factors (biophysical- floods, droughts, rainfall and deforestation); socio-economic (population pressure, ethnicity, market and irrigation technologies) have influence on resource, resource users and existing informal and formal water management institutions thus triggering to institutional evolution in irrigation schemes (Figure 1). The forces may result into formation of new institutional arrangements or innovations that may either be a mix of 'formal' and 'informal' aspects or modification of the two institutions. This situation might have either positive or negative effects on agents and agents' collective choices in resource use and state of the resource, of which might affect livelihood outcomes. In this study the livelihood outcomes are measurable against access to resource, crop yield and income earned from sell of irrigated crops and diversity of water related activities. The proposal study will use the concept of institutional bricolage as described by Cleaver (Cleaver, 2002) to conceptualize the institutional development process resulting from the influence of external interventions introduced in the irrigation schemes.

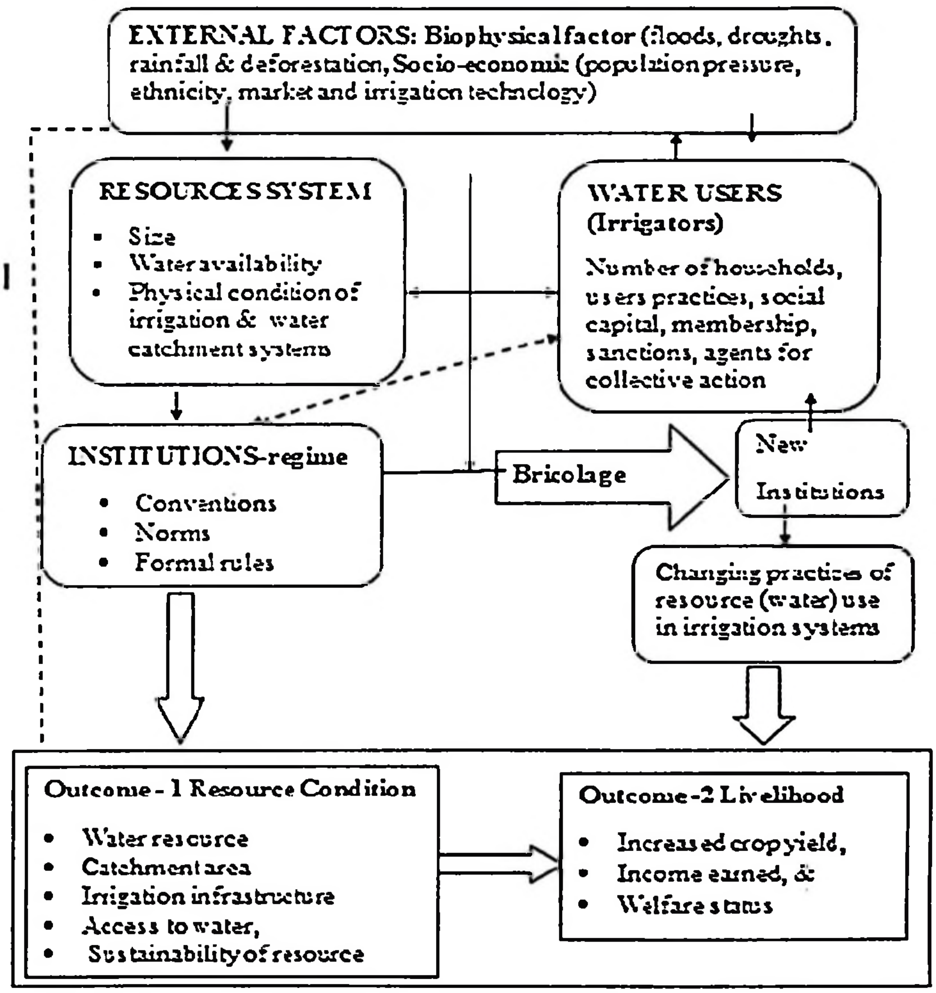

Figure 1: Conceptual framework for institutional and organizational analysis in Social Ecological System in the study areas

(Source: Modified Chambers, R. and Conway, G. (1991)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Basic Concepts of Institutions and Institutional Arrangements

Institutions are basically the established sets of rules derived from a combination of human perceptions and actions. The rules may be in the form of written-down laws, or of norms, conventions and traditional practices accepted by a particular society. (Bandaragoda and Firdousi, 1992).

Institutions are defined as informal and formal organizational arrangements, rules and regulations in a community (Kendie and Guri, 2006). In general, institutions are understood as both enabling in terms of providing people with the rules for action (Mehta *et al.*, 1999). Informal institutions are systems of rules and decision making procedures which have evolved from endogenous socio- cultural codes and give rise to social practices, assign roles to participants and guide interactions among Common Pool Resources (CPRs) users (Appiah-Apoku and Mulamoottil, 1997). Leach *et al.* (1998) reported that institutions are upheld by mutual agreement among the social actors involved, or by relations of power and authority between them. Leach *et al.* (1998) and Smajgl *et al.* (2003) argue that formal institutions may be thought of as rules that require exogenous enforcement by a third- party organization. Often, a general distinction is made between formal and informal institutions. Formal institutions comprise codified and written rules, directives and contracts that are outlined in constitutions, articles of law, company directives, working contracts etc. (North, 1992). They are exercised through organizations, which can be public (the legal system, bureaucratic authorities, political parties, etc.), economic (companies, trade unions, etc) or educational (schools, universities, etc.) (North, 1992) and thus require exogenous enforcement by a third party

(Leach *et al.*, 1997). Informal institutions by contrast subsume (often unexpressed) cultural norms, taboos and values, conventions, customs and practices that are (re) produced by all members of the society (North, 1992). They are considered to be socially embedded. Informal institutions are endogenously enforced; they are upheld by mutual agreement among the social actors involved or by relations of power and authority between them (Leach *et al.*, 1997).

Institutional arrangements are the policies, systems and processes that organizations use to legislate, plan and manage their activities efficiently and to effectively coordinate with others in order to fulfil their mandate (UNDP, 2003). Institutional arrangements determine who has what kind of access and control to which kind of natural resources and what use they can make of such resources (Meynen and Doorenbos, 2004). Institutional arrangements are taken to cover the interrelated set of organisation entities, rules, incentives and cultural practices that affect or influence irrigation development and practice (National Irrigation Policy, 2010).

2.2 Local Water Governance

In the case of irrigation, management and governance of water resources is a result of self-organization embedded in a matrix of institutional arrangements which derive from local formal and informal institutions (Johanna and Wirkus, 2010).

The process of water distribution and thus accessing water in the scrutinized irrigation scheme is rather captured as governance (Johanna and Wirkus, 2010). Governance is here understood as the coordination of collective action (Johanna and Wirkus, 2010). The governance perspective focuses on formal and informal rules, rule-making systems and actor networks on different societal levels (Biermann *et al.*, 2009). The term governance is applied in several disciplines and therefore a variety of definitions exist. One of the most cited definitions of governance is that of the Commission on Global Governance: "Governance is the sum of the many ways individuals and institutions, public and private, manage their common affairs. It includes formal institutions and regimes empowered to enforce compliance, as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interest" (Commission on Global Governance, 1995). In this respect conflicts are regarded as tensions, oppositions and arguments between social units (individuals, groups and organizations) (Geoffrey, 2006). In conclusion the governance perspective focuses on social negotiation processes of collective arrangements of different actors. These negotiation processes are taking place in a social arena, but find also manifestation in the physical space (Bohle and Fünfgeld, 2007); Bohle, 2007).

2.3 Institutional Framework of the Water Resources Management

Water management operates in a three dimensional framework (GWP, 2009). The three parts of the framework, usually constructed at the national scale, are the enabling environment, institutions and management (Table 1). However, not all the elements of such framework may be in place (GWP, 2009).

This means that, to basin integrating water management in basins, it is important to get a clear understanding of the water management framework in which decisions about water are made - the national management framework within a country, or the international water management framework that spans several countries.

Table 1: Three, dimensions of water management framework

Enabling environment	Institutions	Management
Laws and Policies • Frame water resources management within a country and between countries **Water user dialogues** • Cross-sectoral and upstream-downstream dialogues • Basin Committee Budgets **Budgets** • Financing organisation and investment **Co-operation** • Within International River Basins	**Roles and Responsibilities** • Of basin and other water sector organisations at different levels in the government, non-government and private sector • Effective coordination mechanisms • Planning process • Financing	**Structures** • Assess water resources (availability and demand) • Set up communication and information systems • Resolve conflicts in allocation of water • Establish regulation • Establish financing arrangements • Establish self-regulation (voluntary action) • Research and development • Undertake development works • Ensure accountability • Develop organisational capacity • Coordinate

Source: A hand book of Integrated Water Resources Management in Basins. (GWP, 2009)

2.4 Water Permits

Water rights are any mechanism through which a user can access water for a particular use without jeopardising another user's right (Saleth and Dinar, 2004). While water rights can be local or customary, in IWRM they are more formal and statutory in nature and typically are distributed on a basin level. They define volumetric allocation and sometimes the period of allocation and whom it is provided for. (Van Koppen *et al.*, 2004). For this alternative system to function effectively and equitably, legal changes are often needed to facilitate a private and transferable water rights system (a water market) that ensures full legal, physical, and tenure certainty of water rights. With such a water-rights system, economic conditions can create the necessary incentives for water exchanges both within and across sectors, and such exchanges will enhance efficient water use (Saleth and Dinar, 2004).

2.5 Integrated Water Resource Management

The GWP defines integrated water resources management as a "process that promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Miguel and Fernando, 1999). At the river or lake basin and aquifer level, IWRM can be defined as a process that enables the co-ordinated management of water, land and related resources within the limits of a basin so as to optimise and equitably share the resulting socioeconomic well-being without compromising the long-term health of vital ecosystems. Sectoral approaches to water resources management have dominated in the past and are still prevailing. This leads to fragmented and uncoordinated development and management of the resource. Moreover, water management is usually in the hands of top-down institutions, the legitimacy and effectiveness of which have increasingly been questioned (GWP, 2009). Thus, weak governance aggravates increased competition for the finite resource. IWRM brings coordination and collaboration among the individual sectors, plus a fostering of stakeholder participation, transparency and cost-effective local management. A meeting in Dublin in 1992 gave rise to four principles that have been the basis for much of the subsequent water sector reform.

Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.

Principle 3: Women play a central part in the provision, management and safeguarding of water.

Principle 4: Water has an economic value in all its competing uses and should be recognised as an economic good as well as a social good.

Nowadays Tanzania is experiencing a reform of the water sector. As many other developing countries it is implementing Integrated Water Resource Management (IWRM) (Johanna and Wirkus, 2010). The approach of the IWRM in Tanzania is also reflected in the new legal policy bodies like the National Water Policy 2002 and the Water Sector Development Programme 2006-2025 which aims at attaining the objectives of the National Water Policy 2002. These policies stress an integrated approach for water management which is participatory, multi-sectoral and multidisciplinary. The River Basin Management includes several offices and committees at several levels: There is a committee and officers at the basin level, the catchment level and the sub-catchment level, while a Water User Association (WUAs) (in some cases Irrigation Organization) is the institution which encompasses the water users at the local level. The Water Users Associations are obliged to register to obtain a 'water right' and manage water for multiple uses at village and ward level (Van Koppen *et al.*, 2004).

2.6 Performance indicators

Performance of smallholder irrigation around the world has been reported to be below expectations (Svendsen *et al.*, 2009). Different authors and international organisations developed various performance indicators (Rao, 1993), which could be used for identification of malfunctioning components of different schemes. The performance indicators relate to the various disciplines of irrigation performance –technical, socio-economic and institutional set up. The technical performance indicators relate mainly to water conveyance, delivery and use and they include delivery performance ratio, discharge capacity of ratio, output per unit irrigation supply, and output per unit water consumed by crop, among others (Gomo, 2010).

Scheme management failures have frequently resulted in chaos involving illegal tempering with water conveyance structures and water shortages at different locations within the scheme (Albinson and Perry, 2002), thus affecting the irrigation performance. Garces - Restrepo *et al.* (2007) noted that the dissatisfaction among the farmers triggered a non-payment cycle and the general performance of the schemes declined. With the aim of reducing recurring government expenditure on these irrigation schemes, and the general disappointment with the performance of irrigations systems, the governments of China, Bangladesh and the United States of America initiated Irrigation Management Transfer (IMT) in the early 1970s (Garces-Restrepo *et al.*, 2007). The fundamental aim of the IMT reform process was to improve performance of the schemes through handing over the ownership and management responsibilities to the farmers (Perret, 2002). Garces-Restrepo *et al.* (2007) noted that the underlying assumption was that greater participation by the farmers would induce a sense of ownership and responsibility, and hence improve resource use efficiency.

2.6.1 Comparative indicators for irrigation system performance

Comparative indicators (Output per cropped area , output per unit command area, output per unit irrigation supply, output per unit per unit water consumed, relative water supply, relative irrigation supply, Gross return on investment (%) and financial self -sufficiency make it possible to see how well irrigated agriculture is performed at irrigation systems, basin or national scale. As a tool for measuring the relative performance of irrigation systems or tracking the performance of individual systems the International water management institute (IWMI) comparative performance indicators help;

i. Policy makers and planners to evaluate how productively land and water resources are being used for agriculture, and to make more informed strategic decisions regarding irrigation and food production.
ii. Irrigation managers to identify long term trends in performance, to set reasonable overall objectives and to measure progress.
iii. Researchers to compare irrigation systems and identify factors that led to better performance.
iv. Donor agencies, governments and NGOs to assess the impact of interventions in the irrigation sector and to design more effective interventions.

Performance assessment has been prioritized as the most critical element to improve irrigation management (Abernethy, 1986). Without monitoring and controlling water supply, it is difficult to improve irrigation management. It is also known that poor distribution of irrigation supply with respect to time and space is a prime issue for improving the water management as well as overall irrigation performance.

2.6.2 Indicators of irrigated agricultural output

The four basic comparative performance indicators below relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important (Molden *et al.*, 1998). Output per unit of irrigation water supplied and output per unit of water consumed are derived from a general water accounting framework (Molden *et al.*, 1998).

$$\text{Output per cropped area} = \frac{\text{Production}}{\text{Cropped area}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Output per unit command area} = \frac{\text{Production}}{\text{Commad area}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\text{Output per unit irrigation supply} = \frac{\text{Production}}{\text{Diverted irrigation supply}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\text{Output per unit water consumed} = \frac{\text{Production}}{\text{Volume of water consumed by ET}} \quad \ldots\ldots\ldots (4)$$

The water consumed in equation 4 is the volume of process consumption, in this case evapotranspiration. It is important to distinguish this from another important water accounting indicator - output per unit total consumption, where total consumption includes water depletion from the hydrologic cycle through process consumption (ET), other evaporative losses (from fallow land, free water surfaces, weeds, trees), flows to sinks (saline groundwater and seas), and through pollution (Keller and Keller, 1995; Seckler, 1996). We are interested in the measurement of production from irrigated agriculture that can be used to compare across systems. If only one crop is considered, production could be compared in terms of mass. The difficulty arises when comparing different crops, say wheat and tomato, as 1 kg of tomato is not readily comparable to 1 kg of wheat. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as net value of production and gross value of production using local values.

2.6.3 Relative water supply and relative irrigation supply

The two most crucial factors in irrigation planning, design and operation are the available water supply and the water demand. Relative water supply as presented by Levine (1982) and relative irrigation supply as developed for this indicator set (Perry, 1996) are used as the basic water supply indicators:

$$RWS = \frac{\text{Water supplied}}{\text{Crop water demand}} \qquad \text{(5)}$$

$$RIS = \frac{\text{Irrigation Supply}}{\text{Irrigation Demand}} \qquad \text{(6)}$$

Where;

Total water supply	=	Surface diversions plus net groundwater draft plus rainfall.
Crop demand	=	Potential crop ET, or the ET under well-watered conditions.
Irrigation supply	=	Only the surface diversions and net groundwater draft for irrigation.
Irrigation demand	=	The crop ET less effective rainfall.

Relative irrigation supply is the inverse of the irrigation efficiency presented by Bos and Nugteren, 1974). The term relative irrigation supply was presented to be consistent with the term relative water supply, and to avoid any confusing value judgments inherent in the word efficiency. Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity and how tightly supply and demand are matched. Care must be taken in the interpretation of results: an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

2.6.4 Adequacy and equity

Table 2 shows assessment ranges of performance indicators as indicated by Molden and Gates, 1990.

Table 2: Assessment ranges of performance indicators (Molden and Gates, 1990)

Indicator	Good	Fair	Poor
Adequacy	> 0.9	0.8 – 0.9	< 0.8
Equity	< 0.1	0.1 – 0.25	> 0.25
Dependability	<0.1	0.1 – 0.2	> 0.2

2.7 Irrigation Efficiencies

Irrigation efficiency is a critical measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation district, or an entire watershed (Terry, 2003). Irrigation efficiency is a basic engineering term used in irrigation science to characterize irrigation performance, evaluate irrigation water use and to promote better irrigation water use and to promote better or improved use of water resources, particularly those used in agriculture (Israelsen and Hansen, 1962; ASCE, 1978; Bos, 1979 and Hermann *et al.,* 1990). Table 3 shows conveyance efficiency, field canals efficiency, distribution efficiency and field application efficiency adapted by FAO. Irrigation efficiency is defined in terms of: the irrigation system performance; the uniformity of the water application, and; the response of the crop to irrigation. Irrigation efficiency affects the economics of irrigation, the amount of water needed to irrigate a specific land area, the spatial uniformity of the crop and its yield, the amount of water that might percolate beneath the crop root zone, the amount of water that can return to surface sources for downstream uses or to groundwater aquifers that might supply other water uses, and the amount of water lost to unrecoverable sources (salt sink, saline aquifer, ocean, or unsaturated zone).

2.7.1 Water conveyance efficiency (E_c)

Conveyance efficiency is the ratio of water received at the inlet to a block of fields or a night storage reservoir to the water released from the project headwork. Factors affecting this efficiency include canal lining, evaporation of water from the canal, technical and managerial facilities of water control. Conveyance efficiency is higher when water is conveyed in a closed conduit than when it is conveyed in an open one, since water in the latter is very much exposed to evaporation as well as to 'poaching' by people and to livestock watering.

$$E_c = 100\,(W_f / W_s) \quad \text{..} \quad (7)$$

W_f = Water delivered to field

W_s = Water diverted from source.

2.7.2 Water distribution efficiency (Ed)

The distribution efficiency is the efficiency of the water distribution canals and conduits supplying water from the conveyance network to individual fields. It can be expressed as;

$$E_d = 100\,(V_f/V_d) \quad \text{..} \quad (8)$$

Where;

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

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

Table 3: Conveyance, field canal, distribution, and field application efficiencies (Adapted from: FAO, 1992)

Irrigation system and type of efficiency	*USDA	*US (SCS)	*ICID (ILRI)
Conveyance efficiency (E_c)			
Continuous supply with no substantial change in flow			0.9
Rotation supply in projects of 3 000-7 000 ha and rotation areas of 70-300 ha, with effective water management			0.8
Rotational supply in large schemes (> 10 000 ha) and small schemes (< 1 000 ha) with respective problematic communication and less effective management:			
Based on predetermined schedule			0.7
Based on advance request			0.65
Field canal efficiency (E_b)			
Blocks larger than 20 ha : unlined			0.8
: lined or piped			0.9
Blocks below or up to 20 ha : unlined			0.7
: lined or piped			0.8
Distribution efficiency ($E_d = E_c \times E_b$)			
Average for rotational supply with management and communication			
- Adequate			0.65
- Sufficient			0.55
- Insufficient			0.40
- Poor			0.30
Field application efficiency (E_a)			
Surface methods			
- Soil type -light soils	0.55		
-medium soils	0.70		
- heavy soils	0.60		
-irrigation method - Graded border		0.60-0.70	0.53
-Basin and level border		0.60-0.80	0.58
- Contour ditch		0.50-0.55	
- Furrow		0.55-0.70	0.57
- Corrugation		0.50-0.70	
-Subsurface		Up to 0.80	
-Sprinkler : hot dry climate		0.60	
: moderate climate		0.70	0.67
: humid and cool		0.80	
-Rice			0.32

*USDA = United States Department of Agriculture, *US (SCS) = United States (Soil Conservation Section), *ICID (ILRI) = International Commission on Irrigation and Drainage, (International Institute for Land Reclamation Improvement)

2.7.3 Water application efficiency (Ea)

Water application efficiency gives a general sense of how well an irrigation system performs its primary task of getting water to the plant roots. However, it is possible to have high application efficiency but have the irrigation water so poorly distributed that crop stress exists in areas of the field. It is also possible to have nearly 100 per cent application efficiency.

$$E_a = 100\,(W_c / W_f) \quad \text{......(9)}$$

Where:

W_c = Water available for use by the crop

W_f = Water delivered to field

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Nyandira is located on the Western slopes of the Uluguru mountains which lies between latitudes 7^0 05'and 7^0 15' South and longitudes 37^0 30' and 37^0 45^0 East (Sampson and Wright, 1964). Its altitude is over 1600m above the sea level (Figure 2).

3.1.2 Climate

The area has a temperate - like climate and receives annual rainfall of between 1000 mm and 2000 mm (Delobel *et al.*, 1991). It experiences a bimodal type of rainfall with short rains (*Vuli*) from October to December and long rains (*Masika*) from March to June. During the dry season, farmers practice full irrigation mainly for vegetable growth.

3.1.3 Vegetation

The area falls under miombo woodland type of forest being dominated by typical Brachystegia spp, Miombo, Isoberlina spp and Acasia nigrescens. The only timber of importance is Pterocarpus angolesis (*mninga*). The dominant vegetation includes fern, guava cyprus, black wattle, eucalyptus and thatch grass (Themedaspp). The inhabitants are mainly smallholder farmers growing both cash and stable food crops under rainfed and irrigated in risk prone environment. The current major land cultivation practices are ridging (terraces) and no ridge. Ridge and ladder terraces are used for growing crops like maize, beans, irish potatoes and green peas whereas the bench terraces are used for growing cash crops like cabbage, onions, cauliflower, and other vegetable crops which are sold in Nyandira market on the way to Morogoro Municipality and Dar es Salaam City (Kisanga, 1992).

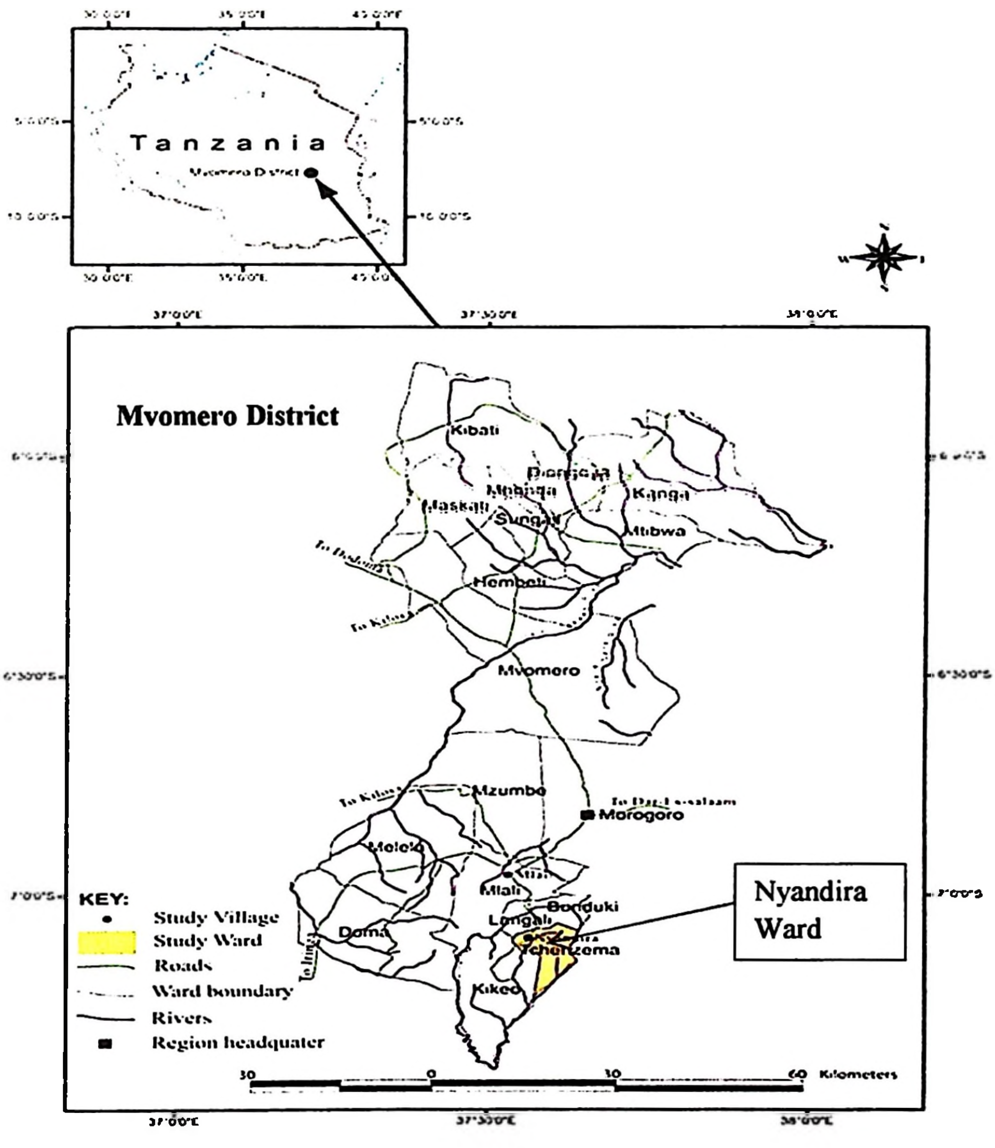

Figure 2: Location Map of the study area

3.1.4 Geology and Soils

According to the soil map of the word (FAO- UNESCO, 1974), the soils of the study area have been classified generally as chromic cambisols associated with regosols. The most widespread rock type is biotite gneiss and which is magmatic and is richer in potash (Sampson and Wright, 1964).

3.1.5 Land use

Nyandira has very steep slopes which limit agricultural land. However, intensive cultivation is practiced; ladder and bench terraces are constructed to control soil erosion. Farmers grow a variety of crops like vegetables, yams, maize and fruits. Vegetables are mainly grown in bench terraces while other crops are grown in ladder terraces under mixed cropping. These crops are either irrigated or rainfed. Indigenous irrigation system is used in the dry season mainly for vegetable production. In this type of irrigation, farmers irrigate their crops by filling ditches with water and then use siphons to irrigate the plants, while others, just let the water in and then use the small containers or cups to scoop water to the plants, while others, just let water from top of the field run down to the bottom of the field. Others make holes in the terraces through which water passes to plants. The area has a lot of stones and cracks (Temple and Rapp, 1972; Kisanga, 1992).

Tillage is normally done before the onset of rains. Some cultivation is done in October especially for maize crops grown during long rains (*masika*) which starts in late February. However, due rainfall distribution which is bimodal; tillage and planting is done almost throughout the year.

3.2 Methodology

3.2.1 Irrigation canals in the Nyandira village

Traditional irrigation scheme in Nyandira village started during the colonial era by German Missionaries. The Missionaries taught the farmers how to divert water from the rivers for agriculture and terrace cultivation. The first people to be taught were Suleiman

Ndoto from Nyandira and John Karoli from Mwalazi. Twelve canals namely Fuku, Mzinga, Mindu No.1, Mindu No.2, Mbakana juu, Mbakana kati, Mbakana chini, Lubangala No.1, Lubangala No.2, Nyamiseta No.1, Nyamiseta No.2 and Nyamiseta No.3 shown on in (Figure 3) were identified and digitised using a GPS. Out of twelve (12) irrigation canals, four canals were purposively selected for the study (Figure 3).

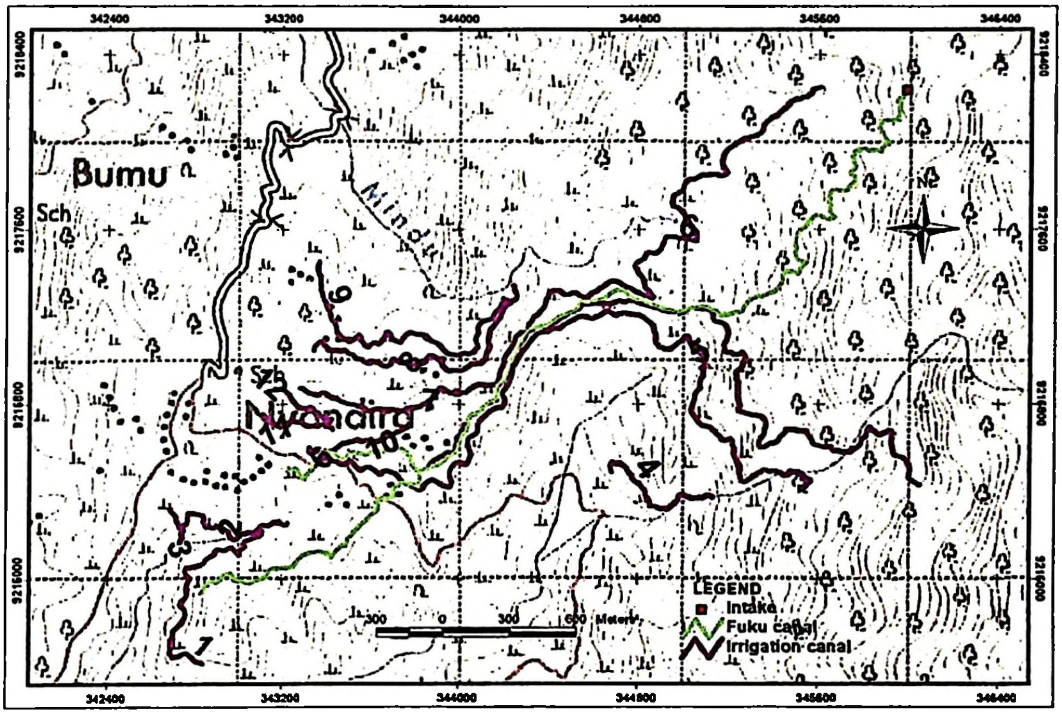

Figure 3: Nyandira irrigation canals

Key:

1: Lubangala No.1; 2 and 3: Lubangala No.2; 4: Mbakana Chini; 5: Mbakana Kati; 6: Mbakana Juu; 7: Mzinga; 8: Mindu No. 2; 9: Mindu No. 1; 10: Nyamiseta No.1; 11: Nyamiseta No.2; 12: Nyamiseta No.3; Green canal: Fuku Canal.

The criteria used were to have two canals from the same river, Fuku canal diverting water from the upstream of the river while Mzinga canal diverting water from the downstream of the river. The third canal was selected from another river which is Mbakana Kati which diverts water from Mbakana River. The fourth canal was selected from the natural spring which has not been intervened which is Nyamiseta (Table 4 and 5). The roles of each irrigation canal associations were analysed using SPSS program. Canal flow measurements were measured using V- notch weir in order to calculate efficiencies of each canal. Performance indicators for each canal were also calculated.

Table 4: Canal details

Canal	Fuku	Mbakana Kati	Mzinga	Nyamiseta No.1
Members	34	23	24	12
Male	23(67.6%)	18(75%)	13(56.5%)	8(66.7%)
Female	11(32.4%)	5(25%)	10(43.5)	4(33.3%)
Canal Length(km)	5.10	2.83	3.73	0.5
Intake level (amsl)	2159	1941	2078	1777
Water source	Mzinga R.	Mbakana R.	Mzinga R	Spring

Table 5: Nyandira Traditional canals length

S/N	Name of Canal	Length in(Km)
1:	Lubangala no.1	1.09
2:	Lubangala no.2	0.84
3:	Lower Mbakana	0.66
4:	Middle Mbakana	2.83
5:	Upper Mbakana	4.66
6:	Mzinga	3.73
7:	Mindu no. 2	1.34
8:	Mindu no.1	1.50
9:	Nyamiseta no.1	0.50
10:	Nyamiseta no.2	0.37
11:	Nyamiseta no.3	0.33
12:	Fuku (Green)	5.10
	Total	**22.95**

3.2.2 Materials

Questionnaire, checklist for key informant's interviews and focus group discussions were prepared. Other published research materials and reports were searched from internet, National Agricultural Library of Sokoine University of Agriculture, Wami Ruvu Basin Office and Ministry of Water in order to formulate research questions. Three different portable sizes of 60cm, 45cm and 30cm wide, 90^0 V - notch weirs were fabricated in the Engineering Department at Sokoine University of Agriculture (SUA) for canal flow measurement depending on the sizes of the canals.

3.2.3 Research design

Cross-sectional research design was adopted because it allows collection of data on multiple cases at a single point in time and detects patterns of association among variables (Bryman, 2004). The design also allowed the use of questionnaires, Focus Group Discussion (FGD) and use of V- notch weirs to gather a body of qualitative and quantitative data within a reasonable period of time and at minimal cost (Agresti and Finlay, 2009). It was also essential in providing precise results (Kothari, 2005).

3.2.4 Sampling unit and sample size

The study population for this study is all households (643 irrigators) in selected irrigation canals. The sampling unit was a household because it is a basic unit for resource management, production and consumption at the micro level (Bryman, 2004). Key informants at national, regional, district and local levels such as government and non-government officers, village leaders, elders, and youth were interviewed in order to supplement information for this study. The sample population (irrigators in irrigation) was stratified according to age, sex and marital status, and a purposive sampling technique was adopted to select respondents from each stratum. A sampling intensity of 5% was adopted in this study (Mbeyale, 2009) where the total number of households is less than 600 in scheme, a sample of 30 cases is randomly selected (Kothari, 2005). In the study area a total of 93 household were selected out 643. This is based on a scientific argument that a sample of 30 cases bears minimum appropriate for statistical analysis regardless of the population size (Bailey, 1994).

3.3 Data collection

3.3.1 Focus group discussions (FGDs)

Focus group discussions were conducted in order to complement information from administered questionnaires. The participants were irrigators and irrigators association of Fuku, Mzinga, middle Mbakana and Nyamiseta No.1 canals. The data collected were the roles of irrigators association and social economic factors influencing the performance of informal and formal institutions in traditional irrigation schemes.

3.3.2 Discussion with key informants

A checklist was used to guide the discussions with key informants. Key informants interviewed were individuals and organisations who are conversant with institutional arrangements and governance in managing traditional irrigation schemes in Tanzania, such as village chairman of Nyandira village, Ward Executive Officer of Nyandira Ward, Ward Agricultural Extension Officer (WAEO), District Agricultural, Irrigation and Cooperative Officer (DAICO), Water Basin Officer of Wami Ruvu Basin Office, Morogoro Zonal Irrigation Engineer, Director of Irrigation and Technical Services from the Ministry of Agriculture and Director of Water Resources from the Ministry of Water. Data collected included the number and type of stakeholders and their roles in managing traditional irrigation schemes, number of formal and informal institutions, and type of power relations, power source and interactions amongst stakeholders. In addition, cultural practices, norms and values were documented.

3.4 Flow Measurement

3.4.1 V-notch weir

The V-notch weirs were used to measure flow rates because V-notch weir works well for measuring low flow rates because the decreasing surface width and flow area with decreasing head over the weir allow accurate measurement of the head even at low flow rates (Bengtson, 2011). The easiest V-notch weir configuration for calculation of flow rates is a fully contracted, 90^0 V-notch weirs (Bengtson, 2011).

Equation (10) is recommended for this configuration in reference to conditions given below (USBR, 2001). The condition needed for fully contracted, V- notch weirs are given in Equation (10). Figure 4, shows the meaning of the parameters P, S and H.

$$Q = 1.36H^{2.48} \qquad \text{.......} (10)$$

Subject to P ≥ 2Hmax

S ≥ 2Hmax, where:

p	=	the height of the V- notch vertex above Channel bottom.
S	=	the distance of the V- notch opening at the top of the water over the channel wall.
Hmax	=	the maximum expected head over the weir.

S. I version of the Equation 10, Q, must be in m^3/s with H, P and S in m.

The recommended usable range for H, the head over a V-notch weir is: 0.06m ≤ H ≤ 0.38m (Bengtson, 2011). Measurements were taken once a week when they were irrigating in order to get the amount of water irrigated for the growing season

Appendix 7 and Figure 5. For the efficiencies the measurement were taken from the intake at the branch canal and at the inlet of the field (see page 101, Appendix 8, 9, 10 and 11).

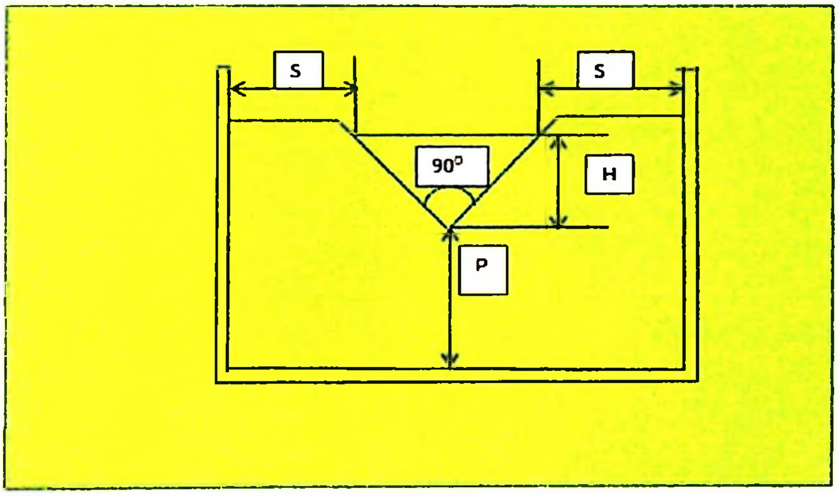

Figure 4: V-notch weir parameters

Figure 5: Flow measurement in Fuku canal using a v- notch weir

3.5 Data Analysis

3.5.1 Qualitative data analysis

Content analysis was used to analyse qualitative information collected from key informants, farmer's interview, FGDs and direct observation. The collected information was broken down into meaningful units of information of either roles, bylaws or responsibilities. This helped in ascertaining the types, patterns, sequences and processes of issues related to water management institutions and household livelihoods.

3.5.2 Quantitative data analysis

Quantitative data from structured questionnaire was analysed statistically using the Statistical Package for Social Sciences (SPSS). The household questionnaire was organised and coded. The open ended questions were categorized and transformed into a form agreeable for further analysis. Descriptive statistics was computed to determine frequencies and percentages of individual variables for multiple comparisons of various data, and tables and graphs were used to present the results.

Binary logistic models were used to find out the relationships between the performance of informal and formal institutions used in relation to social economic factors. In this study, age, sex, marital status, household size and residence duration and awareness of cultural values were considered as independent variables to influence the level of performance of informal institutional arrangements. On the other hand, age, level of education, household size, awareness of National Water Policy of 2002 (Table 9), awareness of Water Resource Management Act No. 11 of 2009 (Table 10) and awareness of National Irrigation Policy of 2010 (Table 11) were considered as independent factors influencing performance of formal institutions.

Dependent variables Y_i and Y_j

Performance of dominant informal institutions underlying irrigation development (Yi) and formal institutions (Yj) were measured using a number of variables indicating characteristic of good governance (United Nations, Economic and social Commission for Asia and the Pacific, 2003) as shown in Table 6. In order to measure performance of dominant governance structures (formal and informal institutions) characteristics were given scores ranging from 1 to 5 and the mean score were computed for each household. The cut off point for performance was subjectively selected to be 3 whereby below 3 was considered as 'poor' and 3 to 5 as considered as 'good'.

Table 6: Characteristic of good governance

Characteristics	Principles of Good governance adopted
Participation	Participation by both men and women is a key cornerstone of good governance. Participation could either be direct or through legitimate intermediate institutions or representatives.
Effectiveness and efficiency	Good governance means that processes and institutions produce results that meet the needs of society while making the best use of resources at their disposal.
Responsiveness	Good governance requires that institutions and processes try to serve all stakeholders within a reasonable timeframe.
Accountability	Accountability is a key requirement of good governance. Not only governmental institutions but also the private sector and civil society organizations must be accountable to the public and to their institutional stakeholders.

Source: United Nations: Economic and Social Commission for Asia and the Pacific, 2003.

Definition of variables

Performance of informal institutions: It is a binary variable that represents the dependent variable. It measures the level of performance of dominant informal institutions (Cultural practices). "One" denotes **good** whereas "zero" denotes **poor.** The model is as shown in Equation 11.

$$Yi = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X)}} \quad \text{...(11)}$$

Where;

Yi = is a binary variable with the value of "1 " if the respondent rates performance of informal institutions as good and "0" if the performance of the informal or formal institutions as poor.

$\beta_0, \beta_1, \beta_n$ = coefficients of independent variables showing marginal effects (positive or negative) of the unit change in the independent variables on the dependent variables.

X_1 to X_n = independent variables

e = natural logarithm base (2.718)

i = 1, 2................n; where n is the total number of variables:

The independent variables X_1 to X_n denote factors that explain the outcome Y. These are;

X_1 = Residence duration (Binary variable). This is a binary variable and represents **one** if a respondent has lived more than twenty years and **zero** if a respondent has lived less than twenty years. The expectation was that people who had lived in the study area could easily abide by the rules and therefore enhance performance of informal institutions underlying traditional irrigation.

X_2 = Household size (continuous variable). This is a continuous variable and it was assumed that a high number in the household tend to increase the demand for water and land resources. Therefore the expected influence of household size was negative. It was also assumed that respondents with big families will diversify their farming activities and sources of income and therefore not adhering to institutions restricting use of water and land resources.

X_3 = Age of the household head (Continuous variable). This is a continuous variable and is measured in years. The expected influence of age is assumed to be positive; it is a proxy measure of farming experience of a household. Aged households are believed to be wise and to have acquired experience of traditional irrigation systems. It is also assumed that aged people in the community would pass on cultural values and norms to the younger generation giving rise to enhanced performance of informal institutions with the view to conserve water resources.

X_4 = Sex of household head (Binary variable). This is a binary variable and one represents men and zero represents women. The expectation was that the participation of both men and women in farming activities will increase the performance of informal institutions.

X_5 = Awareness of cultural practices (Binary variable). This is a binary variable and represents one if respondent is aware and zero otherwise.

Performance of formal institutions: It is a binary variable that represents the dependent variable. It measures the level of performance of dominant formal institutions (Water Resources Management Committee). "One" denotes **good** whereas "zero" denotes **poor.** The model is as shown in Equation 12.

Where;

$$Yj = \frac{1}{1 + e^{-(\vartheta 0 + \theta 1 Z)}} \quad \text{.. (12)}$$

Yj	=	is a binary variable with the value of "1 " if the respondent rates performance of formal institutions as "good" and "0" if the performance of the formal institutions as "poor".
$\theta 0, \theta 1, \theta n$	=	coefficients of independent variables showing marginal effects (positive or negative) of the unit change in the independent variables on the dependent variables.
Z_1 to Z_n	=	independent variables
e	=	natural logarithm base (2.718)
j	=	1, 2...............n; where n is the total number of variables:

The independent variables Z_1 to Z_n denote factors that explain the outcome Y. These are:

Z_1 = Age of the household head (Continuous variables). Age is a continuous variable and is measured in years. The expected influence of age is assumed positive. It is a proxy measure of irrigation farming experience of household head. Older household heads are believed to be wise and that they have acquired skills in irrigation farming hence produce much and supply much.

Z_2 = Household size (continuous variables). This is a continuous variable and it was assumed that a high number of members in a household tend to increase the demand for water and land resources. Therefore increase of household members was expected to have a negative effect on the performance of formal institutions. It was also assumed respondents with big families would diversify their farming activities and sources of income and therefore participate in irrigation.

Z_3 = Education level of the household head. It is a continuous variable and refers to the formal schooling of the respondent during the survey period. Education is an important tool that could enhance the individual farmers' decision making towards adoption of new technologies. It was assumed that increase in education level tend to enhance wise use of land and water resources hence resulting into positive performance of formal institutions.

Z_4 = Awareness of the National Water Policy of 2002. This is a dummy variable and takes the value of one if respondent is aware and zero if otherwise. The assumption was that awareness of the Water Policy of 2002 is a measure of performance of formal institutions and was expected to have a positive influence in performance of formal institutions.

Z_5 = Awareness of Water Resources Management Act of 2009.This is a dummy variable and takes the value of one if respondent is aware and zero if otherwise. The assumption was that awareness of the Water Resources Management Act is a measure of performance of formal institutions and was expected to have a positive influence in performance of formal institutions.

Z_6 = Awareness of National Irrigation Policy of 2010. This is a dummy variable and takes the value of one if respondent is aware and zero if otherwise. The assumption was that awareness of the National Irrigation Policy is a measure of performance of formal institutions and was expected to have a positive influence in performance of formal institutions.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Institutional Arrangement Underlying Traditional Irrigation Schemes in Nyandira

4.1.1 Informal institutions

Institutions are basically the established sets of rules derived from a combination of human perceptions and actions. The rules may be in the form of written-down laws, or of norms, conventions and traditional practices accepted by a particular society as defined by Bandaragoda and Firdousi, 1992.

The results outlining informal institutions underlying traditional irrigation in the study area are presented in Table 7. Four institutions grouped according to cultural practices, norms and values were identified. As reported by most respondents, these institutions are passed from one generation to another. Each institution has its own setting, target and guidelines for implementation and enforcement. Table 7 shows that cultural practices which were defined by most respondents that, traditional culture consists of the beliefs and practices held or observed by specific human groups that have been passed down from their ancestors through their grand-parents, parents and the society around them as a whole. (Figure 6 and 7).

Enforcement of the traditional rules is commonly done through household and household heads. Yami, *et al.,* 2009 observed that setting rules as part of informal institutional arrangements could arise from increasing recognition of the critical roles Common Pool Resources (CPRs) play in sustaining livelihoods of various rural communities.

Table 7: Informal arrangements in traditional irrigation schemes in the study area

Rules / Bylaws	Nature	Target group	Enforcement
All family members are required to participate in farm activities	Cultural practices	Family members	Household, and head of household
Children are allowed to help their parents in farm activities	Cultural practices	Children	Household, Head of household
Livestock are not allowed to be grazed near irrigated farms	Cultural practices	Livestock keepers	Household, Household head and elders
Theft of water is not allowed	Norms	Irrigators and community members	Leaders of the association, a responsible person for water distribution

Figure 6: A child participating in irrigated agriculture

Figure 7: A man and woman tilling land

There is a general consensus among scholars that successful informal institutions serve as mechanisms to achieve outcomes of sustainability by regulating access to and control over CPR, managing resource conflicts (Watson, 2001), sharing benefits equitably among resource users (Tefera *et al.*, 2005) and mobilising social capital for sustainable resource management (Chisolm,1998).

4.1.2 Formal institutions

Table 8 shows a number of important formal institutions in traditional irrigation schemes in the Study area. Formal institutions are dominantly executed by the village governments through a set of by- laws established by village authorities and approved by the District Council. Figure 8 shows the institutional structure at village and ward level which is vital in the management of CPRs including water sources, streams, rivers and river banks. These structures were depicted in the studied village of Nyandira in Mvomero district, Tanzania.

The institutional structures illustrated in Figure 8 form the village authority responsible for setting by-laws, control of natural resources including CPRs and is the focal point of the Tanzanian Government vision of development on agriculture, forestry, and livestock (URT, 1982). The structures are supported by formal institutions (URT 1982; Leach *et al.*, 1998; Smajgel *et al.*, 2003).

Table 8: Formal arrangements influencing traditional irrigation schemes in the study area

Rules /bylaws	Nature	Target group	Enforcement
Setting bush fire is not allowed	Village by- laws	Community members	VNRC
It is not allowed to wash a chemical canister in a canal, or to put chemicals in water.	Village by –laws	Community members	WSCC EMC
Leaving 60m buffer zone along a river channel or water source	Land Act. No.4 of 1999. National Land Policy of 1995; National Water Policy of 2002; Water Resources Management Act of 2009; Environmental Management act No.20 of 2004	Community members	VNRC VLUMC EMC
It is not allowed to wash clothes or your body in the water of the canal	Village by-laws	Community	VNRC EMC

VNRC- Village Natural Resources committee; VLUMC- Village Land Use Management Committee; EMC - Environmental Management Committee; WSCC- Water Sources Conservation committee.

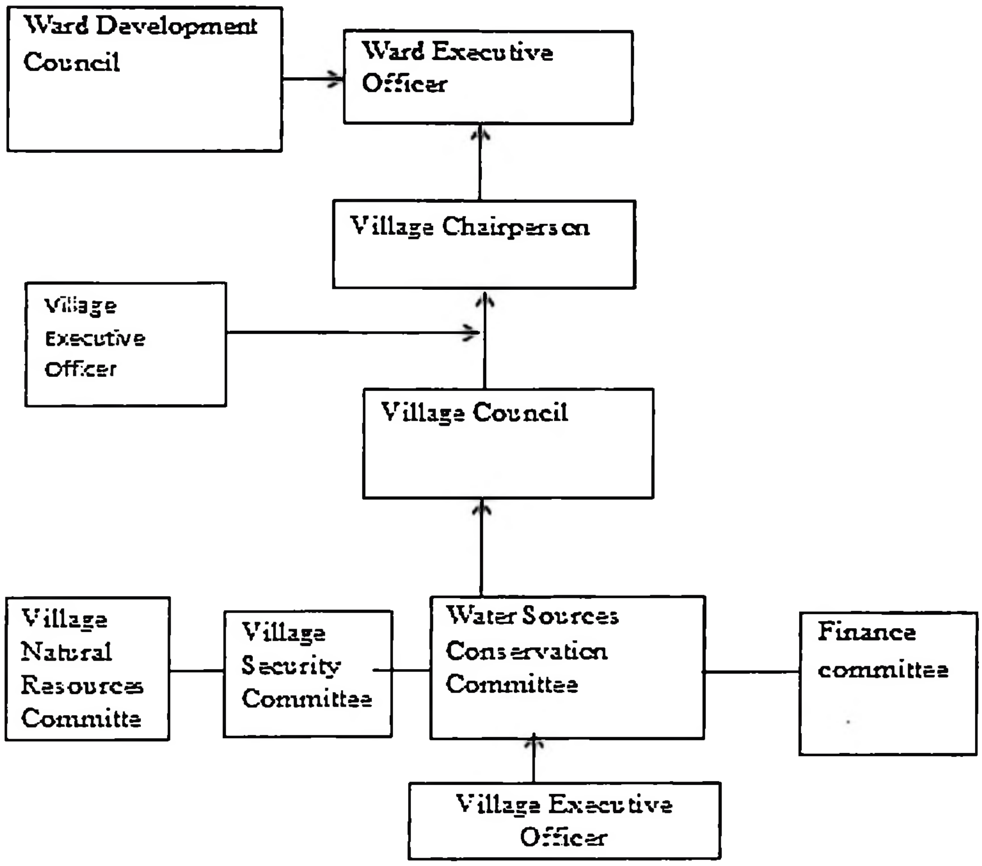

Figure 8: Institutional structure at village and ward level

4.1.3 Roles of the irrigator's organisation

Roles of the irrigator's organisation were analysed using Statistical Package for Social Science (SPSS) (Appendix 1 and 2) The results of the analysis indicates that Fuku canal was better compared to the rest of the association in terms of water management, allocation and distribution, maintenance of infrastructures, stable leadership and contribution of operation and maintenance fee (Appendix 3). The results were 85.71%, 80.95%, 57.14% and 31.10% for Fuku, Mbakana, Mzinga and Nyamiseta respectively. Figure 9 to 12 shows malfunctions structures of the Fuku canal which needs to be repaired.

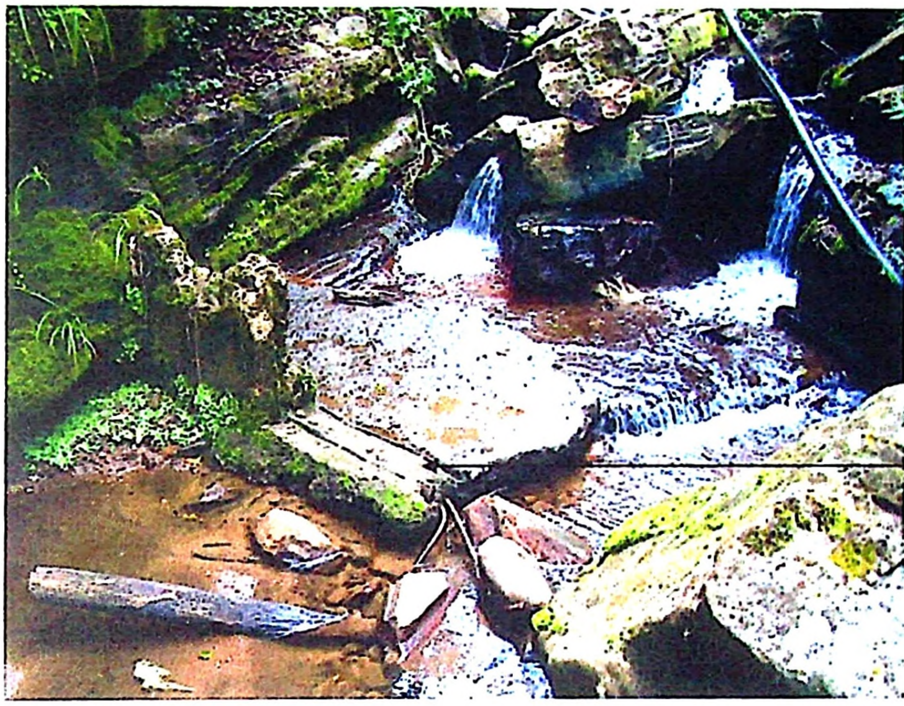

Figure 9: A broken diversion weir of Fuku canal

Figure 10: A broken division box of Fuku canal

Figure 11: A repaired portion of broken Fuku canal

Figure 12: A locally constructed aqueduct over Fuku canal

4.1.4 Awareness of National Water Policy of 2002

Table 9 shows that (91.4%) 85 of the respondents were not aware of the water policy 2002. This shows that policies are formed and remain to the management (Decision and Policy makers) while people on the ground who are the actual implementers are not aware of what is going on. The main objective of this revised policy is to develop a comprehensive framework for sustainable development and management of the Nation's water resources, in which an effective legal and institutional framework for its implementation will be put in place. The policy aims at ensuring that beneficiaries participate fully in planning, construction, operation, maintenance and management of community based domestic water supply schemes. This policy seeks to address cross-sectoral interests in water, watershed management and integrated and participatory approaches for water resources planning, development and management. Also, the policy lays a foundation for sustainable development and management of water resources in the changing roles of the Government from service provider to that of coordination, policy and guidelines formulation, and regulation.

Table 9: Awareness of National Water Policy of 2002

	Numbers	Percent	Cumulative Percent
Yes	8	8.6	8.6
No	85	91.4	100.0
Total	93	100.0	

4.1.5 Awareness of WRM Act 2009

Table 10 shows that the majority of the respondents (93.5%) 87 in the study area were not aware of the Water Resources Management Act of 2009. This implies that the community members do not understand their role in water conservation and management in line with the Water Resources Management Act of 2009. The Government through the Ministry of Water is responsible for creating awareness of the Water Resources Management Act of 2009. According to URT (2009) the objective of the Water Resources Management Act is to provide for institutional and legal framework for sustainable management and development of water resources; to outline principle for water resources management; to provide for the prevention and controls of water pollution; to provide for participation of stakeholders and the general public in implementation of the water policy, repeal of the water utilization (Control and regulation) Act and to provide for related matters.

Table 10: Awareness of Water Resources Management Act, 2009

	Numbers	Percent	Cumulative Percent
Yes	6	6.5	6.5
No	87	93.5	100.0
Total	93	100.0	

4.1.6 Awareness of National Irrigation Policy of 2010

From Table 11, out of 93 farmers which were interviewed only 2.2% (2) are aware of the National Irrigation Policy, 2010. According to the Irrigation and drainage Policy, 2010, the main objective is to ensure sustainable availability of irrigation water and its efficient use for enhanced crop production, productivity and profitability that will contribute to food security and poverty reduction.

Table 11: Awareness of National Irrigation Policy of 2010

	Numbers	Per cent	Cumulative per cent
Yes	2	2.2	2.2
No	91	97.8	100.0
Total	93	100.0	

4.2 Wami/Ruvu Basin

Wami/Ruvu Basin lies in the eastern central part of Tanzania and occupies 74 000 km^2 of the area. Wami/Ruvu Basin consists of three catchments of Wami, Ruvu and the Coast, and each of the Wami and Ruvu basins are divided into three Sub-Catchments (Figure 13).

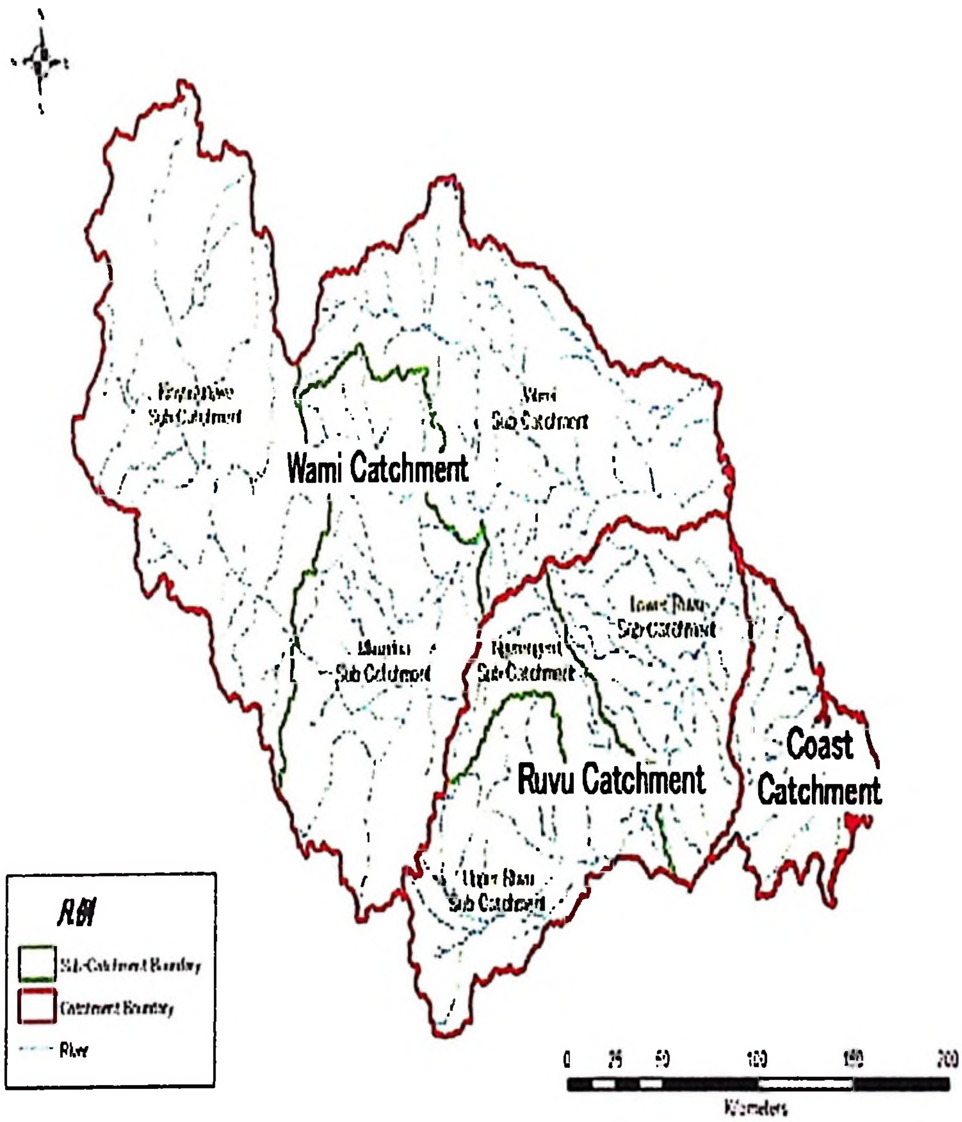

Figure 13: Wami/Ruvu basin (Source: JICA final report, 2013)

The basin therefore, is divided into seven (7) Sub-Catchments namely: Kinyasungwe, Wami, Mkondoa in Wami Basin; Ngerengere, Upper Ruvu, Lower Ruvu in Ruvu Basin and Coast (The basin covers 22 Local Government Authorities (LGAs) in six regions of the country which are Morogoro, Dodoma, Dar es Salaam, Manyara, Tanga and Coast. Wami/Ruvu basin has 78 members of staff. In which 54 (12 Engineers and 42 Technicians) are technical staff in the discipline of hydrology, hydrogeology, civil engineering and chemistry. The roles of the Wami/ Ruvu basin authority is to measure rivers flows, issue water use permits, collect data on water resources, conservation water sources, control water pollution, prepare IWRM plan, Coordinate stakeholders meetings and form Water Users Association(WUA).

4.2.1 Water use permit

Water Resources Management Act no. 11 of 2009 requires any person who diverts, dams, stores, abstracts or uses water from surface or underground water source, for any purpose such as to construct or maintain any work, shall apply for a Water Use Permit. Based on findings the Wami/ Ruvu Basin has 960 registered water users who had water use permits as of 2014. The analysis showed that 30 big water users (3%) (Appendix 10) in the Wami/Ruvu who uses160 302 litres/sec which is 89% of the total volume of water used while 930 small water users (97%) uses 19 743litres/sec (11%) of the total volume used (Figure 14). Others have been abstracting water without having formal procedures to update their status with new permits while the old documents became invalid. Research findings also revealed the situation that some water users who applied for the permits have been continuously using the water sources without receiving conclusions on examination of their applications by Wami Ruvu Basin Water Board (WRBWB) for some reasons. In other case, there are numbers of water users who do not apply for the permit intentionally or due to insufficient knowledge on the related legal procedure even if they are subject to regulation (a vivid example of Nyandira people). In the interview with them, the permit holders expressed their complaint on unfairness of the situation that the non-permit holders had been left enjoying access to water resources without fulfilling their obligations such as payment of the water user fee. This situation has also aroused mistrust of the water users to the water resources management system and BWB.

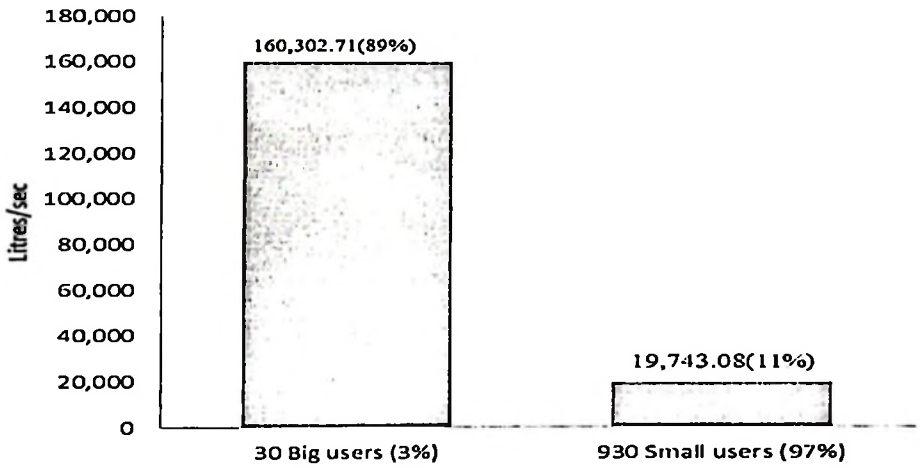

Figure 14: Water use permits in Wami/Ruvu basin

4.2.2 Discharge permit

The Water Resource Management Act No. 11 of 2009 empowers the Wami/ Ruvu Basin Office to issue the discharge permits. It was found that the River Basin Water Board has not issued discharge permits to approximately 15 applications received as of December 2014 as the examination procedures are not fully put in place. Also, there are some of water users who are subject to acquisition of the discharge permits apart from Urban Water Supply Authority (UWSA) and large-scale manufacturers which have already submitted the applications. Majority of the industrial water users do not have facilities to treat wastewater to satisfy the water quality standards of effluent, which makes difficult for BWB to issue them the discharge permit. Except for the cases that water pollution is actually observed, the water users who need to have the discharge permit are not identified and regulated strategically by WRBWB although the Water Resources Management Act of 2009 vests power to BWB to instruct them to suspend the activities which cause or would cause pollution and take measures to remedy the situation. As the regulation of the discharge of effluent has a direct influence on production of goods and services by the water users, administrative instructions by BWB were politically intervened in some cases, which threats practicability of enforcement of law.

4.2.3 Water users association (WUA)

Twelve (12) WUAs have been formed in Wami/Ruvu Basin as of December 2014 namely, Lumuma, Mkondoa, Kisangata, Msowero, Mayombo, Ilonga, Wami, Mkindo, Upper Ngerengere A, Upper Ngerengere B, Lower Ngerengere and Mfizigo.

The observations from the study were as follows:

i. Roles of WUA are not well articulated by the water users and offices of the LGAs such as, Ward Executive Office and village government, where are located within the jurisdiction of WUA. Also, roles and responsibilities of the stakeholders at the community level are not clearly demarcated in terms of water resources management, which has resulted into duplication of activities of the different organizations and rules set by them.

ii. Operation of WUA is not financially supported as few water users pay enrollment and annual membership fees which are the major source of fund for WUA. The causes of low response of the water users to payment to WUA are insufficient understanding of the water users on the roles of WUA as well as confusion on the purpose of those fees with that of the water user fee levied by BWB.

iii. Neither BWB nor LGAs conduct systematic follow-up of activities being conducted by WUA/WUG after completion of registration of the association. Consequently, capacities of executive members of WUA/WUG are still weak in terms of formulation, coordination and facilitation of the action plans and negotiation with different actors.

iv. No existing WUA in Nyandira but it is in formulation stage.

v. Demarcation of roles and responsibilities is not effectively done between WUA and WUG. WUG is required to play a role to link water users in the village with WUA. Contrary to this expectation, both executive members of WUG and water users do not recognize it as a responsible organization for coordination of water resources management in the village. In most cases, the members of the executive committee and steering committee of WUA have to handle issues related to water use and water resources management in individual villages instead WUG to conduct such activities and WUA to put more focus on coordination among the villages and collaboration with external organizations.

vi. A collaboration model between BWB and WUA is yet to be established for formulation and implementation of the water resources management plan. BWB is not fully utilizing the network and local resources governed by WUA in the operation at the community level.

4.3 Water Resource Management in the Country

Tanzania is divided into nine river Basins that do not follow administrative boundaries such as Regions and Districts. Considering this fact, the management of water resources have five main levels; National level, Basin level, catchment level, Sub catchment level, and Community or Water User Association level which is the lowest level and will bring integrate users of the same source. An institutional framework for water resources management defined by National Water Sector Development Strategy (NWSDS) and Water Resources Management Act of 2009 is shown in Figure 15.

4.3.1 Water resources management Act (WRMA) 2009

The Water Resources Management Act No.11 of 2009 was passed by the National Assembly of the United Republic of Tanzania on 28th April 2009 and assented by the President on 12th May 2009. WRMA came into operation on 1st August 2009. WRMA repeals the Water Utilisation (Control and Regulation) Act No. 42 of 1974. Thus, the Water Utilisation (Control and Regulation) Act ceased to apply since 1st August 2009. Despite the repeal of Act No. 42 of 1974 orders, notices, directions, appointment and acts of things lawfully made, issued or done under the repealed Act continue to have effects such as any decree or order of the court passed or made before the recommended of this Act may be enforced as if this Act had not been enacted.

The Water Resources Management Act is a result of National Water Policy (NAWAPO) of 2002 and thus gives legal back-up policy issues which require legal force. National Water Policy emphasizes the principle of involvement of user organizations and private sector so as to attain equitable, efficient and sustainable water resources management. Water resources management is a multi-sectoral activity that requires an effective collaboration and coordination mechanism among sectors at all levels (Figure 15).

WRMA 2009 Covers issues of institutional and legal framework; principles for water resources management (WRM); prevention and control of water pollution; establishment of National Water Board; Basin Water Boards (BWB); Catchments and sub-catchments and offences and penalties. WRMA objective is "to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled to meet the basic human needs of present and future generations".

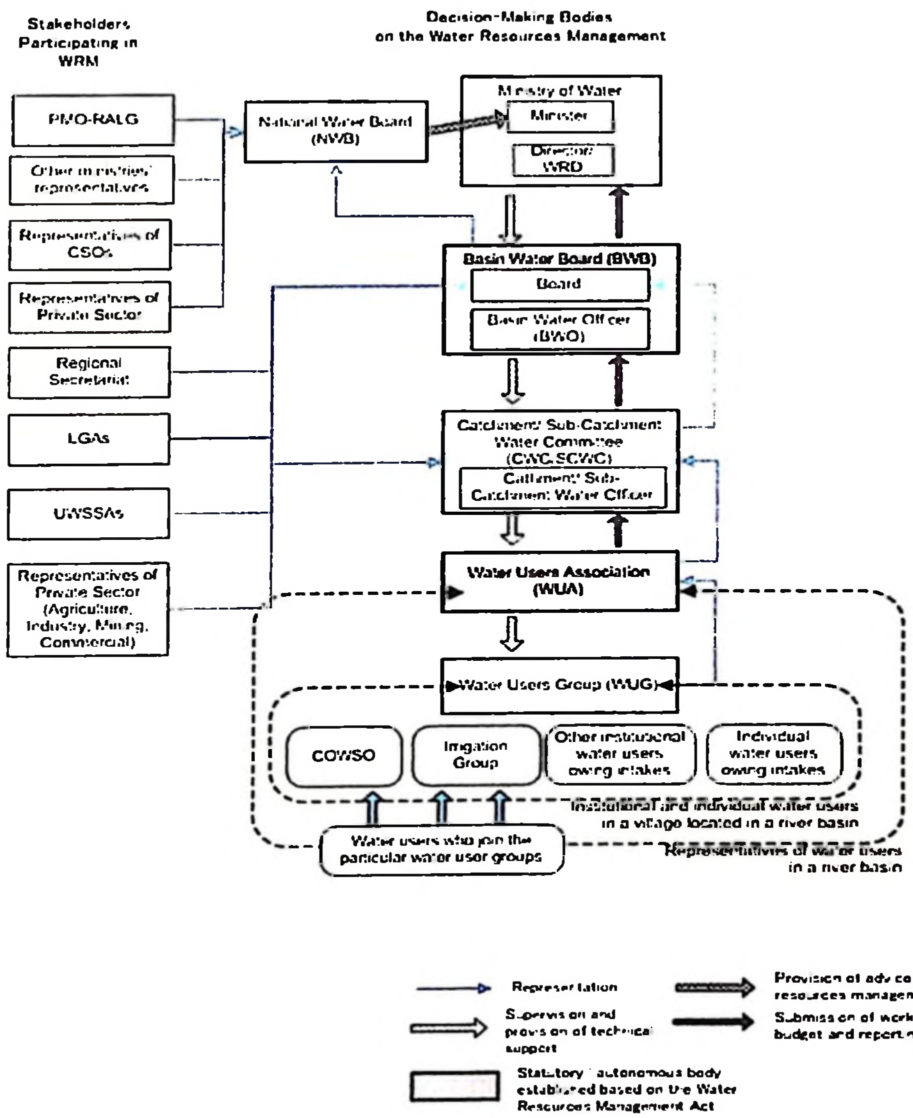

Figure 15: Implementing structure of the water resources management (JICA final report, 2013)

4.3.2 Water related laws

Legislation governing water sector is divided into two regimes i.e. water resources, and water supply and sanitation services. The Water Resources Management Act No.11/2009 and the Water Supply and Sanitation Act No.12/2009 were enacted in 2009 to repeal and replace WUA Cap 331 and WWA Cap 272 respectively. Water legislations are implemented parallel with other pieces of legislation of the country. Other water related legislation includes Environmental Management Act (EMA) No.20/2004, Land Act No.4/1999, Energy and Water Utility Regulatory Authority (EWURA) Act No.11/2001, Forest Act, Water Supply and Sanitation Act, and Irrigation Act 2013.

4.3.3 National water sector development strategy 2006–2015 (NWSDS)

The National Water Sector Development Strategy (NWSDS) specifies implementing strategies to realize the principles and basic policies for the water sector development described in NAWAPO 2002. There are ten areas of the strategies with regard to the water resources management sub-sector in NWSDS covers 10 areas of "Water Resources Assessment", "Integrated Water Resources Planning", "Water Resources Development", "Environmental Protection and Conservation", "Water Quality and Pollution Control", "Water Conservation and Demand Management", "Water Utilization and Allocation", "Trans-Boundary Waters", "Disaster Management" and "Water Resources Management Legislation".

4.4 Irrigation Efficiencies of Nyandira Furrows

4.4.1 Conveyance efficiency

From Appendix 9 to 12 the conveyance efficiency for the four canals, i.e. Fuku, Mbakana Kati, Mzinga and Nyamiseta were calculated and found to be 63.05%, 62.74%, 60.89%

and 60.5% respectively which is fairly good (Table 12) even though the canals are not lined (Figure16).

The conveyance efficiency was calculated using the formula.

$$\text{Conveyance efficiency} = \frac{\text{Water delivered to the distribution system}}{\text{Water diverted from river}} \quad \ldots\ldots\ldots\ldots (13)$$

Table 12: Conveyance efficiency

	Fuku	Mbakana	Mzinga	Nyamiseta
Water diverted from the river(L/s)	12.45	13.42	9.87	2.0
Water delivered to the distribution system(L/s)	7.85	8.42	6.01	1.21
Conveyance efficiency	63.05%	62.74%	60.89%	60.5%

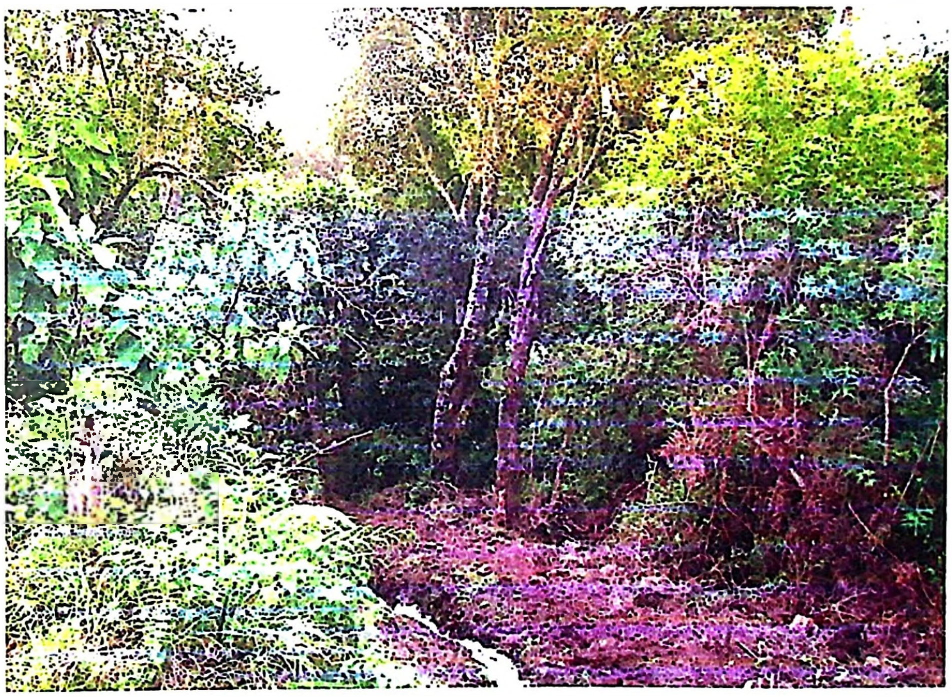

Figure 16: Unlined Fuku canal

In Table 13 the distribution efficiency of Nyamiseta canal is higher as compared by the other canals of Fuku, Mbakana and Mzinga because this canal is shorter (0.5km) while the others have 5.1km, 2.83km and 3.73km respectively.

Table 13: Distribution efficiency

	Fuku	Mbakana	Mzinga	Nyamiseta
Water delivered to the distribution system(L/s)	7.85	8.42	6.01	1.21
Water delivered to the field (l/s)	2.49	3.58	2.15	0.8
Distribution efficiency	31.72%	42.51%	35.77%	66.11%

4.5 Performance Indicators

The necessary primary and secondary data to calculate the performance indicators were collected such as measurement of water flow, total volume of irrigated water, area irrigated per crop per season, crop types, production per season, and climatic data (Appendix 4 and 5) in order to calculate crop water requirement and net irrigation requirement using CROPWAT version 8. The indicators used are output per cropped area, output per irrigation diverted, output per water consumed, relative water supply, relative irrigation supply, equity and adequacy.

4.5.1 Indicators of water supply

The results of the analysis shows that the ratio of RWS for Fuku, Mbakana Kati, Mzinga and Nyamiseta were 1.21, 1.22, 1.18 and 0.91 respectively (Table 14). According to Molden and Gates, 1990 values of RWS greater than one (RWS >1) indicates adequate supply of water while RWS less than one (RWS <1) indicate inadequate supply of water for respective canal. From the above analysis it shows that Fuku, Mbakana Kati and

Mzinga they have enough water to irrigate the type of crops grown which are peas and beans. Even though the RWS for Nyamiseta is less than one i.e. 0.91 (Figure17) but the crop yield is almost the same with other canals. Given the similarity of crop yield probably seepage water from the springs which feed the canals raised the ground water table to a level that it could be accessed through capillary.

The RIS for Fuku, Mbakana Kati, Mzinga and Nyamiseta were 0.91, 0.94, 0.87 and 0.43 respectively. According to Molden *et al.,* 1998) the Relative Irrigation Supply (RIS) focuses on supply of irrigation water alone, in contrast to RWS which also includes rainfall. When irrigation fills the gap of water requirements after they are met by rain, RIS is near unity. The RIS values plotted in Figure 18 indicate there is a wide variation among the systems studied (0.43 to 0.94). According to Molden *et al.,* 1998), in situations where return flows go to a sea or a sink, and there is a scarce water supply in the river basin, it is better to have a relative irrigation supply near 1 than a higher value.

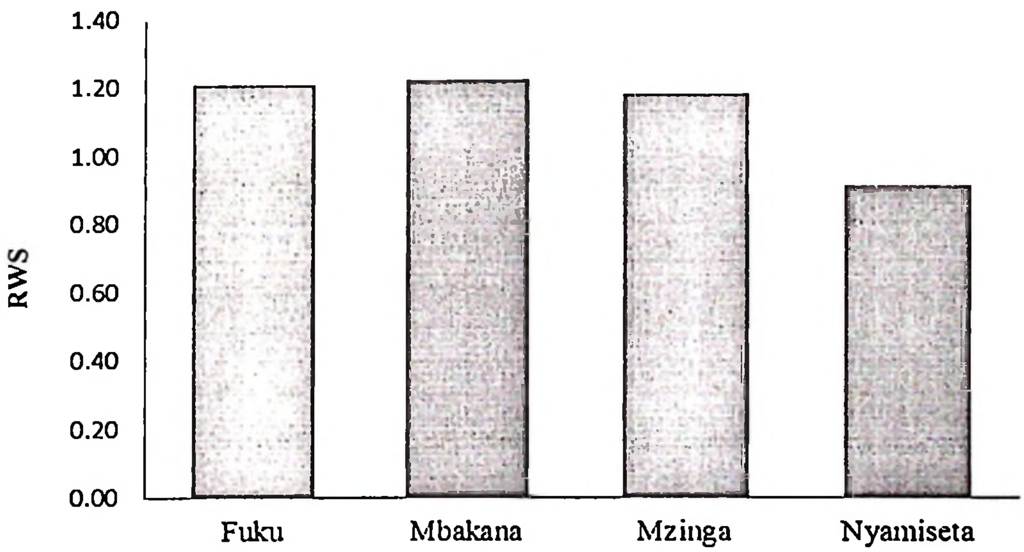

Figure 17: Relative Water Supply (RWS)

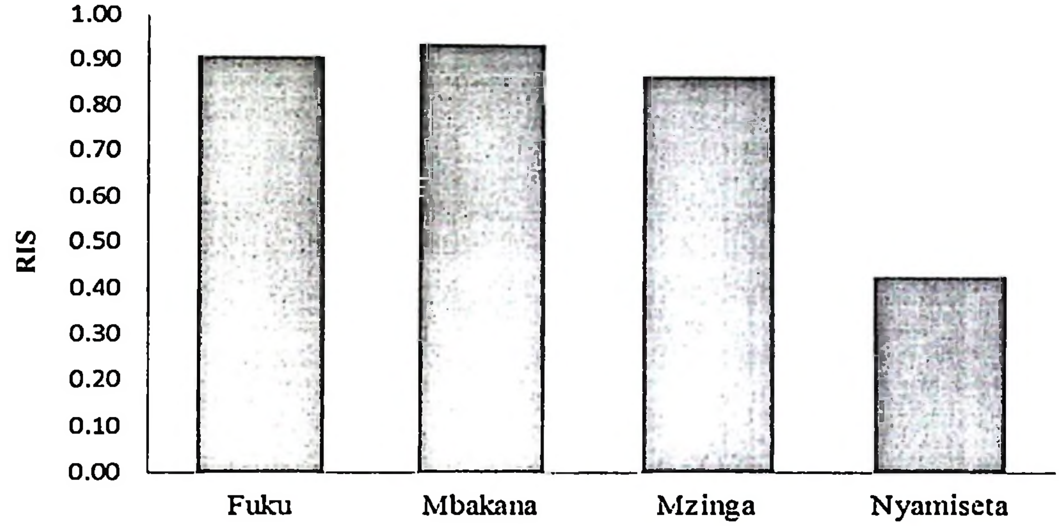

Figure 18: Relative Irrigation Supply (RIS)

4.5.2 Land and water productivity

The three agricultural indicators; output per cropped area (ton/ha) were 2.79, 2.78, 2.67 and 2.65 for Fuku, Mbakana Kati, Mzinga and Nyamiseta respectively (Table 14). According to FAO production year book, 1994 the yield is within the range even though on the lower side because yield ranges from 2.0 tons per hectare in Russia Federation; 5.0 tons per hectare for Africa to 17.9 tons per hectare for Belgium- Luxembourg. Output per irrigation supply and output per water consumed were in the order of 1.0732, 0.6 for Fuku, 1.0439, 0.59 for Mbakana Kati, 1.075, 0.57 for Mzinga and 1.0742, 0.57 for Nyamiseta. (Figure 19, 20 and 21). The literature says moisture of 250 - 450 mm is sufficient for the growing season where for Nyandira we had 301mm from rainfall and 279.60mm from irrigation.

Table 14: Performance indicators

S/N	Performance Indicators	Fuku	Mbakana	Mzinga	Nyamiseta
1.0	Cropped area (acre)	0.63	0.62	0.48	0.24
2.0	Production (Ton)- Fresh Peas	0.703	0.690	0.512	0.255
3.0	Volume of water supplied by irrigation (m^3)	652.00	661.00	476.0	273.9
4.0	Irrigation supply (mm)	255.72	263.42	243.0	121.0
5.0	Total rainfall per season (Aug-Dec 2014) mm	301.60	301.60	301.6	301.60
6.0	Total water supply (mm)	557.32	565.02	544.6	422.6
7.0	Crop Water Requirement (mm)	462.30	462.30	462.3	462.30
8.0	Irrigation requirement (mm)	279.60	279.60	279.6	279.60
9.0	Volume of water consumed by crop ET	1178.68	1159.98	898.0	448.89
10.0	Output per cropped area (ton/ha)	2.79	2.78	2.67	2.65
11.0	Output per unit irrigation (Kg/m^3)	1.0782	1.0439	1.075	0.93
12.0	Output per unit water consumed (Kg/m^3)	0.60	0.59	0.57	0.57
13.0	Relative Water Supply (RWS)	1.21	1.22	1.18	0.91
14.0	Relative Irrigation Supply (RIS)	0.91	0.94	0.87	0.43

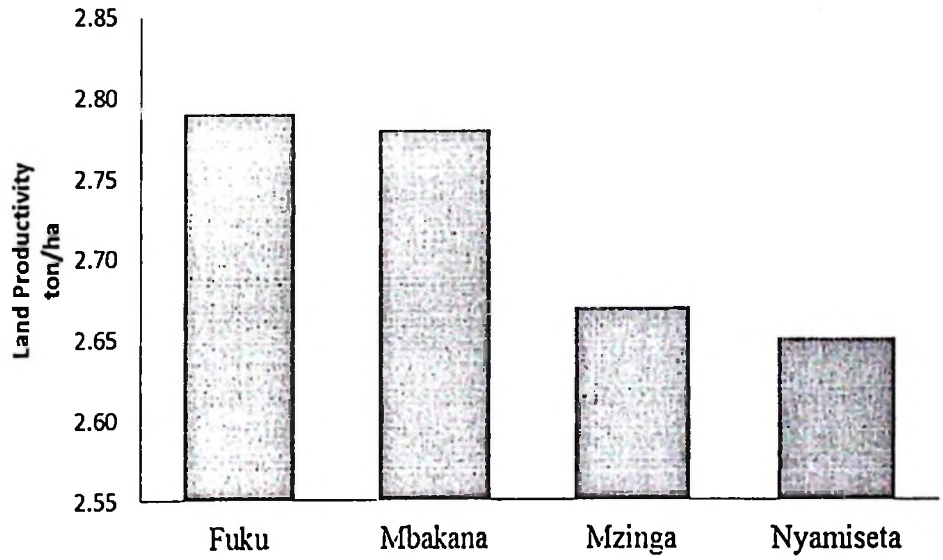

Figure 19: Output per unit cropped area (ton/ha)

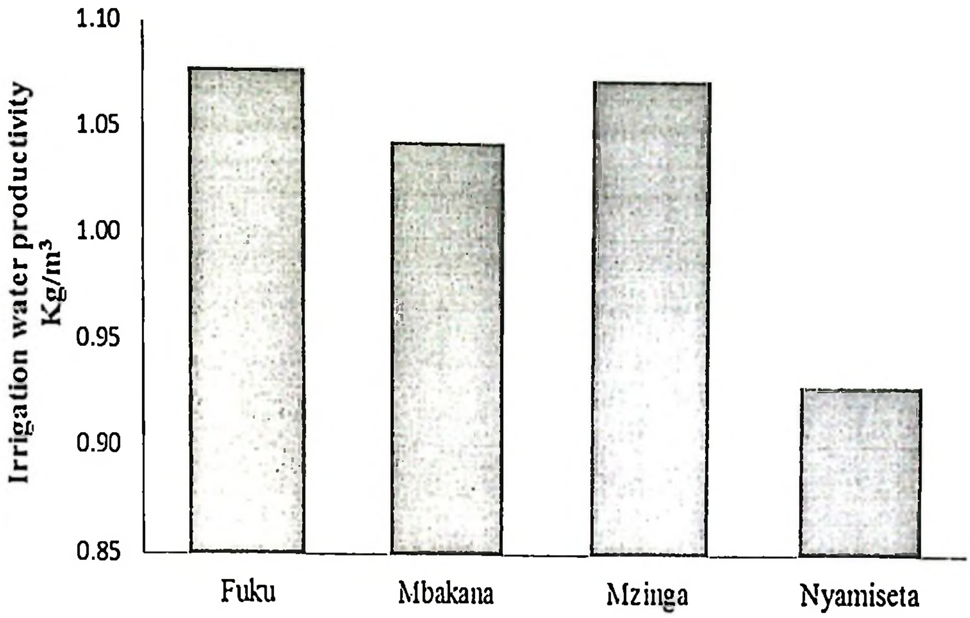

Figure 20: Output per unit irrigation (kg/m^3)

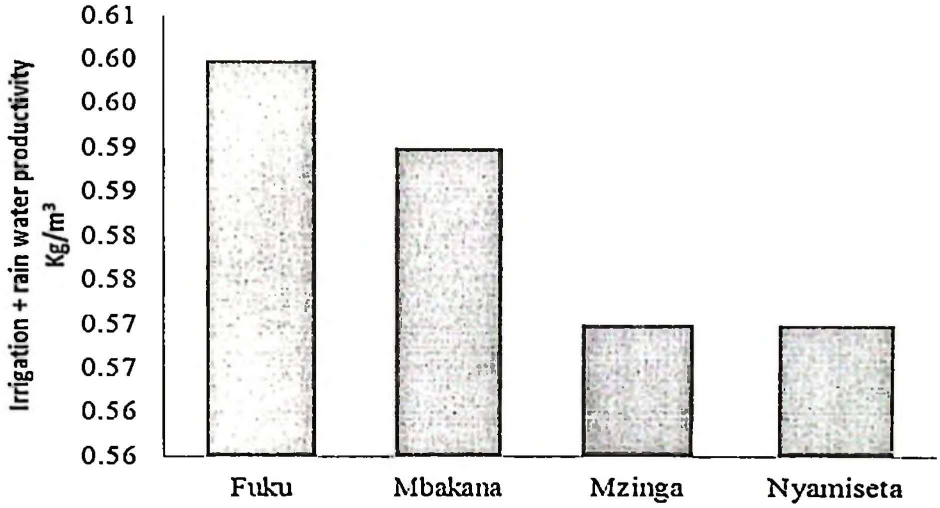

Figure 21: Output per unit water consumed (kg/m^3)

4.5.3 Opinion of farmers on equity, adequacy, and dependability

The result of the analysis on the opinion of farmers on equity, adequacy and dependability is as shown in Table 15, 16 and 17.

Table 15: Farmers opinion on equity (n=93)

Name of Irrigators Association	Adjective class	Frequency	Percentage
Fuku	Good	31	91.2
	Fair	3	8.8
	Poor	0	0.0
Mbakana Kati	Good	18	75.0
	Fair	6	25.0
	Poor	0	0.0
Mzinga	Good	13	56.5
	Fair	10	43.5
	Poor	0	0.0
Nyamiseta	Good	2	16.7
	Fair	10	83.3
	Poor	0	0.0

Table 16: Farmers opinion on adequacy (n=93)

Name of irrigators Association	Adjective class	Frequency	Percentage
Fuku	Good	11	32.4
	Fair	23	67.6
	Poor	0	0.0
Mbakana Kati	Good	7	29.2
	Fair	17	70.8
	Poor	0	0.0
Mzinga	Good	4	17.4
	Fair	17	73.9
	Poor	2	8.7
Nyamiseta	Good	12	100
	Fair	0	0.0
	Poor	0	0.0

Table 17: Farmers opinion on dependability (n=93)

Name of Irrigators Association	Adjective class	Frequency	Percentage
Fuku	Good	23	67.6
	Fair	11	32.4
	Poor	0	0.0
Mbakana Kati	Good	17	70.8
	Fair	7	29.2
	Poor	0	0.0
Mzinga	Good	15	65.2
	Fair	8	34.8
	Poor	0	0.0
Nyamiseta	Good	8	66.7
	Fair	4	33.3
	Poor	0	0.0

From Table 15 to 17 the ranges of equity, adequacy and dependability of irrigation water supply ranged from fair to good according to Molden and Gates, (1990) classification.

4.5.4 Calculated values of Adequacy, Equity and Dependability

Adequacy was measured through RWS which is another measure of adequacy Tarimo *et al.*, 2008). From Table 18 it shows that water is adequate for both canals and hence concludes the farmer's opinion that water is adequate.

Equity of water distribution is an expression of the share for each individual or considered fairly by all system members.

$$Equity\ (Eq) = \frac{RWS\ head}{RWStail} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Table 18: Calculated values of Equity

	Fuku	Mbakana	Mzinga	Nyamiseta
RWS_{head}	1.58	1.65	1.42	0.91
RWS_{tail}	1.21	1.22	1.18	0.85
Equity	1.3	1.35	1.20	1.07
Co (RWS)	1.86	1.94	1.67	1.07

Note:

*RWS calculated using equation 14

*Coefficient of spatial water distribution (CSWD) obtained by diving the smallest RWS value by other RWS values.

The measured values of Equity shows that there is inequity in water supply, the tail end gets little water as compared to the upper part. Even though that the tail end gets low water but it is adequate looking to the RWS of the tail end Table 18. Dependability of water supply is an expression of confidence in irrigation system to deliver water as promised and is indicative of the timeliness and adequacy of deliveries – Deals with quality of irrigation service (Equation 15).

$$\text{Dependability} = Cov\ (RWS) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

The values of 1.86, 1.94, 1.67 and 1.07 for Fuku, Mbakana, Mzinga and Nyamiseta canals respectively from table 18 tells us that the irrigators depend much on irrigation water.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the findings from the study, the following can be concluded:

i. The study has demonstrated that traditional irrigation has been practised for many decades and has been embedded in their cultural values.

ii. The village authority (Village Executive Officer, Village Council, and Ward Agricultural Officer) is of formal character since it is established by the state and constitutes the lowest level of state administration. But still it is strongly embedded into social sphere of the village practices and customs.

iii. The existing infrastructures starting from the intake up to the fields are all temporal, poorly constructed and pose difficulty in overall water management resulting to low water use efficiencies. This contributes substantially to water losses and overall poor performance of the scheme.

iv. Smallholder farmers are completely unaware of the policies and laws that govern the development and management of irrigation in the country. From the study area 91.4% (85) of the interviewed farmers (93) are not aware of the National Water Policy of 2002; 97.8 % (91) are not aware of the National Irrigation Policy of 2010; and 92.5% (86) are not aware of the Water Resources Management Act of 2009.

v. Small scale water users with water use permits in the Wami/ Ruvu Basin which are a bigger number (930) which is 97% of the total users use only 19,743.08

litres/sec which 3% of the water as compared with big users who are only 30 which is 3% of the total users but they use 160 302.71 litres per second which is 97% of the total water users with water permits.

5.2 Recommendations

i. The government should provide both financial and technical support in order to improve the irrigation infrastructures such as construction of permanent diversion weirs and lining of irrigation canals in traditional irrigation schemes bearing in mind that 80% of the irrigation areas are under traditional irrigation schemes.

ii. Awareness creation on formal institutions and establishment of institutional framework to guide traditional irrigation at community level for sustainable management of natural resources is of paramount importance.

iii. The Wami/Ruvu Basin should concentrate on the big water users to pay for water use permits and leave the small users since it is very costly for them to make follow up for small amount which will be paid and find another way which will make these small users to conserve the water.

iv. Appropriate crop mixtures and sequential cropping patterns should be further explored.

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APPENDICES

Appendix 1: Sociological Statistical Programme data analysis for farmer's interview

S/N	Variable name	Description	Codes	Units
1	Constitution	Presence of Constitution	1= Yes	I
2	Bylaws	Presence of By Laws	2= No	
3	IO meetings	Conducting of IO meetings		
4	IO frequency	No. of times of conducting meetings		
5	IO leaders	Availability of IO Leaders		
6	Gender participation	Gender participation in irrigation activities		
7	OM fees	Payment of OandM fees		
8	Budget	Participation in Budget preparation		
9	Fund security	Fund security		
10	Water conflict	Water conflict reduction		
11	Water use efficiency	Promotion of water use efficiency		
12	Farmers interaction	Farmers interaction with other organization		
13	Canal Maintenance	Maintenance of Irrigation Infrastructures		
14	Farmers participation	Participation in monitoring and evolution meetings		
15	Environment	Environmental issues		
16	Education to non member	Education to non-members to join irrigation activities		
17	Farmers list	Presence of farmers list		
18	Crop intensity	Crop intensity		
19	Food security	Irrigation as a means of producing enough food (Food security)		
20	Water policy	Awareness of 2002 water policy		
21	Irrigation policy	Awareness of Irrigation Policy of 2010		
22	WRM Act	Awareness of WRM Act of 2009		
23	Water permit	Awareness of water use permit		
24	Equity	Farmers opinion on Equity		
25	Adequacy	Farmers opinion on Adequacy		
26	Dependability	Farmers opinion on Dependability		

Appendix 1: (Continued) Sociological Statistical Programme data analysis for farmers interview

1.Presence of Irrigators Organisation Constitution

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	No	24	100.0	100.0	100.0
Mzinga	Valid	No	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

2. Presence of By-laws

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

3. Irrigators Organisation meetings

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

4. Irrigators Organisation help to reduce water conflicts

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	Yes	5	41.7	41.7	41.7
		No	7	58.3	58.3	100.0
		Total	12	100.0	100.0	

5. Water use efficiency

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	18	78.3	78.3	78.3
		No	5	21.7	21.7	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	No	12	100.0	100.0	100.0

6.0 Presence of Operation and Maintenance funds

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

7.0 Maintenance of Irrigation Infrastructure

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	28	82.4	82.4	82.4
		No	6	17.6	17.6	100.0
		Total	34	100.0	100.0	
Mbakana Kati	Valid	Yes	15	62.5	62.5	62.5
		No	9	37.5	37.5	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Yes	13	56.5	56.5	56.5
		No	10	43.5	43.5	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	No	12	100.0	100.0	100.0

8.0 Crop intensity

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	9	26.5	26.5	26.5
		No	25	73.5	73.5	100.0
		Total	34	100.0	100.0	
Mbakana Kati	Valid	Yes	2	8.3	8.3	8.3
		No	22	91.7	91.7	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Yes	1	4.3	4.3	4.3
		No	22	95.7	95.7	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	No	12	100.0	100.0	100.0

9 Food security

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	18	52.9	52.9	52.9
		No	16	47.1	47.1	100.0
		Total	34	100.0	100.0	
Mbakana Kati	Valid	Yes	3	12.5	12.5	12.5
		No	21	87.5	87.5	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	No	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

10 Participation in irrigation activities

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	30	88.2	88.2	88.2
		No	4	11.8	11.8	100.0
		Total	34	100.0	100.0	
Mbakana kati	Valid	Yes	11	45.8	45.8	45.8
		No	13	54.2	54.2	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	No	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

11.0 Village effort for irrigation development

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	16	69.6	69.6	69.6
		No	7	30.4	30.4	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	No	12	100.0	100.0	100.0

12.0 Environmental issues

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	23	67.6	67.6	67.6
		No	11	32.4	32.4	100.0
		Total	34	100.0	100.0	
Mbakana kati	Valid	Yes	6	25.0	25.0	25.0
		No	18	75.0	75.0	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	No	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

12.0 Irrigation as a means of sustainable crop prod

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	23	67.6	67.6	67.6
		No	11	32.4	32.4	100.0
		Total	34	100.0	100.0	
Mbakana kati	Valid	Yes	8	33.3	33.3	33.3
		No	16	66.7	66.7	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Yes	3	13.0	13.0	13.0
		No	20	87.0	87.0	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	No	12	100.0	100.0	100.0

13.0 Education to non members to join the Irrigators Organisation

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

14. 0 Education to irrigators to pay Operation and Maintenance fees

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

15.0 Farmers list

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	24	100.0	100.0	100.0
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

16.0 Fund security

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Yes	34	100.0	100.0	100.0
Mbakana Kati	Valid	Yes	23	95.8	95.8	95.8
		No	1	4.2	4.2	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Yes	23	100.0	100.0	100.0
Nyamiseta	Valid	No	12	100.0	100.0	100.0

17.0 Awareness of 2002 water policy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	8	8.6	8.6	8.6
	No	85	91.4	91.4	100.0
	Total	93	100.0	100.0	

18.0 Awareness of 2010 Irrigation policy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	2.2	2.2	2.2
	No	91	97.8	97.8	100.0
	Total	93	100.0	100.0	

19.0Awareness of Water Resource Mgt Act 2009

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	6.5	6.5	6.5
	No	87	93.5	93.5	100.0
	Total	93	100.0	100.0	

20.1 Awareness of water permits

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	8	8.6	8.6	8.6
	No	85	91.4	91.4	100.0
	Total	93	100.0	100.0	

22.0 Where should water permit be vested

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Kikundi	34	100.0	100.0	100.0
Mbakana Kati	Valid	Kikundi	24	100.0	100.0	100.0
Mzinga	Valid	Kikundi	23	100.0	100.0	100.0
Nyamiseta	Valid	Kikundi	12	100.0	100.0	100.0

23.0 Farmers opinion on adequacy

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Good	11	32.4	32.4	32.4
		Fair	23	67.6	67.6	100.0
		Total	34	100.0	100.0	
Mbakana kati	Valid	Good	7	29.2	29.2	29.2
		Fair	17	70.8	70.8	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Good	4	17.4	17.4	17.4
		Fair	17	73.9	73.9	91.3
		Poor	2	8.7	8.7	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	Fair	12	100.0	100.0	100.0

24.0 Farmers opinion on dependability

Name of Irrigators Association			Frequency	Percent	Valid Percent	Cumulative Percent
Fuku	Valid	Good	23	67.6	67.6	67.6
		Fair	11	32.4	32.4	100.0
		Total	34	100.0	100.0	
Mbakana kati	Valid	Good	17	70.8	70.8	70.8
		Fair	7	29.2	29.2	100.0
		Total	24	100.0	100.0	
Mzinga	Valid	Good	15	65.2	65.2	65.2
		Fair	8	34.8	34.8	100.0
		Total	23	100.0	100.0	
Nyamiseta	Valid	Good	8	66.7	66.7	66.7
		Fair	4	33.3	33.3	100.0
		Total	12	100.0	100.0	

Appendix 2: Summary of results of farmer's interview

S/N	Variables	Fuku	Mbakana	Mzinga	Nyamiseta
1	Presence of Constitution	Yes	No	No	No
2	Presence of By Laws	Yes	Yes	Yes	No
3	Conducting of IO meetings	Yes	Yes	Yes	No
5	Availability of IO Leaders	Yes	Yes	Yes	Yes
6	Gender participation in irrigation activities	Yes	Yes	Yes	Yes
7	Payment of OandM fees	Yes	Yes	Yes	No
8	Participation in Budget preparation	Yes	Yes	No	No
9	Fund security	Yes	Yes	No	No
10	Water conflict reduction	Yes	Yes	Yes	Yes
11	Promotion of water use efficiency	Yes	Yes	No	No
12	Farmers interaction with other organization	Yes	Yes	No	No
13	Maintenance of Irrigation Infrastructures	Yes	Yes	Yes	Yes
14	Participation in monitoring and evaluation meetings	Yes	Yes	No	No
15	Environmental issues	Yes	Yes	Yes	Yes
16	Education to non-members to join irrigation activities	Yes	Yes	Yes	Yes
17	Presence of farmers list	Yes	Yes	Yes	Yes
18	Awareness of 2002 water policy	No	No	No	No
19	Awareness of Irrigation Policy of 2010	No	No	No	No
20	Awareness of WRM Act of 2009	No	No	No	No
21	Awareness of water use permit	Yes	Yes	No	No

Appendix 3: Crop water requirement

Year	Date	ETo mm/day	Kc coeff	ETc mm/day	Eff.rain mm/day	Irrig. Req mm/day
Sept 2015	1-Sep	3.95	0.15	0.59	0.0	0.59
	2-Sep	3.88	0.15	0.58	0.0	0.58
	3-Sep	3.28	0.15	0.49	0.0	0.49
	4-Sep	2.89	0.15	0.43	0.0	0.43
	5-Sep	3.23	0.15	0.48	0.0	0.48
	6-Sep	4.39	0.15	0.66	0.0	0.66
	7-Sep	2.65	0.15	0.40	0.0	0.40
	8-Sep	4.87	0.15	0.73	0.0	0.73
	9-Sep	5.51	0.15	0.83	0.0	0.83
	10-Sep	5.78	0.15	0.87	0.0	0.87
	11-Sep	5.77	0.15	0.86	0.0	0.86
	12-Sep	5.29	0.15	0.79	0.0	0.79
	13-Sep	5.74	0.15	0.86	0.0	0.86
	14-Sep	4.36	0.15	0.65	0.0	0.65
	15-Sep	3.10	0.15	0.46	0.0	0.46
	16- Sep	4.93	0.15	0.74	0.0	0.74
	17- Sep	5.05	0.15	0.76	0.0	0.76
	18-Sep	4.02	0.15	0.63	0.0	0.63
	19-Sep	5.96	0.15	0.89	0.0	0.89
	20-Sep	5.42	0.15	0.81	0.0	0.81
	21-Sep	5.93	0.15	0.89	0.0	0.89
	22-Sep	5.85	0.15	0.88	0.0	0.88
	23-Sep	5.89	0.15	0.88	0.0	0.88
	24-Sep	5.45	0.15	0.82	0.0	0.82
	25-Sep	4.97	0.15	0.75	0.0	0.75
	26-Sep	5.56	0.15	0.83	0.0	0.83
	27-Sep	5.89	0.15	0.88	0.0	0.88
	28-Sep	5.72	0.15	0.86	0.0	0.86
	29-Sep	5.87	0.15	0.88	0.0	0.88
	30-Sep	5.96	0.15	0.89	0.0	0.89
	1-Oct	6.08	0.17	1.03	0.0	1.03
	2-Oct	5.98	0.17	1.02	0.0	1.02
	3-Oct	5.87	0.17	1.00	0.0	1.00
	4-Oct	5.70	0.17	0.97	0.0	0.97

5-Oct	5.32	0.17	0.90	0.42	0.48
6-Oct	5.11	0.17	0.87	0.0	0.87
7-Oct	5.20	0.17	0.84	0.0	0.84
8-Oct	4.46	0.17	0.76	0.0	0.76
9-Oct	5.46	0.17	0.93	0.30	0.63
10-Oct	5.10	0.17	0.87	0.0	0.87
11-Oct	6.46	0.48	3.10	0.0	3.10
12-Oct	5.23	0.48	2.51	1.38	1.13
13-Oct	5.85	0.48	2.81	0.0	2.81
14-Oct	5.49	0.48	2.63	0.0	2.63
15-Oct	5.71	0.48	2.74	0.0	2.74
16-Oct	5.98	0.48	2.87	0.0	2.87
17-Oct	6.06	0.48	2.91	0.0	2.91
18-Oct	4.66	0.48	2.24	0.0	2.24
19-Oct	4.95	0.48	2.38	0.0	2.38
20-Oct	5.52	0.48	2.65	0.0	2.65
21-Oct	6.22	0.90	5.60	2.22	3.38
22-Oct	6.02	0.90	5.42	12.84	7.42
23-Oct	5.75	0.90	5.17	0.0	5.17
24-Oct	5.83	0.90	5.25	0.0	5.25
25-Oct	6.26	0.90	5.63	0.0	5.63
26-Oct	6.62	0.90	5.96	0.0	5.96
27-Oct	6.52	0.90	5.87	0.0	5.87
28-Oct	6.03	0.90	5.43	0.0	5.43
29-Oct	6.12	0.90	5.51	0.0	5.51
30-Oct	5.53	0.90	4.98	0.0	4.98
31-Oct	6.41	0.90	5.77	0.0	5.77
1-Nov	5.96	1.13	6.73	18.0	0.00
2-Nov	3.44	1.13	3.89	9.0	0.00
3-Nov	5.71	1.13	6.45	0.0	6.45
4-Nov	6.52	1.13	7.37	0.0	7.37
5-Nov	6.49	1.13	7.33	0.0	7.33
6-Nov	6.35	1.13	7.18	0.0	7.18
7-Nov	6.22	1.13	7.03	0.0	7.03
8-Nov	2.99	1.13	3.38	27.0	0.00
9-Nov	5.60	1.13	6.33	0.0	6.33
10-Nov	6.30	1.13	7.12	0.0	7.12

11-Nov	5.53	1.13	6.25	0.0	6.25
12-Nov	5.32	1.13	6.01	0.0	6.01
13-Nov	6.70	1.13	7.57	13.8	0.00
14-Nov	6.64	1.13	7.50	0.0	7.5
15-Nov	4.07	1.13	4.60	0.0	4.6
16-Nov	6.88	1.13	7.77	0.0	7.77
17-Nov	5.15	1.13	5.82	0.0	5.82
18-Nov	6.71	1.13	7.58	0.0	7.58
19-Nov	6.03	1.13	6.81	0.0	6.81
20-Nov	5.78	1.13	6.53	0.0	6.53
21-Nov	5.84	1.13	6.60	0.0	6.6
22-Nov	6.27	1.13	7.09	0.0	7.09
23-Nov	6.11	1.13	6.90	0.0	6.9
24-Nov	7.33	1.13	8.28	0.0	8.28
25-Nov	6.99	1.13	7.90	0.0	7.9
26-Nov	6.33	1.13	7.15	0.0	7.15
27-Nov	6.27	1.13	7.09	0.0	7.09
28-Nov	6.17	1.13	6.97	24.0	0.00
29-Nov	7.10	1.13	8.02	0.0	8.02
30-Nov	6.03	1.13	6.81	0.0	6.81
1-Dec	4.68	1.12	5.24	0.0	5.24
2-Dec	4.20	1.12	4.70	9.0	0.00
3-Dec	3.94	1.12	4.41	0.0	4.41
4-Dec	5.28	1.12	5.91	0.0	5.91
5-Dec	6.42	1.12	7.19	0.0	7.19
6-Dec	6.93	1.12	7.76	0.0	7.76
7-Dec	6.62	1.12	7.41	0.0	7.41
8-Dec	6.60	1.12	7.39	0.0	7.39
9-Dec	6.84	1.12	7.66	0.0	7.66
10-Dec	6.86	1.12	7.68	0.0	7.68
11-Dec	5.90	1.10	6.49	0.0	6.49
12-Dec	5.40	1.10	5.94	0.0	5.94
13-Dec	6.86	1.10	7.55	0.0	7.55
14-Dec	6.56	1.10	7.22	0.0	7.22
15-Dec	6.08	1.10	6.69	0.0	6.69
16-Dec	6.25	1.10	6.88	0.0	6.88
17-Dec	6.10	1.10	6.71	0.0	6.71

18-Dec	6.48	1.10	7.13	0.0	7.13
19-Dec	6.79	1.10	7.47	0.0	7.47
20-Dec	6.58	1.10	7.24	31.8	0.00
21-Dec	6.83	1.08	7.38	0.0	7.38
22-Dec	6.14	1.08	6.63	0.0	6.63
23-Dec	4.15	1.08	4.48	0.0	4.48
24-Dec	6.38	1.08	6.89	0.0	6.89
25-Dec	7.02	1.08	7.58	0.0	7.58
26-Dec	6.78	1.08	7.32	0.0	7.32
27-Dec	6.73	1.08	7.27	16.2	0.00
28-Dec	6.61	1.08	7.14	14.4	0.00
29-Dec	3.87	1.08	4.18	0.0	4.18
30-Dec	6.45	1.08	6.97	0.0	6.97
31-Dec	2.60	1.08	2.81	0.0	2.81

Appendix 4: Rainfall data for Nyandira

Year	Date	Rainfall mm
Sept 2014		
	1-Sep	0.00
	2-Sep	0.00
	3-Sep	0.00
	4-Sep	0.00
	5-Sep	0.00
	6-Sep	0.00
	7-Sep	0.00
	8- Sep	0.00
	9- Sep	0.00
	10- Sep	0.00
	11- Sep	0.00
	12- Sep	0.00
	13- Sep	0.00
	14- Sep	0.00
	15- Sep	0.00
	16 -Sep	0.00
	17- Sep	0.00
	18- Sep	0.00
	19- Sep	0.00
	20- Sep	0.00
	21- Sep	0.00
	22-Sep	0.00
	23- Sep	0.00
	24- Sep	0.00
	25- Sep	0.00
	26 -Sep	0.00
	27- Sep	0.00
	28- Sep	0.00
	29- Sep	0.00
	30- Sep	0.00
	1-Oct	0.00
	2-Oct	0.00

3-Oct	0.00
4-Oct	0.00
5-Oct	0.70
6-Oct	0.00
7-Oct	0.00
8- Oct	0.00
9- Oct	0.50
10-Oct	0.00
11-Oct	0.00
12- Oct	2.30
13- Oct	0.00
14- Oct	0.00
15- Oct	0.00
16- Oct	0.00
17- Oct	0.00
18- Oct	0.00
19- Oct	0.00
20- Oct	0.00
21- Oct	3.70
22- Oct	21.4
23- Oct	0.00
24- Oct	0.00
25- Oct	1.00
26- Oct	0.00
27- Oct	0.00
28- Oct	0.00
29- Oct	0.00
30-Oct	0.00
31-Oct	0.00
1-Nov	30.00
2-Nov	0.00
3-Nov	0.00
4-Nov	0.00
5-Nov	0.00
6-Nov	0.00
7-Nov	0.00
8-Nov	45.00

9-Nov	0.00
10-Nov	0.00
11-Nov	0.00
12-Nov	0.00
13-Nov	23.00
14-Nov	0.00
15-Nov	0.00
16-Nov	0.00
17-Nov	0.00
18-Nov	0.00
19-Nov	0.00
20-Nov	0.00
21-Nov	0.00
22-Nov	0.00
23-Nov	0.00
24-Nov	0.00
25-Nov	0.00
26-Nov	0.00
27-Nov	0.00
28-Nov	40.00
29-Nov	0.00
30-Nov	0.00
1-Dec	0.00
2-Dec	15.00
3-Dec	0.00
4- Dec	0.00
5- Dec	0.00
6- Dec	0.00
7- Dec	0.00
8-Dec	0.00
9-Dec	0.00
10-Dec	0.00
11-Dec	0.00
12-Dec	0.00
13-Dec	0.00
14-Dec	0.00
15-Dec	0.00

16-Dec	0.00
17-Dec	0.00
18-Dec	0.00
19-Dec	0.00
20-Dec	0.00
21-Dec	0.00
22-Dec	0.00
23-Dec	0.00
24-Dec	0.00
25-Dec	0.00
26-Dec	0.00
27-Dec	27.00
28-Dec	24.00
29-Dec	0.00
30-Dec	0.00
31-Dec	0.00

Appendix 5: Meteorological data at Morogoro station for Nyandira Traditional Irrigation schemes (Jan 2014- December 2014)

Month	Tmin °C	Tmax °C	Humidity %	Wind Km/day	Sunshine Hours
Jan	14.1	23.0	84	130	4.1
Feb	14.0	23.0	84	121	3.6
Mar	13.8	23.0	87	104	3.7
April	12.9	22.6	88	130	5.6
May	11.0	21.9	87	156	6.4
June	8.7	21.0	83	173	8.0
July	7.9	21.1	79	190	8.1
Aug	8.7	22.3	74	199	9.0
Sept	10.8	26.1	67	233	9.5
Oct	12.5	26.7	67	276	8.5
Nov	13.6	26.5	69	225	6.7
Dec	14.0	24.2	79	156	4.7
Average	11.8	23.4	79	174	6.9

Source: http://power.larc.nasa.gov/common/AgroclimatologyMethodology/ AgrParameter(s)

Appendix 6: 30 big users with water permits in Wami/Ruvu basin

S/N	Individual or Institution with water use permit	L/s
1	SEKAB Bioenergy Tanzania Limited	48 250.00
2	Azania Investment and Management ServicesLtd	41 800.00
3	Director of Water and Drainage Division	13 500.00
4	Sugar Development Cooperation	9080.00
5	Ruvu Valley Sugar Ltd	8895.28
6	Chama cha ushirika wa wamwagiliaji Mpunga Dakawa	5000.00
7	Mwenyekiti Halm Kijiji Tulo/Kongwa	5000.00
8	D.R.Singh	4430.00
9	DAWASA Lower Ruvu intake	3156.25
10	Mtibwa Sugar Estate Ltd	2500.00
11	SEKAB Bioenergy Tanzania Limited	2500.00
12	Mtibwa Sugar Estate Ltd	1500.00
13	District Development Director	1345.19
14	Meneja wa Shamba la Taifa la Mbegu	1140.00
15	DED Kilosa	1140.00
16	Mtibwa Estate	1135.00
17	Director General National Urban Water Authrity	1050.93
18	Mtibwa	1047.10
19	Alec Frances Misangu	1030.50
20	St. Philips Theological College	1010.00
21	Mtibwa Sugar Estates	990.5
22	Ingla Co Ltd	833.34
23	Mkindo Farmers Irrigation Scheme	624
24	Umoja wa wakulima wa Umwagiliaji-Mvumi	586
25	New Msowero Farm	566
26	Tanzania Sisal Cooperation,Ubena Zomosi Estate Ltd at Kate Sisal Estate	525.56
27	Dayaiji Purshotam Limited	431.58
28	DDD Chanzuru Ujamaa Village	424.5
29	Msagali Irrigation Scheme	411.6
30	Bagamoyo Distict Council	399.39

Appendix 7: Irrigation Frequencies

S/N	Name of Member	Crop	Time of Planting (Month)	Time of Harvesting (Month)	Irrigation Frequency per week	No. Months of Irrigatio n	Total No. of days of Irrigation
1.0	SospeterKidawahlo	Cabbage	April	July	1	2	8
		Tomatoes	August	December	1	4	16
		Maize	October	March	1	2	8
		Beans	August	December	1	4	16
2.0	Alfred Zacharia	Tomatoes	October	February	1	1	4
		Hoho	October	June	1	2	8
		Maize	July	December	1	4	16
		Peas	July	October	1	4	16
3.0	ConstantinoChung uke	Cabbage	June	October	1	4	16
		Cauliflower	March	June	1	1	4
		Irish potatoes	June	October	1	4	16
		Maize	June	December	1	4	16
		Tomatoes	September	December	1	4	16
4.0	Gaitani Luanda(Bokasa)	Tomatoes	June	October	1	4	16
		Cabbage	June	October	1	4	16
		Peas	June	October	1	4	16
		Maize	June	December	1	4	16
5.0	MedadiMkali	Maize	August	April	1	3	12
		Irrish Potatoes	May	August	1	4	16
6.0	Beatrice Joviti/KireguJoviti	Irish Potatoes	June	October	1	4	16
		Peas	June	October	1	4	16
		Tomatoes	September	December	1	2	8
7.0	Martin Gerald	Peas	September	December	1	2	8
		Beans	September	December	1	2	8
		Cabbage	September	December	1	2	8
		Peas	August	November	1	4	16
		Maize	August	March	1	3	12
8.0	Luanda Kitalubile						
9.0	KulwaRaymond	Peas	May	August	2	4	24
		Tomatoes	August	December	2	4	24
10.0	Peter DaudiDimoso	Peas	May	August	2	4	24
		Maize	June	December	2	4	24
		Cabbage	September	December	2	4	24
		Beans	September	December	2	4	24
11.0	Antoneta Stephen	Peas	April	August	1	4	16
			August	December	1	2	8
		Maize	June	March	1	4	16
		Beans	September /October	November/ December	1	2	8
		Cabbage	December	March	0	0	0

		Tomatoes	August	December	1	2	8
12.0	Editha Zeno	Beans	August	December	2	2	16
		Maize	August	February	2	3	24
		Peas	August	December	2	3	24
		Tomatoes	September	December	2	3	24
		Cabbage	March	June	2	2	16
13.0	Kevin Julius Mkuwe	Maize	July	March	2	4	24
		Cabbage	March	July	1	3	12
14.0	GalusTheofili	Peas	April	July	1	3	12
		Maize	July	January	1	4	16
15.0	Luanda Kifulubile/ Emmanuel Valelian	Peas	May	August	2	4	32
		Beans	July	October	2	4	32
		Tomatoes	July	October	2	4	32
		Maize	August	March	2	4	32
16.0	Julius Michael Mkuwe	Cabbage	April	July	2	3	24
		Peas	April	August	1	3	12
		Hoho	September	December	1	2	8
		Maize	May	November	1	6	24
17.0	Bubu/ Geroda Barnabas	Maize	June	February	1	4	16
		Cauliflower	April	July	1	3	12
		Peas	April	August	1	4	16
18.0	IsdoryMshindo	Beans	October	December	2	1	8
		Maize	October	April	2	1	8
		Tomatoes	October	December	2	1	8
		Peas	May	August	2	4	32
19	Michael Chamlungu	Tomatoes	August	December	2	3	24
		Peas	May	August	2	4	32
		Beans	April	August	2	3	24
		Maize	September	March	1	2	8
		Cabbage	August	December	3	2	24
		Cauliflower	June	September	2	4	32
20.0	Joseph Sanze	Cabbage	May	September	1	4	16
		Peas	May	September	1	4	16
		Beans	September	December	1	4	16
		Maize	September	April	1	2	8
		Tomatoes	September	January	1	2	8
21.0	James Masuza	Tomatoes	September	January	1	2	8
		Cabbage	April	August	1	4	16
		Maize	September	March	1	2	8
22.0	SarafiniLabangu	Peas	April/Aug	July/ November	1	3	12
		Maize	July/Aug	April/May	1	4	16
		Beans	September	December	1	2	8
		Tomatoes	September	January	1	2	8
23.0	Agatoni P. Maumba	Peas	April	August	1	4	16

		Cabbage	September	December	1	2	8
		Maize	September	March	1	4	8
		Irish potatoes	July	October	1	4	16
		Peas	November	February	0	0	0
24.0	Charles Mogha	Irish Potatoes	July	November	1	4	16
		Cabbage	June	October	1	4	16
		Maize	September	April	1	2	8
25	Simon Masharubu	Cabbage	May	September	1	4	16
			September	January	1	2	8
		Beans	October	February	1	1	4
		Peas	May	September	1	4	16
		Maize	July	March	1	4	16
		Salad	April	June	1	2	8
			July	October	1	4	16
26.0	Ferdinand Mtali	Irish Potatoes	February	May	1	1	4
		Chinese	March	April	0	0	0
		Peas	April	July	1	3	12
		Maize	July	March	1	4	16
27	Alexander Mitumbu	Cabbage	May	August	1	4	16
		Maize	June	March	1	4	16
		Beans	July	October	1	4	16
		Irish potatoes	June	October	1	4	16
		Peas	June	October	1	4	16
28	Ferdinand Kiruga	Cabbage	July	November	1	4	16
		Peas	July	October	1	4	16
		Beans	October	February	1	1	4
		Maize	July	March	1	4	16
29	Bosco George	Peas	May	October	1	4	16
		Beans	October	February	1	1	4
		Maize	August	March	1	3	12
		Tomatoes	September	January	1	2	8
30.0	Nathaniel Chamlungu	Cauliflower	June	September	1	4	16
		Tomatoes	September	December	1	2	8
		Cabbage	March	July	1	3	12
		Peas	June	September	1	4	16
		Maize	August	March	1	3	12
31.0	Nesfora Stephen	Cabbage	June	October	1	4	16
		Tomatoes	August	December	1	3	12
		Beans	August	November	1	3	12
		Maize	August	February	1	3	12
32.0	CansianaVitalis	Cauliflower	August	December	1	3	12
		Salad	August	December	1	3	12
		Beans	April	July	1	3	12
		Peas	April	July	1	3	12

Appendix 8: Fuku canal flow measurement

Height of water above the weir crest (cm)	Flow (l/s)	Remark
15.10	12.45	Flow at the intake
13.80	9.95	Below the intake
12.80	8.27	Below the intake
11.70	6.65	Junction to the field
10.60	5.19	Below the junction
8.90	3.35	Below the junction
7.84	2.46	End of canal

Appendix 9: Mbakana canal flow measurement

Height of water above weir crest (cm)	Flow (l/s)	Remark
15.50	13.42	Flow at the intake
14.85	12.00	Below the intake
13.35	9.22	Below the intake
12.87	8.42	Below the intake
12.00	7.08	Below the intake
11.43	6.27	Junction to the field
10.79	5.44	Below the junction
9.10	3.58	End of field

Appendix 10: Mzinga canal flow measurement

Height of water above weir crest (cm)	Flow (l/s)	Remark
13.8	9.87	Flow at the intake
11.74	6.54	Below the intake
11.24	6.01	Junction to the field
11.19	5.95	Below the junction
10.63	5.24	Below the junction
7.20	1.99	End of canal

Appendix 11: Nyamiseta canal flow measurement

Height of water above weir crest (cm)	Flow (l/s)	Remark
7.20	2.0	From source of the spring
6.50	1.6	Down the sources of spring
5.90	1.21	End of canal