MANAGEMENT PRACTICES OF IRRIGATION WATER AND THEIR EFFECTS ON WATER ALLOCATION AMONG FARMERS IN KILADEDA SUB-CATCHMENT, TANZANIA

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FEBRUARY, 2016

DECLARATION

This thesis is my original work and has not been presented for a degree or any other award in any other university.

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DEDICATION

I dedicate this thesis to my dearest mother Akama Ame Rajab. This work is also dedicated to my late father Juma Khatib Ame.

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ACRONYMS AND ABBREVIATIONS

AGRA	Alliance for a Green Revolution in Africa
ANOVA	Analysis of Variance
DAAD	German Academic Exchange Service
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIS	Geographical Information System
GPS	Global Positioning System
IFAD	International Fund for Agricultural Development
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
IWUE	Irrigation Water Use Efficiency
KWUC	Kiladeda Water Users Committee
m^3/s	Cubic metre per Second
Mm^3	Million Cubic Meter
MOWI	Ministry of Water and Irrigation
NSSP	Nigeria Strategy Support Programme
PBWO	Pangani Basin Water Office
RS	Remote Sensing
SD	Standard Deviation
SEI	Stockholm Environment Institute

SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SWAT	Soil and Water Assessment Tool
URT	United Republic of Tanzania
WEAP	Water Evaluation And Planning
WRMA	Water Resources Management Authority
WUAs	Water Users Associations
WWAP	World Water Assessment Program
WWR	Water Withdrawal Ratio

ABSTRACT

Irrigated agriculture plays a major role in the livelihoods of Kiladeda sub catchment, Pangani Basin, Tanzania. However, the sub catchment is experiencing a problem of inequitable distribution of irrigation water among farmers. The challenge is escalated by rapid population growth, economic growth, other water users and irrigation management practices. This situation has increased conflicts and insufficiency in irrigation particularly in downstream of the river. This study aimed at assessing the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub-catchment, Tanzania. Specifically, the study analysed socio-economic factors influencing irrigation water demand; examined irrigation management practices adopted by farmers and their effects on irrigation water demand; investigated irrigation water demand and allocation among farmers and evaluated strategies used to mitigate irrigation water demand and allocation disparities among farmers. The study employed both primary and secondary data. The primary data were collected by interviewing 150 farmers, key informant interviews and measurement of river discharge while secondary data were collected from relevant institutions in Moshi, Tanzania. Numerical tools for data analysis comprised of descriptive statistics, independent sample t-test, stepwise regression, content analysis and WEAP model. The stepwise regression results showed that farm location and farm size (13.5%); income and farm location (19.8%) and; farm ownership, education level and income (39.6%) were the predictors of irrigation water demand for the whole river, upstream and downstream zones respectively. On the other hand, all nine factors in the middle stream zone were eliminated by the model. The study also revealed that furrow irrigation (86.7%) and plastic buckets (13.3%) were the main irrigation techniques employed by farmers in the sub catchment. However, there was no significant difference between irrigation techniques adopted and irrigation water demand in the sub catchment ($p > 0.05$). On the contrary, there was a significant difference between irrigation water demand and irrigation techniques in upstream zone of the sub catchment ($p < 0.05$). The results of WEAP model revealed that the sub catchment has water shortage of about 53% of the total irrigation water required. The current annual irrigation water demand is 18.44Mm^3 and unmet demand is 9.8Mm^3. Both water demand and unmet demand are expected to increase twice in 2020. The high water demand for irrigation could be the main cause of excessive water abstraction in the upstream and downstream zones of the sub catchment. Moreover, the study identified water pricing, formation of water users associations, public education, reduction of farm sizes, changing crop types, water rights as well as laws and regulations on water allocation, as the main strategies implemented to reduce water demand and allocation conflicts. The study found that despite of water shortage in the sub catchment, water was not used efficiently for irrigation activities. Therefore, the study recommends partnering approach to improve irrigation water management; reviewing of laws, regulations and water rights to conform to the current irrigated areas and irrigation water requirements. More so, extension services to farmers should be improved. This will serve as a source of information and training forum for farmers on irrigation water management practices and therefore enhance efficient use of water for irrigation.

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1 Background to the Study

Water is a unique substance in the types of goods and services provided to mankind (Booker *et al.*, 2012). It is a basic natural resource for socio-economic activities such as industries, hydropower production, industrial production, irrigated agriculture, livestock keeping, mineral processing, navigation, recreation and tourism (MOWI, 2010). But its demand has already exceeded supply in nearly 80 countries with more than 40% population of the world due to an uneven distribution of water resources and population densities worldwide (Qadir *et al.,* 2010). Among the different uses of water, agricultural water use has been considered to be critical factor in assuring food security and protection against adverse drought conditions. It also important in sustaining incomes of farmers by providing greater opportunity for crop diversification (Hussain *et al.,* 2011). However, it is clear that agricultural uses of water particularly in irrigation agriculture are the most important off stream water uses that are placing an increasing pressure on the available water resources (Smith and McDonald, 2009; Booker *et al.*, 2012). In most developed and developing countries, irrigation agriculture is the largest consumer of available water (Michailidis *et al.*, 2010).

Globally, agriculture consumes more than 70% of the total water withdrawn for human activities (WWAP, 2012). About 270 million hectares are irrigated in the world, accounting for two-thirds of the total water consumption, which is currently estimated at 4 billion m^3 yr^{-1} (Perry, 2007). This represents 20% of total arable cropland which are under irrigation, producing about 40% of the global harvest (Sauer *et al.,* 2010). Moreover, recent studies show that global agricultural water demand will increase by

5% from 2,743 km^3 in 2008 to 3,858 km^3 in 2050 (FAO, 2011a, 2011b; WWAP, 2012). Thus, regions with water scarcity will be highly affected and this will lead to inefficient allocation of water and also increase the cost of water to the society (Sauer *et al.,* 2010).

In like manner, irrigated agriculture contributes significantly to the most Sub Sahara African (SSA) countries' economies, employments, and food supplies (FAO, 2008; IFAD, 2012a). It contributes an average of 30% of Gross Domestic Product (GDP) and 67% of employment in the region, thus, it is essential for accelerating agricultural growth and stabilizing the livelihoods of the region (Shah *et al.,* 2013). However, the proportion of water going to irrigated agriculture is often much higher. It accounts for more than 90% of the total water withdrawal (Perry, 2007; FAO, 2011b). Nonetheless, water availability for irrigation in Africa is already limited, and this is set to worsen in the near future (WWAP, 2012). Henceforth, several countries in SSA region are already facing absolute water scarcity, and water is distributed inequitably among farmers in the upstream and downstream reaches of rivers in many regions (Hamdy, 2005). Moreover, inequitable water allocation has also been identified as one of the causes of poor performance by some farmers in these countries. This consequently leads to water scarcity to less fortunate farmers located in the downstream reaches of river system. The increasing water scarcity has complicated irrigation water allocation and this subsequently has led to more people questioning its value (Hope *et al.,* 2008). The challenge is therefore to optimize the use of available water sources and to make water available during dry seasons (FAO, 2008).

Irrigated agriculture is the backbone of most of the East African countries. For instance, it contributes 25% of the GDP and 51% of total employment in Kenya (Ntale and

Litondo, 2013). It also contributes 40% of GDP and 80% of employment in Tanzania (URT, 2009). However, the demand for irrigation water is increasing alongside rapidly increasing populations. For example, agriculture consumes 92.9% of the total water withdrawn in Tanzania and 88.7% of this water is consumed by irrigation farming. Water availability for irrigation is a growing challenge in most countries in Africa (UN-Water, 2013). This situation has been attributed to insufficient and inappropriate irrigation infrastructure leading to low water use efficiency and water losses of about 85% of water (MOWI, 2008).

Furthermore, in the Pangani River Basin in Tanzania, irrigation agriculture is commonly practised by smallholder farmers (IUCN, 2009; Komakech *et al.*, 2012a). It consumes 400 to 480Mm^3 of water annually which is more than 80% of total water abstracted from the Pangani river (IUCN, 2009). This share is higher than any other uses. Farmers utilise most of the available water but with very low efficiencies leading to water stress (Komakech *et al.,* 2012a). Most of the irrigation water is used for growing a variety of crops such as coffee, banana, maize, flowers and vegetables (Kulindwa, 2005). Nonetheless, despite the big amounts of fresh water available, farmers are still faced with shortages of water in Kiladeda sub catchment in the Pangani river basin (DAAD, 2009). This has been attributed to rapid population growth, expansion of agriculture and limited understanding of the irrigation water demand in the sub-catchment. The increase of irrigation water demand in the sub catchment which is associated with the rapidly growing population and competition between domestic and agriculture sectors has amplified the need for a better water resource management which lies under principles of IWRM in order to avoid damaging the performance of the irrigated sector. Since the area has scarce information on irrigation water demand, this study sought to assess the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub catchment of the Pangani Basin for holistically and sustainable water management.

1.2 Statement of the Problem

Although irrigation agriculture consumes more than 70% of water in Pangani Basin, the area is still experiencing a growing irrigation water. In Kiladeda sub-catchment, the demand for irrigation water has increased enormously causing serious water allocation challenges. Thus, the sub catchment has often experienced a problem of inequitable distribution of irrigation water among farmers (DAAD, 2009). These challenges are escalated by rapid population growth, economic growth, other water users sectors and irrigation management technologies adopted by farmers. This has increased conflicts and water insufficiency for irrigation particularly in the downstream part of the sub cacthment. Can people of Kiladeda sub catchment meet their food security without equitable water allocation among irrigated farmers? The need to understand the irrigation water demand management practices and their effects on water allocation among farmers in Kiladeda sub catchment is the purpose of this study so as to provide appropriate measures of irrigation water management towards sustainable development based on the principles of IWRM.

1.3 Justification of the Study

The study was motivated by the need to understand the water conflict due to an inequitable water distribution situation among irrigating farmers in Kiladeda sub catchment. This is necessary because the irrigation agriculture is the backbone of the economy of the people of Kiladeda. The river plays a vital role of providing water for agricultural activities of the sub catchment. The other motives for conducting this study in Kiladeda sub-catchment were; Firstly, Kiladeda sub-catchment has rapid population growth due to high population growth rate in Kilimanjaro region is 1.8%. The population has increased from 1,376,702 in 2002 to 1,640,087 people in 2012 (URT, 2013). This has increased the demand for irrigation water and other uses. Secondly, the river is experiencing water over abstraction as a result of increased irrigation activities. This has placed the river under water stress and in the recently years there has been a decline in the river flow (Mromba, 2012). Lastly, the sub catchment has experienced a rapid expansion of land under cultivation and this has increased the demand of water for irrigation. The agricultural land use of the sub catchment has increased from 10.9% in 2000 to 13.3% in 2009 (Chiwa, 2012). Therefore, the study was carried out in order to provide the framework for water sharing in the sub catchment and to model the available water for irrigation farming. This is because the national strategies are geared to ensure an equitable water allocation for farming activities that can fulfil the water demand and reduce water use conflicts among the farmers in the sub-catchment areas.

1.4 Research Hypotheses

The study evaluated the following hypotheses:

$H_0$1: There is no significant relationship between socio-economic factors of farmers and irrigation water demand in Kiladeda sub-catchment.

$H_0$2: There is no significant relationship between irrigation management practices adopted by farmers and irrigation water demand in Kiladeda sub-catchment.

1.5 Research Questions

The study was guided by the following research questions:

i. How do socio-economic factors influence irrigation water demand in Kiladeda Sub-catchment?

ii. What are the effects of irrigation water management practices adopted by farmers in Kiladeda Sub-catchment?

iii. Is there difference between irrigation water demand and allocation among upstream, middle and downstream farmers in Kiladeda sub-catchment?

iv. Which strategies are used to mitigate irrigation water allocation disparities among farmers in Kiladeda sub catchment?

1.6 Objectives of the Study

1.6.1 General Objective

The main objective of this study was to assess the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub-catchment for efficient and sustainable water use.

1.6.2 Specific Objectives

This study had the following specific objectives:

i. To analyse the socio-economic factors influencing irrigation water demand among farmers in Kiladeda Sub-catchment.

ii. To examine irrigation water management practices adopted by farmers and their effects on irrigation water demand in Kiladeda Sub-catchment.

iii. To investigate irrigation water demand and allocation among upstream, middle stream and downstream farmers in Kiladeda sub-catchment.

iv. To evaluate strategies used to mitigate irrigation water allocation disparities among farmers in Kiladeda sub catchment.

1.7 Significance of the Study

Kiladeda River is the main source of water for irrigation and domestic uses. Thus, an assessment of irrigation water demand is important for proper water allocation. Therefore, the findings of this study provided useful information that may help to mitigate the problem of inequitable distribution of water for irrigated agriculture. Again, the findings and recommendations that the researcher made in this study may enhance effective irrigation water management technologies and proper irrigation schedule that may reduce illegal water abstraction in the river. Moreover, the study contributed to basic knowledge of irrigation water use and availability to the farmers that can be useful for enhancing irrigation water use efficiency. In addition, the findings of this study added information on irrigation water use and allocation to Pangani river basin management and policy makers, therefore, provided contribution to water demand and allocation policy for optimal and sustainable water use in the sub catchment.

1.8 Scope and Limitations of the Study

This study was concentrated on the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub-catchment, Pangani river basin, Tanzania. The study covered small scale irrigation farming. Small scale irrigation was chosen because it is done in farmer's homeland and involves large number of farmers in the sub catchment. The study considered a survey of farmer's socio-economic factors, irrigation technologies adopted and measures used to mitigate water allocation disparities among farmers using questionnaire and key informant interviews. The study used WEAP model to investigate irrigation water demand and allocation among farmers. Secondary and primary data were obtained from Pangani Basin Water Office, Moshi Meteorological Station and through the measurement of river discharge.

The limitation encountered in conducting this study was indistinguishable criteria that were used to divide the Kiladeda sub catchment areas. In order to overcome encountered barrier, this study divided the sub catchment into three zones according to the agro ecological factor and altitudes to differentiate the upper, middle and lower zone of the area.

1.9 Operational Definitions of the Key Terms and Concepts

Allocation scenarios: These are alternative sets of assumptions that affect irrigation water demand and allocation.

Irrigation Water Management Practices: These are the methods or innovative inventions which enhance crop production, optimal water use and allocation that reduce demand for irrigation water.

Irrigation Water Demand: Is the amount of water required to reach the farmers for fulfilling irrigation purpose.

Irrigation Water Use: Is the actual amount of water reaching the farmer which is used for irrigation purposes.

Irrigation Water Demand Management: This is the method which improves efficiency and sustainable water use for irrigation.

Water Users: These are individuals, associations, government agencies and farmers that use water within the sub-catchment for various purposes.

Water Allocation: Is the quantity of water allocated to irrigating farmers. It may meet the desired quantity for irrigation purpose or not.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section focuses on the review of previous research works done by scholars related to irrigation management practices, irrigation water demand and allocation. It also describes the conceptual framework for irrigation water management, types of irrigation water management technologies and their influence on irrigation water demand and allocation, and mitigation measures of water demand and allocation disparities. It also identifies research gaps from previous studies.

2.2 Conceptual Framework for Irrigation Water Demand

There are various drivers which affect water demand and allocation for irrigation. For example, Adeoti (2009) indicates that socio-economic factors such as education, gender and household size affect irrigation water demand and allocation. Brooks and Brandes (2011) mentioned that population growth is a key factor which increase irrigation water need. Similarly, farm characteristics such as farm size, type of crops, farm position and farm ownership influence the amount of water and irrigation technologies to be used (Ramirez *et al.*, 2008). Again, river over abstraction and adopted irrigation technologies are the major drivers which cause pressures on the demand and allocation of water in the river (Matekole, 2003; Mromba, 2012). These drivers increase water competition, inequitable water distribution and conflicts among farmers.

Hence, to resolve the situation, measures such as implementation of policies, regulations and bylaws on the allocation and the use of water are required to ensure proper water management. Again, adjustments mechanisms such as changing of planting dates and growing of high value crops are important to be used by farmers

(Mutiga *et al.*, 2010). In addition, effective WUAs are important to enhance water management since they encourage efficient water use and equitable water allocations (Inocencio *et al.*, 2007; Ward, 2010). It is therefore, important for this study to examine variables that influence water demand and allocation for irrigation in Kiladeda sub-catchment as described in Figure 2.1.

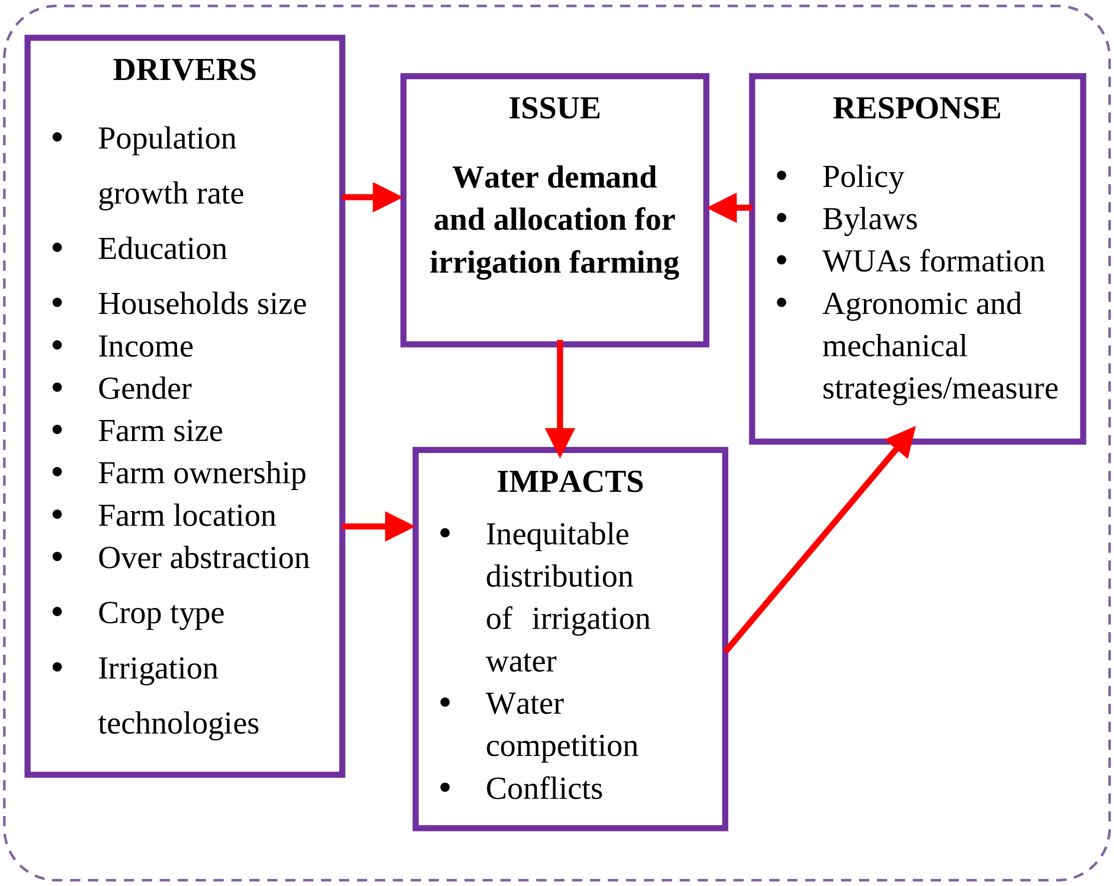

Figure 2.1: Conceptual framework of water demand for irrigation (Adopted and modified from Kristensen, 2004).

2.3 Empirical Studies on Irrigation Water Demand and Management

Irrigation water and its managed use have been an essential factor in raising the productivity of agriculture. It has therefore been considered to be a powerful for socio-economic development in developing countries (AGRA, 2013). In this regard, Speelman (2009) evaluated water use efficiency and its influence on the management policies for the small-scale irrigation in South Africa. He used Tobit model to explain the efficiency of water use in terms of various farm and farmer characteristics. The results showed that cultivated area (farm size), landownership and crop type have a significant impact on the irrigation water use efficiency. Socioeconomic characteristic such as age, gender and educational level were rejected by the model and therefore had no significant impact on water efficiency in the study (Speelman, 2009).

More so, Chebil *et al.* (2012) conducted a similar study on irrigation water use efficiency in collective irrigated schemes of Tunisia. They employed non parametric Data Envelopment Analysis model and Tobit regression. The findings revealed that education, agriculture extension services and income were potential determinants of irrigation water use in Tunisia. They also noted that land tenure, farmer's age and farm size did not significantly influence irrigation water use. However, the gap noted was that, the study did not determine the effect of gender and household size on the irrigation water demand and allocation.

International Union for Conservation of Nature and Natural Resources (IUCN) conducted a situation analysis of Pangani Basin, Tanzania in 2009. The study used GIS and Environmental Flow assessment tool aimed at identifying the resources in the river basin, the processes and events that affect the resources. The study found that irrigation farming is practiced much by traditional furrows which are highly inefficient and lose as much as 85% of water. The study also noted that Basin's water is threatened by extremely high demand that have led water stressed condition of the water resources. This was confirmed later by Komakech *et al.* (2012a) that the main sources of water stress and increased water demand in the basin are inefficient furrow irrigation systems. The IUCN (2009) study calls for integrated river basin management which involves the consideration of both utilisation and conservation of water resources together. Nevertheless, the study did not indicate alternative irrigation technologies and allocation systems to be used to rescue water

Besides, Mromba (2012) conducted a study on the effects of water abstraction on riparian vegetation along Kiladeda River in Pangani Basin. The study adopted regression analysis, water withdrawal ratio and percentage flow reduction as analytical tools. The results indicate that water abstraction in upstream and middle stream was very high compared to downstream of the river. The findings also indicate that there was strong relationship between increasing water abstraction and declining river discharge. This is because the river has been altered by human uses particularly irrigation farming. The study recommended water right allocation review to conform to the current irrigated areas and water requirements which can be supported with the regular auditing and assessment of water availability in the river and uses in irrigation furrows. The reform of water right allocation system was also recommended by Shaghude (2006) who noted that the basin is under water stress due to increasing water demand for various socio-economic activities. However, the study did not determine water demand leading to over abstraction of the river water, and it did not provide quantitative data revealing the amount of water consumed and demanded for irrigation farming.

Moreover, Matekole (2003) examined factors influencing irrigation technology and water management in Georgia. He employed multivariate linear regression model to estimate the degree to which certain factors influence irrigation water use and to assess the relationship between irrigation water use and farmers' water-related managerial considerations. The study points out the strategies and techniques used to control irrigation water demand and use. The results showed that higher pumping costs as an econometric measure for water saving are accompanied by reducing irrigation water use. Conversely, the gap identified in the study is the failures to probe legal aspects such as policies and bylaws as measures of reducing irrigation water use. As well, the study did not consider effects of irrigation technologies on water demand and allocation process. This study seeks to further examine different irrigation water management practices adopted by farmers and their effects on irrigation water demand and allocation among farmers in the sub catchment to enhance sustainable irrigation water use.

Table 2.1: Summary of Selected Key Empirical Studies and Gaps identified

S/N	Author(s)/place	Methods	Summary of Findings	Gaps Identified
1	Matekole (2003). Georgia	Multivariate linear regression model	The higher pumping costs (economic measure) are accompanied by reducing irrigation water use.	The study did not address legal aspects such as policies and bylaws as measures of reducing irrigation water use. Also, It did not consider effects of irrigation technologies on water demand and allocation process.
2	IUCN (2009). Pangani Basin, Tanzania	GIS and Environmental Flow assessment tool	Irrigation is practiced much by traditional furrows which are highly inefficient and lose as much as 85% of water.	The study did not indicate alternative irrigation technologies and allocation systems to be used to rescue water loose.
3	Mromba (2012). Kiladeda, Pangani Basin, Tanzania	Descriptive, regression analysis, content analysis, percentage flow reduction and WWR.	The result indicates that water abstraction in the upstream and middle stream was very high compared to downstream	The study focused on the effects of water abstraction on the riparian vegetation. It did not explain on the water demand leading to over abstraction.
4	Chebil *et al.* (2012). Zaghouan, TUNISIA	Non parametric Data Envelopment Analysis model and Tobit regression.	The findings suggested that education, income, land tenure and irrigated area determine irrigation water use	The study did not determine the impact of gender and household size on allocation mechanism of irrigation water use/demand

Source: Synthesis of Literature

2.4 Socio-Economic Factors Influencing Irrigation Water Demand

Socio-economic characteristics of farmers are the major factors affecting the irrigation water use. These factors are used in decision of adopting irrigated agricultural technologies and have great influence on water demand in irrigation farming as noted by many scholars (Mendola, 2005; Calatrava-Leyva *et al.,* 2005). This is because; water demand for any uses is based on the behaviour of the community. Therefore, increase water competition among the users (Mendola, 2005). It has also been noted by Mosa *et al*. (2013) that in addition to technical, social and cultural factors effect water use through acceptance, employing and continuation of irrigation technology adopted by farmers.

For instance, farmers with different socio-economic status, regardless of their proximity to water resources, are affected by different access to irrigation water and the use of irrigation technology to control water. Thus, mutual relationship between irrigation water, irrigation technology and social factors must be given special attention (Ramirez *et al.*, 2008). Socio-economic factors affecting irrigation water demand and uses are such as education, income, gender, age, household size, farm ownership, farm location, farm size and crop type (Ramirez *et al.,* 2008; Adeoti, 2009; Rockaway *et al.,* 2011; Schaible and Aillery, 2013). Therefore, the effects of the individual factor on the irrigation water demand (use) and allocation are discussed in this section.

2.4.1 Education

Education enhances the capacity of farmers to adopt appropriate water conservation technologies by enhancing the ability to obtain, understand and utilise these practices, and improving overall managerial ability of farmers (Alufah, 2010; Rockaway *et al.*, 2011; Getacher *et al.*, 2014). Thus, by utilizing proper water conservation and usage practices, farmers would be able to reduce irrigation water use. Moreover, educational attainments contribute to attitude to sustainable water use habit and technologies decision-making that can reduce water demand (Rockaway *et al.*, 2011). Aslan *et al*. (2007) investigated that innovation adoption is faster and more frequent among farmers with a higher level of education than those who are not educated. In addition, education level of farmers have positive and significant impact on irrigation water use efficiency in the farm (Chebil *et al.*, 2012). Therefore, education promotes farmers in adoption of affordable irrigation management practices. Chebil *et al*. (2012) concluded that variability of education level of farmers have positive and significant impact on irrigation water use efficiency (IWUE) in Tunisia. There is positive coefficient of education variable, implying that the high education to farmers increases water use efficiency.

2.4.2 Income

Income of a farmer is a critical variable for assessing the potential of socio-economic impact on irrigation water use and demand in the communities. Income is believed to be a major constraint to adopt improved technologies of irrigation in developing countries and therefore, associated with increasing irrigation water use (Adeoti, 2009). Jansen and Schulz (2006) found that farmer's income is the main determinant of water consumption and demand for irrigation by controlling the uses and management options of water in the farm. Also, a study by Ramirez *et al.* (2008) found that income of farmers results in irrigation water use restrictions. Therefore, farmers of less income and for whom farming is the main source of income appear to use water in efficient manner.

This means low income farmers use less water per unit of area. Hence, there is positive relationship between irrigation water use, and technology adoption and income of farmers (Adeoti, 2009).

2.4.3 Household size

Individual differences between households influence their water demand (Jansen and Schulz, 2006). Normally, household size is relevant in water demand and allocation because of its effects on the amount of water required in irrigation farming and other supplementary domestic uses. High number of people in the house leads to huge amount of water use. Moreover, according to the study conducted by Adeoti (2009) in Ghana concerning irrigation water management using Treadle pump showed that the number of people in the households are expected to affect adoption decisions of irrigation water management practice that has impact on water use. This conforms the findings of Aseyehegn *et al*. (2012) in Ethiopia that household size and labour availability are important factors influencing households' decision to adopt small-scale irrigation technologies. Therefore, there is positive association between household size and irrigation technology adoption, and irrigation water use.

2.4.4 Farm ownership

Farm ownership affects irrigation water use decisions and potential irrigation water management as well (Ramirez *et al.*, 2008). It was noted that farm ownership and irrigation technology choice are key factors in the water demand estimation. This is because; farm ownership determines the irrigation technology adoption and water use efficiency (Belay and Beyene, 2013). For instance; farmers who own the land have a longer-term planning horizon and are thus more inclined to make a careful use of this finite resource than those who do not own the land. In addition, farm ownership has deterred farmers from investing in irrigation water management which would reduce water use.

2.4.5 Farm size

The size of irrigated land is expected to influence irrigation water use efficiency, water conservation programs and water policy goals to be implemented (Schaible and Aillery, 2006). It also affects irrigation system improvements and irrigation techniques adoption which largely determine the amount of water used for irrigation (Schaible and Aillery, 2013). For example; farmers with large farms may be in better position to adopt system improvement and hence reduce water use, though, they account for more water than the smaller one requires. Therefore, this confirms the results of Abu-Madi (2009) on farm-level perspectives regarding irrigation water prices in the Tulkarm district, Palestine that the farm size is inversely correlated to water consumption. Moreover, Price and Moore (2009) analysed irrigation water usage in two dimensions of farm type and farm size in Georgia. They found that large farms are more efficient while small farms tend to be less efficient in water usage which was measured on the basis of average number of hours irrigated per acre. Thus, large farms often are believed to maximize the use of irrigation water than small farms.

2.4.6 Gender

Gender is believed to influence irrigation water use because it exerts more influence in water management and irrigation policy (Sultana, 2012). Men and women have different priorities for water use in irrigation (IFAD, 2012b), while men prefer to use water to irrigate cash crops, most women like to use water to irrigate home gardening.

Therefore, women are often interested in using irrigation water for purposes other than irrigating field crops. However, Nigeria Strategy Support Programme (NSSP) reported that irrigation is a predominantly male affair, female farmers tend to use traditional water lifting device such as bucket in contrast to their male counterparts who tend to use modernized technologies (NSSP, 2010). The idea is supported by the study of Adeoti (2009) on factors influencing irrigation technology adoption in Ghana who also found that irrigated farming is male dominated with the percentage of males generally high in different parts of Ghana.

Belay and Beyene (2013) used the probit model to study small-scale irrigation and household income linkage. The results show that gender of the household head had a significant positive effect on the use of irrigation water. Male-headed households had relatively more active on the irrigation water use than their counterpart. It has also been noted by (IFAD, 2012b) that in most developing countries, access to water for productive use in particularly irrigation farming is dominated by men. This leads to inequitable water resources allocation which increase demand for irrigation water to women rather than men due to failure of incorporating appropriate gender strategies (Zwarteveen, 2006; IFAD, 2012b). However, a number of initiatives have been made to introduce irrigation controlled by either poor people in general or, more specifically, by poor women in developing countries (Sultana, 2012).

2.4.7 Age

In many cases, the behaviour and decisions made by individuals differ substantially according to age factor. The age of a farmer might play a mostly imperative role in the decisions that could be implemented in regard to water use and demand for irrigation farming (Ramirez *et al.*, 2008). It influences the quality of decision and farmer's attitude towards accepting the new irrigation water use innovations (Ahmed *et al.*, 2012). This implies that it has a vital role on the efforts to reduce agricultural water use especially in irrigation. Study conducted by Owilla (2010) noted negative association between farmer's age and water use in Mwea irrigation scheme in Kenya. He also noted that, old farmers tend to be more restricted to irrigation water use than their younger, and hence use water efficiently. Similarly, Adeoti (2009) studied factors influencing irrigation technology adoption and its impact on household poverty in Ghana. He reported negative relationship between age of farmers and irrigation technology adoption which has an effect on the water use for irrigation farming. More so, studies conducted by Ahmed *et al.* (2012) and Ahmed *et al.* (2013) on the factors influencing farmers' treatments to use irrigation water and tenants' conceptions in using irrigation water in River Nile State, Sudan found the negative correlation between a farmer's age and irrigation water use as well as irrigation technology adoption. Therefore, farmer's age is anticipated to be positively linked with less water use, and hence greater efficiency.

2.4.8 Farm Location

The average farm distance (farm location) from the irrigation water source had an implication for access to irrigation water (Belay and Beyene, 2013). Farmers who are closer to the irrigation source do not suffer much to irrigate their farms than those who are very far from the source. This has an implication on water availability for farmers with different positions along the course of the irrigation area. Belay and Beyene (2013) study found that much water was diverted by upstream farmers whose farms are near to the irrigation water source than by downstream farmers. This is because distance of their farms from the water source was smaller than downstream users. This conformity was also observed by Owilla (2010) in Mwea irrigation scheme in Kenya who found that farmers located far distance from the water source and at downstream are more vulnerable to water shortage and therefore irrigate their farm less often. This means that the quantity of irrigation water is affected by the location of the farm along the water source.

2.4.9 Crop Type

The type of crop is among the main factors that influence the irrigation water use and effectiveness of irrigation practices. It also has an influence on irrigation system design and management (Scherer *et al.,* 2013). The crop type not only has an influence on the daily water need of a fully grown crop but also has an influence on the duration of the total growing season of the crop. Each crop has different water requirement, however, this vary from one season to another due to changes in climatic variables. For example, crops like rice or sugarcane need more water than crops like beans and wheat. Schaible and Aillery (2013) in their study on irrigated agriculture (water use, costs, and technology) noted that irrigation water use efficiency and types of irrigation system used tend to vary based on type of crops irrigated. On the contrary, Abu-Madi (2009) did not find correlation between irrigation water use and type of crops cultivated. However, it is possible to determine how much water farmers need by observing the type of crop that is irrigated.

2.5 Practices of Irrigation Water Management

Practices of irrigation water management are important element of irrigation farming. This is because, they help farmers to increase yields and income, and diversify their cropping and livelihood options (Evans *et al.,* 2012). The management practices also help to control the amount and frequency of irrigation water use (Irmak *et al.*, 2007). They increase water conservation and saving of limited water resource, enhances distribution and supply of irrigation water on farmlands thus can be easily reducing water need and save money (Brooks and Brandes, 2011). According to Matekole (2003) irrigation water management practices are the technological methods and innovative inventions which enhance crop production, optimal water use and allocation that reduce demand for irrigation water. Various irrigation management practices are available to enhance the efficiency of applied water in irrigated agriculture are explained by scholars.

For instance, Matekole (2003) mentioned advanced and traditional practices of irrigation water management that can improve water use efficiency such as gravity system, sprinkler, drip, flood irrigation, buckets and watering cans. More so, Osteen *et al.* (2012) categorized the practices of irrigation water management into four basic methods namely, surface (flood), sprinkler, trickle and subsurface. Surface or flood irrigation includes, furrow, basin, border and contour levee.

Further, Hornidge *et al.* (2011) and Evans *et al.* (2012) asserted that RS and GIS have become more widespread techniques for irrigation water management in various areas of the world nowadays. RS and GIS data are used to improve the performance of irrigation water management. Nonetheless, the efficiency of irrigation water management can vary widely depending upon soil, topography, crop, climate, and management characteristics. For example, the advanced irrigation management practices require capital and increased management costs while the traditional practices often require only minimal maintenance of conveyance systems. However, study conducted by Matekole (2003) showed that advanced irrigation water practices provide opportunities in lowering water use compared to traditional irrigation practices. Therefore, improved irrigation water management practices successively impact positively on irrigation water use.

Besides, Adeoti (2009) suggested that traditional practices are suitable to small-scale farmers who usually irrigate relatively small farms and operate in small capital. This was also observed by Kadigi *et al.* (2012) who noted that though advanced practices of irrigation water management have the potential to increase productivity and increase water use efficiency, they are not affordable to the majority of farmers in Sub Saharan African countries. This implies that advanced practices are manageable to those farmers who can afford operational costs of the technologies. On the contrary, lack of simple and affordable irrigation techniques for small scale farmers is a serious limiting factor for achieving food security and water saving goal (Getacher *et al.*, 2014). This is because, poor irrigation techniques are the major drivers which cause pressures on water demand for irrigation in the water sources leading to water shortage to the farmers (Matekole, 2003). This was observed by Evans *et al.* (2012) in Ethiopia that some irrigation schemes are not functioning due to damaged structures and poor water management. However, Kadigi *et al.* (2012) argued that the major problem which hinder farmers from taking part in the water management include lack of knowledge of the water management practices. Therefore, this study endeavoured to examine irrigation water management practices adopted by farmers and their effects on irrigation water demand in Kiladeda Sub-catchment to enhance the efficient irrigation water use.

2.6 Irrigation Water Allocation

Allocation of limited water resources for sustainable water use is an issue of increasing concern in many countries (Conway *et al.,* 2009; Speed *et al.,* 2013). This is because the demand for water is growing with population growth and income growth (Smith *et al.,* 2010; Freebairn, 2011), thus leading to inadequate water supply. Many farmers in the river basins in East Africa face water allocation challenges. For instance, Kadigi *et al.* (2004) and Mutiga *et al.* (2010) noted a serious water shortage to the downstream farmers in Ruaha, Pangani and Upper Ewaso Ng'iro Basin.

According to FAO (2004), water allocation is done by considering several criteria in the river basins based on the equity in allocation process and flexibility in the allocation of supplies system to the users. It can also consider water availability and use in the river. Nevertheless, integrated water management modelling methods for evaluating water allocation capabilities of the river systems becomes essential for effective water allocation nowadays (Mounir *et al.,* 2011). One of the important integrated water management tool used is Water Evaluation and Planning (WEAP) model.

WEAP model is an integrated water management tool for evaluation of water use and allocation (SEI, 2012). It governs the allocation of available water to meet the different water needs of farmers (Mounir *et al.,* 2011). The model was selected for this study due to its two primary functions (Yates *et al.,* 2005), namely: simulation of natural hydrological processes (evapotranspiration, runoff and infiltration) to enable assessment of the availability of water within a sub catchment and, simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use. It uses a wide range of hydrological, demographic and meteorological data to simulate water demand and allocation (Yates *et al.,* 2005).

Recent studies show that WEAP model has been used in many basins to compute water demand and allocation. For instance, Azlinda and Mohd (2012) investigated the water demand and allocation trend in Langat catchment, Malaysia. They also assessed water availability and storage capacity in the catchment. They found that Langat catchment is relatively sensitive to the growth of demands, suggesting that the slight changes in population growth will alter the present water availability. More so, Mutiga *et al.* (2010) applied WEAP model to evaluate water resources development based on an equilibrium scenario of the current water demand in Upper Ewaso Ng'iro, Kenya. They simulated water use of five different sectors (domestic, livestock, wildlife, irrigation and reserve). The analyses revealed that high water demand for irrigation was the main cause of excessive water abstraction particularly in the upstream of the catchments, giving rise to water shortages and consequently, water use conflicts downstream.

In addition, Ndiiri (2011) employed WEAP model to assess the impacts of possible water demands on the water resources of the Mara catchment. She found that the irrigated agriculture development will increase water shortage in the catchment of by about 65%. Therefore, this study employed WEAP model to investigate irrigation water demand and allocation among farmers in Kiladeda sub-catchment in Tanzania.

2.7 Strategies for Mitigating Disparities between Water Demand and Allocation

Implementation of demand management strategies for irrigation water use is of crucial importance for maintaining food security and attaining national level policy goal. Demand management strategies improve irrigation water use and allocation services because they provide the most available path to meet future demands and achieving water savings in agriculture (Speelman, 2009). According to Dziegielewski (2011) any activity, practice, technological device, law, or policy that can potentially reduce water use can be considered as a demand management (or conservation) strategy. Therefore, strategies for water demand and allocation management among irrigation farmers to enhance water use efficiency involve mechanical, managerial and agronomic aspects.

In this regard, Celio (2009) and Kadigi *et al.* (2012) suggested that the challenges of effective management and allocation of the available water resources can be addressed through development of policies that encourage better water resources management. These laws must be designed and implemented to allow water allocation while achieving required demand and social objectives (Caponera, 2007). Also, Calzadilla *et al.* (2011) conducted study on water scarcity and the impact of improved irrigation management in African regions. They analysed the extent to which improvements in irrigation management would be economically beneficial and the amount of water savings that could be achieved. The results show that water policy directed toward improving irrigation efficiency led to regional water savings, though it was not beneficial for all regions. More so, a related study by Gersfelt (2007) in Egypt concluded that policy instruments consideration can be used to achieve an efficient allocation of irrigation water to farmers in developing countries. However, the implementation of policy to manage irrigation water demand and allocation is determined by economically and politically matter (Freebairn, 2011).

Moreover, based on the Organisation for Economic Co-operation and Development (OECD) (2010) water policy guidelines for sustainable management of water resources. Water policy development should consider the following criteria:

- Policies need to consider the complexity and heterogeneity of water resources and the linkages between quantity and quality; and should shift to include more demand aspects.
- Agriculture and other water users need to cover the full cost of water supplied including delivery, maintenance and infrastructure.
- There should be a greater integration of policy across sectors such as agriculture, energy and environment.
- Increase the knowledge base of water resources and costs to better manage water and make appropriate policy

On the other hand, WUAs are important for reducing water allocation conflicts and have been recommended by various scholars (Inocencio *et al.,* 2007; Mutiga *et al.,* 2010; Veldwisch, 2010). Mutiga *et al*. (2010) suggested the formation of water resource users associations in Upper Ewaso Ng'iro North Basin, Kenya as it incorporates ideas from different stakeholders who can easily solve the problems. Also, water resource users associations enhance users' involvement and participation in designing and implementing development of water use goals for the basin. In addition, WUAs increase water management, water use efficiency, coordinate water distribution and equitably collects water charges from members to improve irrigation services and infrastructure (Wang *et al.*, 2010).

Besides, water pricing mechanisms have been used as the primary means to regulate irrigation water consumption in several regions (Zhang, 2013). Water pricing was shown to be an efficient instrument in controlling water use. Water prices can either cover the costs of supplying water or reflect the real water resources value and also reflecting the resource scarcity. Freebairn (2011) suggested that efficient allocation of water among different uses and users requires application of the standard economic principle (pricing) of water across the different uses and users. This idea supports the findings of Matekole (2003) from his study on factors influencing irrigation technology and water management in Georgia. He found that economic measures (cost of water) are accompanied by reducing irrigation water use. Similarly, Abu-Madi (2009) pointed out that increasing irrigation water prices could influence water consumption and thus make water available for non-agricultural (more economic) uses in Palestine. However, Brandes *et al.* (2010) noted that increasing water price greatly expands the potential for demand management.

Furthermore, agronomic measures are widely documented to enhance water demand and allocation. Agronomic measures also used to reduce water conflicts among farmers (Mutiga *et al.*, 2010; Veldwisch, 2010). These measures are such as, changing of planting date, changing crop patterns (move to crops that need less or no irrigation), and increase drought tolerate crops. These methods can be extensively used in the sub catchment to cater for water shortage claims among farmers since they enhance water saving.

Also, the uses of alternate sources of water have been extensively used to cope with increasingly water demand. For instance, Shah *et al.* (2013) observed that farmers in SSA depend on rain water (rain fed irrigation) as alternate irrigation option because of lack of access to other waters. In this end, Mutiga *et al.* (2010) recommends that rainwater harvesting should be promoted in the basins in order to improve water availability for productive use.

Indeed, engineering solutions such as water diversions and storage are potential methods to reduce water allocation problems (Smith *et al.,* 2010). Study conducted by Hamdy (2005) on water use efficiency in irrigated agriculture recommends engineering measures which can be used to control irrigation water use and allocation, and enhance irrigation efficiency. These measures include furrows lining, improvement of irrigation structures and reconstruction of irrigation systems. In conclusion, environmental education also plays an important role in examining the efficient use of water resources. The literature revealed many areas where environmental education has managed to conserve and enhance the better use of available water resources (Hamdy, 2005). Environmental education can be used to facilitate irrigation water use and water saving in order to strengthen efficient water use and allocation (Oberkircher and Hornidge, 2011). Therefore, this study evaluated the strategies used to mitigate water demand and allocation disparities among farmers in terms of agronomic, mechanical and managerial measures, and recommends the most suitable for effective management of the irrigation water use in Kiladeda sub catchment.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This chapter presents the data collection and analytical tools used to accomplish the objectives of this study. Measurement of river discharge, questionnaire, key informant interviews and observation guide employed to collect data. Analytical tools used for data analysis were descriptive statistics, stepwise regression, independent sample t-test and WEAP model. The objectives were linked with corresponding materials and methods as described in Table 3.4.

3.2 Description of the Study Area

3.2.1 Location

Kiladeda sub-catchment has an area of 20 km^2 located within the North Western part of Pangani River Basin, Tanzania. It originates from the Shiri springs in Shiri Njoro village located at 7 km from Moshi town, and ends in Chekereni village (Kiladeda-Weruweru confluence). The river is bounded by latitudes 3^o00’ S and 3^o30’ S and longitudes 36^o 30’ E and 37^o15’ E (Figure 3.1), (DAAD, 2009). The river was selected because of the water over abstraction driven by irrigation activities and agricultural land expansion which have increased irrigation water demand (Chiwa, 2012; Mromba, 2012).

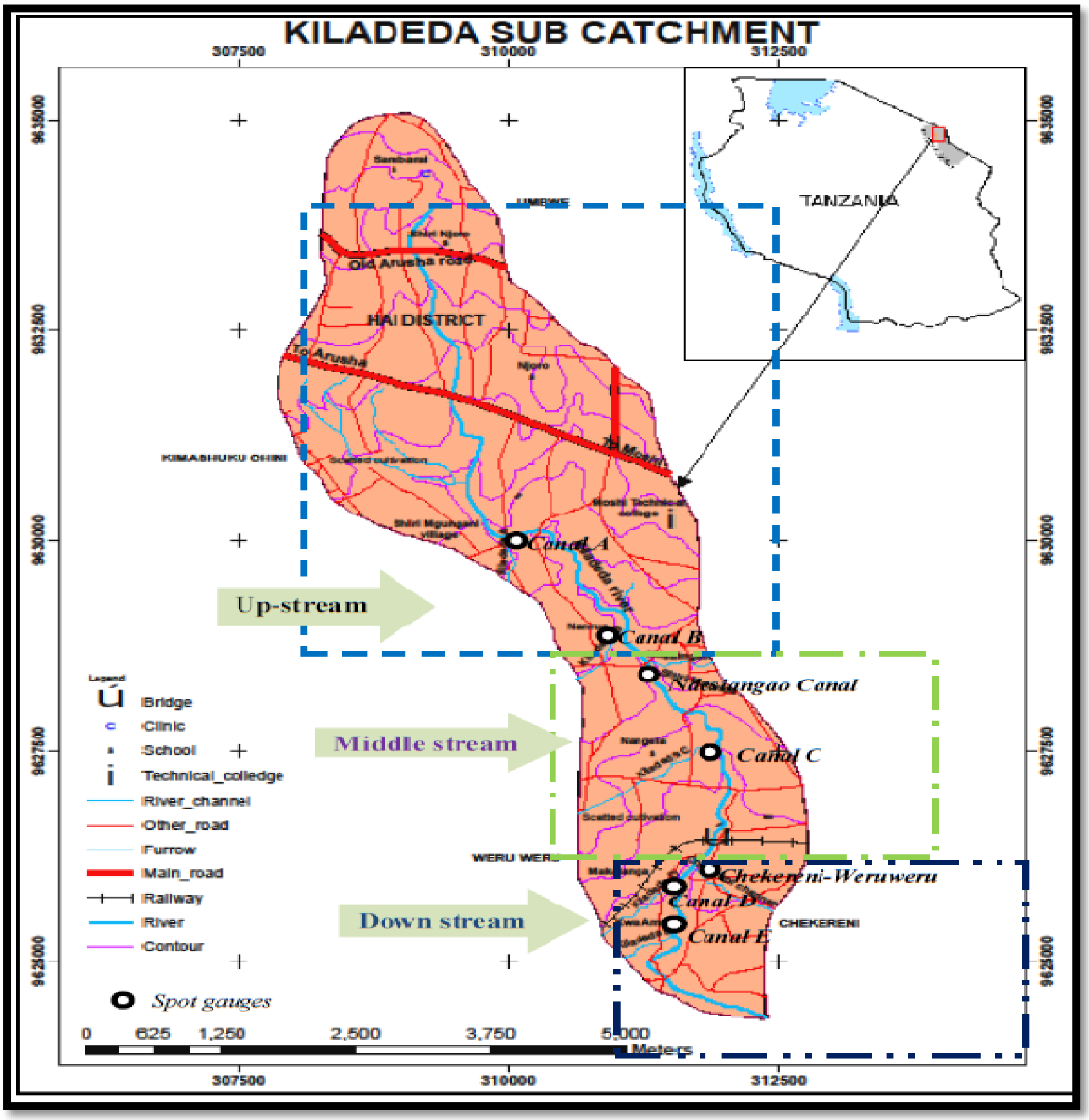

Figure 3.1: Kiladeda sub-catchment (Extracted from Kilimanjaro region survey, 2011)

3.2.2 Population and Administrative Units

Population of Kiladeda sub-catchment is apportioned among three administrative districts namely; Moshi Urban, Moshi rural and Hai. The sub catchment cuts across four villages in these districts namely; Shiri Njoro and Shiri Mgungani (Hai District), Chekereni (Moshi rural) and Shiri Matunda (Moshi Urban). The area has total population of 16,586 people and 3,560 households (URT, 2013). Out of this population, the sub catchment serves about 1,112 registered farmers in Upstream, Middle and Downstream reaches of the Kiladeda sub catchment.

3.2.3 Geology and Soils

The geology of the Kiladeda sub catchment can be classified as Neogene volcanics, sediments and Precambrian basement complex. However, the large part of the sub catchment falls under the Neogene volcanics of Mount Kilimanjaro. Based on the geological chronology, the Precambrian complex encompasses of high grade metamorphic rocks essentially gneisses, amphibolites and granulites of different compositions (DAAD, 2009).

3.2.4 Land Use

Large parts of the Kiladeda sub catchment are occupied by forests and built up land, with approximately 21.12% and 57.72% of the total area respectively (Table 3.1). Agricultural land occupies 9.41% while bare land covers 8.87% (Chiwa, 2012).

Table 3.1: Land-Use and Land Cover Distribution of Kiladeda sub catchment

CATEGORIES	**AREA (Ha)**	**Percentage (%)**
Water	83.98	3.88
Agriculture land	203.80	9.41
Bare land	192.04	8.87
Forest	457.48	21.12
Built up land	1228.42	57.72
Total covered area	**2165.72**	**100**

Source: (Chiwa, 2012)

3.2.5 Topography

Kiladeda sub catchment is characterized by steep slope valleys to gentle slopes, lowlands and in a few areas rolling topography. The altitude ranges from 840-1,060 metres above sea level (DAAD, 2009). The upstream is characterized with steep valley sides slopes while the lowland has gentle slopes.

3.2.6 Climatic Conditions

The climate condition of the area is affected by Inter Tropical Convergence Zone (ITCZ), which determines the duration and the time of the rainy season and subsequently the dry season. The area experiences bimodal rainfall with two distinct rainy seasons divided into short rains lasting from October to November while long rains is from mid-March to mid-May or June, as large variations are sometimes experienced causing rainfall unreliability (DAAD, 2009). The sub catchment experiences lowest temperature of 14^0C to 18^0C which occurs during July to August and the highest temperature of 32^0C to 35^0C occur during January to February as described on temperature trend (Figure 3.3). On average the sub-catchment receives 1000 mm of rainfall per year (DAAD, 2009), shown in Figure 3.2. The physical features together with the climatic conditions which characterize the study area create a favourable environment for the cultivation of maize, beans, bananas, vegetables and horticultural crops like cucumber, coffee, ground nuts, water melons and sunflowers.

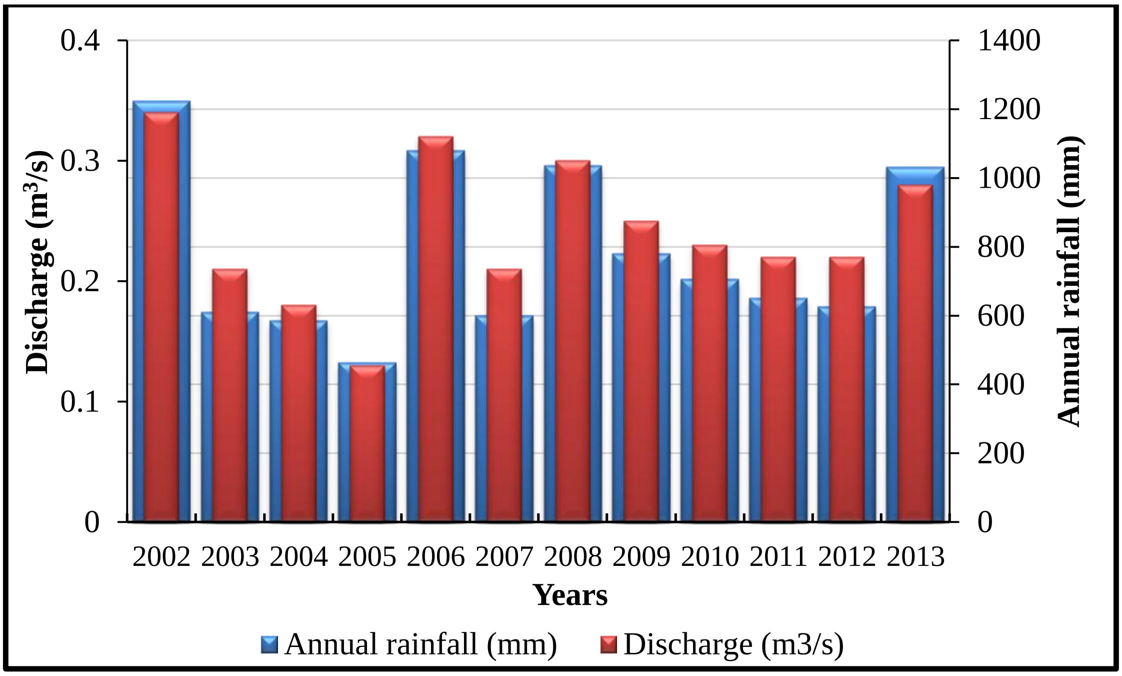

Figure 3.2: Annual rainfall and Discharge trend (Moshi Met station and PBWO, 2014)

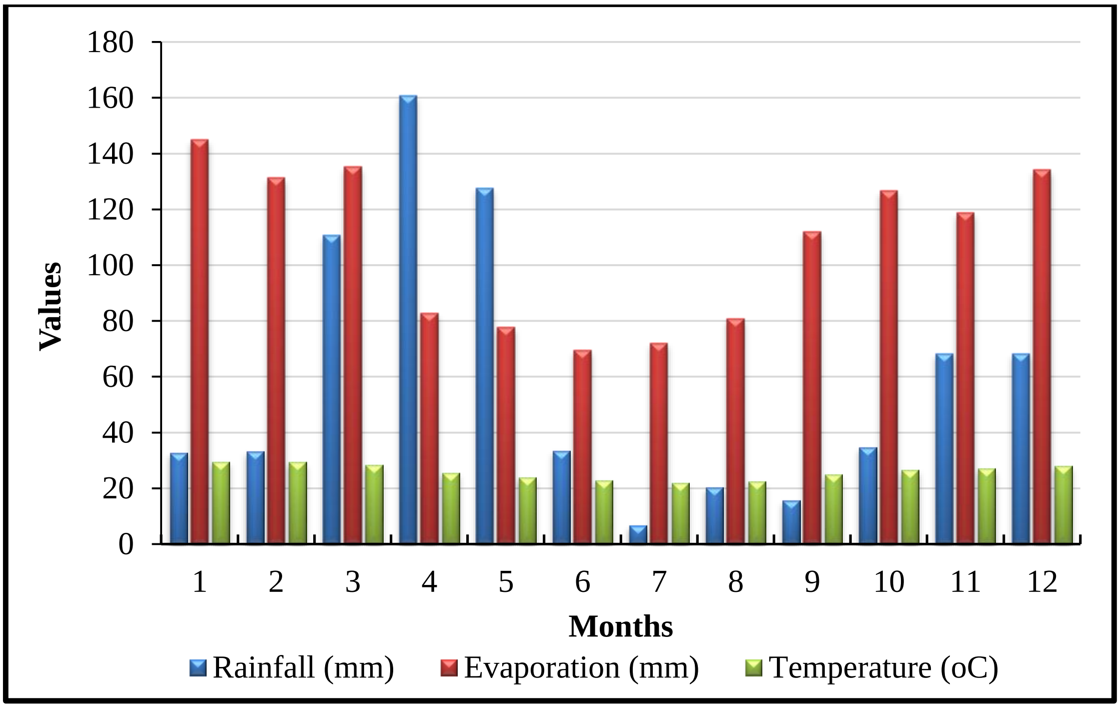

Figure 3.3: Temperature, rainfall and evaporation at Kiladeda sub catchment (Moshi Meteorological station, 2014).

3.2.7 Hydrology and Drainage

The Kiladeda River is one of the many tributaries of Weruweru River in Pangani Basin as shown in Figure 3.1. All water in the sub-catchment drains towards southwest through Kiladeda River. The river is fed by underground springs and catchment runoff during the wet season. The average flow rates are approximately 0.4 m^3/s. Kiladeda river hydrology is characterised by a high degree of spatial and temporal flow variability, with the annual hydrograph generally reflecting the pattern of rainfall while extreme discharge events which occur during the wet season (Figure 3.4). Stream discharge generally increases during March and peaks during April gradually decreasing in May. Discharge fluctuates widely during the wet season and begins to decline in June and stabilize as base flow from July onward throughout the dry season. The river has relatively low discharges dry season and extremely high flow during rainy season (DAAD, 2009; Mromba, 2012).

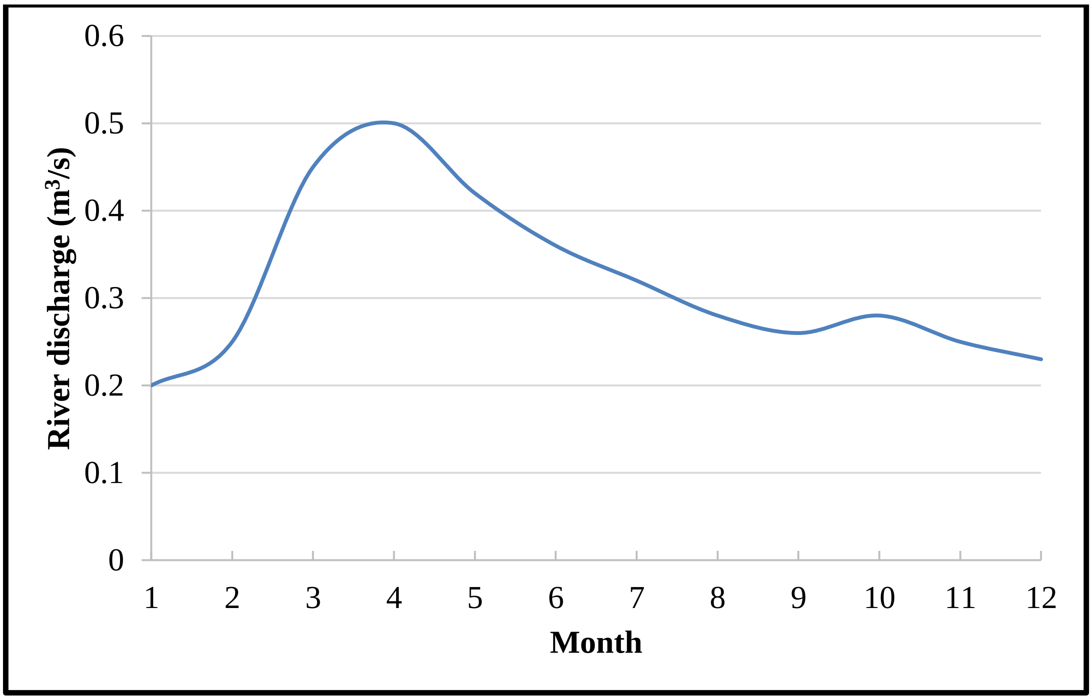

Figure 3.4: Mean flow hydrograph of 2013 of Kiladeda Sub catchment (PBWO, 2014)

3.2.8 Socio-Economic Activities

The main socio- economic activity carried out in the Kiladeda sub catchment is farming at subsistence level. Most of the people depend on the agricultural sector for their livelihood, with 90% directly or indirectly employed in the sector (IUCN, 2009). The land ownership in the sub catchment is under trust land. This allows farmers to claim permanent ownership. A variety of food crops that are grown in the sub catchment including maize, beans, bananas, vegetables and different types of fruits. Market-gardening of fruits and vegetables are carried out to supplement household's income. Commercial farming involves growing of horticultural crops like cucumber, ground nuts, water melons, tomatoes, carrots and sunflower. Livestock rearing includes dairy and beef cattle, sheep and goats, poultry and pigs. Vegetables are highly cultivated in Upstream and middle zones of the river. The main source of energy is firewood for domestic purposes. This has made people to invade and cut trees along the river area (DAAD, 2009).

3.3 Research Design

The study employed descriptive and causal research design. Descriptive survey used to describe the existing situation of irrigation water demand, water allocation, irrigation techniques used and strategies used to minimize water allocation disparities. Causal research design is due to involvement of the on-site field measurements of river discharge in order to determine river discharge trend of the river. Also, data of the discharge measurements were used in WEAP model calibration and validation. Farmer's socio-economic characteristics data were collected by using questionnaires, key informant interviews and observation guides. The data was then analysed using statistical tools such as step-wise regression model, descriptive statistics and t-test.

These tools were used to analyse socio-economic factors of farmers affecting irrigation water demand and to find the relationship existing between irrigation water demand and irrigation technologies adopted by farmers in the sub catchment. WEAP model was used to investigate irrigation water demand and allocation in the three zones of the river. The findings were then interpreted and presented in cross-tabulation, frequencies, and percentages from which inferential were drawn. The findings were validated and confirmed with similar empirical works for accuracy and reliability of results.

3.4 Pilot Study

A pilot survey was done for three days in December 2013. The pilot survey was carried out to pre-test the research instruments such as questionnaires, key informant interview guide and observation guide. The pilot survey enabled identification of research assistants for the main study and to familiarize with the environment of the actual study area. After the pilot survey, various items in the research instruments that were inconsistent and redundant were corrected.

3.5 Research Assistants Selection and Training

Three research assistants for questionnaire work were hired from the study area based on their ability to speak Kiswahili and English languages. The research assistants were given one day training on how best to translate the questionnaire from the English language to Kiswahili with assistance from Pangani Basin Water Office (PBWO) officers. The training also involved the relevance of each question in the questionnaire as far as the research is concerned, how best to introduce the topic to the respondent and its importance for the Kiladeda sub-catchment and research ethics. The training was concluded with demonstration of how to administer the questionnaire in the field in the presence of the research assistants. Then, the research assistants were asked to administer some of the questionnaires under supervision of the researcher. Additionally, the researcher also hired another two research assistants from Pangani Basin Water Office for discharge measurement based on their technical expertise and experience.

3.6 Ethical Considerations

Ethical clearance is essential for a researcher who is conducting research that involves collecting data from human participants. Therefore, the following ethical guidelines were put into place during the research period. Firstly, the researcher respected the rights, privacy, dignity, and sensitivities of their research participants and also the integrity of the institutions within which the research occurs and their research policy. Hence, the researcher has put measures into place to seek permission from the Department of Geography, Kenyatta University. Thereafter, permission was obtained from Pangani River Basin Water Office, Hai and Moshi District Officers. When permission was granted, the research topic was introduced at a staff meeting at PBWO and farmers in Kiladeda sub catchment. Secondly, participant‘s right and privacy was addressed as indicated in the preamble of the research questionnaire and interview guide (Appendix I and II) in order to guarantee the participant‘s confidentiality. Therefore, this research tried as much as possible to respect the right of the people that provided information and on whom information was collected.

3.7 Sampling Methods and Techniques

The study adopted a stratified random sampling for field data collection. The selected river was stratified into three river zones namely; Upstream, Middle stream and Downstream zones. The total number of farmers sampled was 150 as indicated in Figure 3.5. The study area was spread across four villages within three administrative districts. The totals of 50 farmers were randomly selected from each zone of the river. Equal number of farmers was sampled based on the method of proportional allocation suggested by Kothari (2004). It describes that if the study seeking to compare the differences between the strata should adapt equal proportion in selecting its sample size. Equal sample size from each stratum would be more efficient even if the strata are different in size (Kothari, 2004).

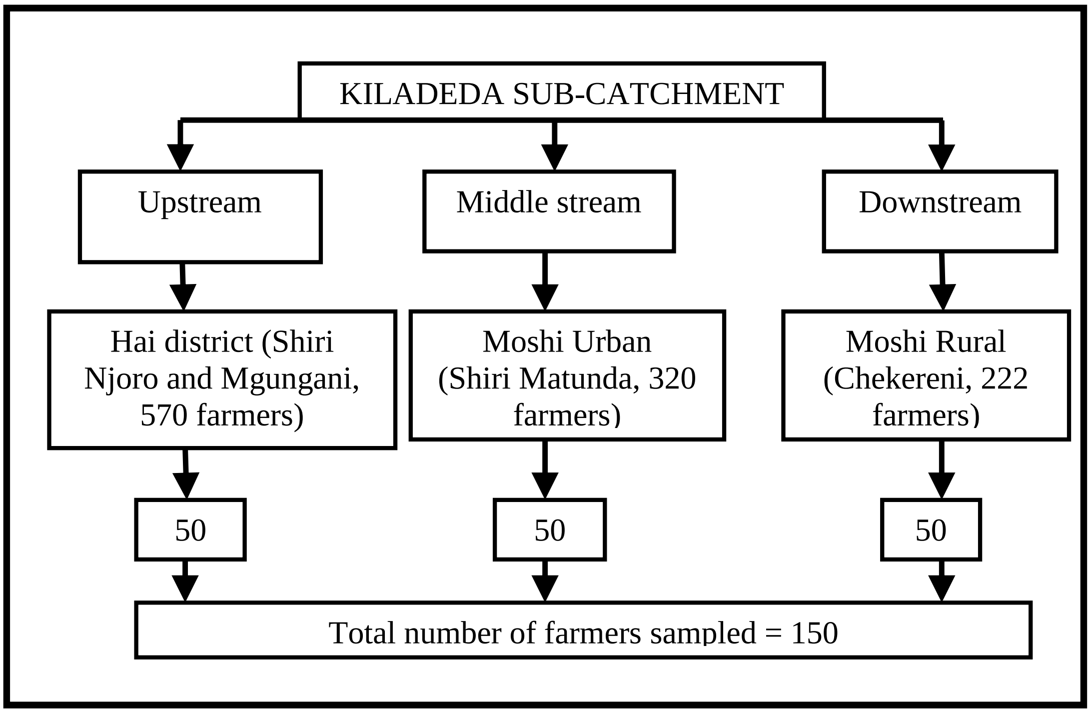

Figure 3.5: Sampling Frame of Kiladeda sub catchment.

3.8 Primary Data

The study employed different primary data collection techniques ranging from questioning, photography, river discharge measurement, on-farm observation guide (Appendix III) and mapping farmers activities nearby the river and irrigation techniques conducted along the river using GPS.

3.8.1 Questionnaire

The study employed questionnaires that consist of open and closed ended questions as described in Appendix I. A total of 150 questionnaires were administered to 150 farmers (50 farmers from each zone). The farmers were selected in randomly sampling method in the three zones of the river. The questionnaire explored the farmer’s socio-economic characteristics, irrigation techniques adopted, irrigation water allocation, benefits and constraints of adopted irrigation technique, laws and regulations on irrigation water use and measures being taken to mitigate irrigation water disparities among farmers.

3.8.2 Interview

Interview guides (Appendix II) were administered to fifteen key informants, namely; WUAs members (6), sub-catchment officials (6) and local government officials (3). They provided data on the role of their respective institutions to mitigate irrigation water demand and allocation disparities, extension services, improving irrigation water use training and laws enforcement.

3.8.3 River Discharge Measurement

River discharge measurements were conducted in referenced spot gauging stations in Kiladeda sub catchment. Measurements were also conducted in the furrows which are used for irrigation purpose. Spot gauges stations were selected based on Nolan and Shields (2000) criteria namely; streambed should be free of large rocks, weeds and protruding obstructions, and reaches should be straight and uniform for a long enough distance to provide uniform flow through the measuring section. GPS coordinates were recorded from each measurement point and transferred to the sub-catchment map in Quantum GIS. Measurements were taken in two months which are February 2014 (Dry season) and April 2014 (Wet season) in a daily basis. The Small Current Meter (OTT C2) was used to measure flow velocity in the river and furrow sections as shown in Plate 3.1. The small current meter (OTT C2) was preferred because it measures the flow velocity at low water levels.

Plate 3.1: Discharge measurement using Current Meter (Source: Author, 2014)

Discharge measurement was done by using Wading method (Cross sectional-velocity method). River cross section was divided into numerous sub sections perpendicular to the stream flow (Plate 3.1). The area of each sub-section was determined by direct measurement of width and depth. The width was measured by using a tape measure while the depth was measured using a wading rod which marks every section depth. Water velocity in each sub-section was measured using OTT current meter. The velocity was determined by placing a current meter in the river and counting the number of revolutions in a measured amount of time (40 seconds in this case) in each sub-section. Data for all measurements were recorded in a discharge rating table sheet. Discharge of each sub-section was calculated by multiplying cross-sectional area and average velocity. The total river discharge was obtained by the sum of the discharges in all the sub-sections.

3.9 Secondary Data

To accomplish the objectives of this study, secondary data were collected from both published and unpublished materials on the area of irrigation water management practices and irrigation water allocation. Secondary data of river discharge was obtained from Pangani Basin Water Office. Crop type, area under crop, and crop coefficient were obtained from Moshi Agriculture Office and daily rainfall, daily average temperature and evaporation were obtained from Moshi Meteorological Station. The above mentioned secondary data were used in WEAP model. The study also used relevant data from journals, magazines, books, reports; thesis, media, encyclopaedia and internet were used to acquire information related to the study area. Other information from public, private and international organization’s resource centres and libraries were used to obtain realistic interpretation of results.

3.10 Data Analysis

3.10.1 Analysis of Descriptive Statistic

Descriptive statistics was used to provide simple quantities like percentages, mean, frequency, standard deviation and cross tabulation. It was accomplished by using both SPSS and Microsoft excel. Descriptive measurements were used to grasp and report the socio-economic characteristics of farmers, irrigation water management practices, adoptive technologies employed by farmers and strategies used to mitigate irrigation water demand and allocation disparities among farmers for all villages surveyed in Kiladeda sub catchment.

3.10.2 Parametric Test

For a qualitative study of this nature where irrigation techniques with different groups are assumed to be influencing the irrigation water demand in the sub catchment, there is the need to test variables identified in the study with a parametric statistical test. In this study, the parametric test chosen was independent sample t-test. Independent - sample t-test was chosen due to its ability of comparing the means between two independent groups (Kothari, 2004; Pallant, 2011). For instance, in this study two irrigation techniques employed by farmers in upstream, middle and downstream were compared with irrigation water demand as a continuous dependent variable.

3.10.3 Stepwise Regression Model

The study sought to analyse the socio-economic factors influencing irrigation water demand among farmers in Kiladeda Sub-catchment. To accomplish this objective, stepwise regression model was used. Stepwise regression is a statistical technique that allow to assess the relationship between one dependent variable and several predictors (Tabachnick and Fidell, 2007). The model was chosen because it is designed to provide the most parsimonious set of predictors that are most effective in predicting the dependent variable (Pallant, 2011). More so, it develops a sequence of linear models (equations) when predictor variables are entered one at a time and the model deletes predictors in subsequent steps if they no longer contribute appreciable unique predictive power to the regression (Mitzi, 2007). Thus, it provides all sets of socio-economic factors (best predictors) which influence irrigation water demand and excludes those factors which are no longer contribute significantly to irrigation water demand in the study area. After then, the regression equation for predicting irrigation water demand can be generated. The stepwise regression equation can be represented as follow;

$$y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \text{ .... (Equation 1)}$$

Where;

Y is the dependent variables for the irrigation water demand.

$X_1, X_2, \dots, X_k$ are explanatory independent variables: Socio-economic factors such as education, income, gender, age, household size, farm ownership, farm size, farm location and crop type.

$\beta_1, \beta_2, \dots, \beta_k$ are known as the model parameters (Beta coefficients), and "k" is the number of observations which is equivalent to the number of independent variables.

ε is the random error is assumed to be independent random variable with mean 0 and variance (σ^2) which was assumed as constant for this study.

The interpretation of the model results was based on the value of the multiple correlation coefficient (R), adjusted R^2 and beta value. The value of R measures the correlation between the dependent variable and predicted independent variable. R^2 indicates the proportion of the variance in the criterion variable which is accounted for by our model. For example, if R^2 gives 0.198, indicating that approximately 19.8% of the variance in the irrigation water demand as a dependent variable can be accounted for by the linear combination of the predicted independent variables. Similarly, adjusted R^2 value gives the most useful measure of the success of our model. For instance, if adjusted R^2 value is 0.75, means the model has accounted for 75% of the variance in the criterion variable (Pallant, 2011). Moreover, the beta value measures how strongly each predictor variable influences the dependent variable (irrigation water demand in this case). The beta is measured in units of standard deviation. Thus, the higher the beta value the greater the impact of the predictor variable on the criterion variable (Tabachnick and Fidell, 2007; Pallant, 2011). Finally, to assess the statistical significance of the results, ANOVA report generated by the regression model is used to test the overall significance of the model at $p < 0.05$. Hence, ANOVA provides justification for the step-wise regression results obtained.

3.10.4 Water Evaluation and Planning Model

The study employed Water Evaluation and Planning (WEAP) model to investigate water demand and allocation in three zones of Kiladeda sub-catchment. WEAP model is an integrated water management tool for evaluation of water use and allocation in sub-catchments (SEI, 2011). It governs the allocation of available water to meet the different water needs for farmers. The model was selected in comparison to other models such as SWAT and Mike Basin because of its ability of using a wide range of secondary data of hydrological, demographic and meteorological/climate data to simulate water demand and allocation (Figure 3.8) (Yates *et al.*, 2005; Mounir *et al.*, 2011; SIE, 2011). It accommodates extensive primary and secondary spatial data sets and allows the simulation of various water allocation and demand scenarios. Data that were required for modelling was collected from different sources as indicated in the Table 3.2.

Table 3.2: Data required for WEAP model

Purpose of data	Data required	Source
Water availability	River flow data (Discharge)	PBWO and Field measurement
Irrigation Water demand	Crop type, area under crops, crop coefficient. Daily rainfall, daily average temperature and evaporation	Ministry of agriculture-zonally office. Moshi Airport Meteorological station and PBWO

3.10.4.1 Calculation of Irrigation Water Requirement

Irrigation water requirement for WEAP model was calculated by using evapotranspiration (ET_o) and effective precipitation (P_{eff}) concept as outlined in FAO Irrigation Water Management Training Manual No. 3 (FAO, 2002;1986). The reason for selecting this method is because there is no data available on the exact amount of water used for irrigation and farmers do not know how much water they use for irrigation purposes. Also, the method has been used by various scholars to calculate irrigation water requirement in many basins and worked well (Adeniran *et al.*, 2010; Mutiga *et al.*, 2010; Bithel and Smith, 2011; Ndiiri, 2011).

According to FAO Irrigation Water Management Training Manual No. 3, irrigation water requirement can be estimated on the basis of the crop with the highest water requirement or the crop that will ultimately occupy the largest area. Therefore, maize is the dominant crop in the sub catchment, hence was chosen for the purpose of computing crop water requirements. The formula for calculating Irrigation Water Requirement (IWR) is given by;

$$IWR = Kc.ETo - Pe \ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 2)}$$

Where;

Kc = Crop factor (unit less)

ET_o = Reference crop evapotranspiration (mm)

P_e = Effective rainfall (mm)

The maize growing days are ranging from 125- 180 and the average crop factors (Kc) is 1.15. The effective rainfall was determined by using the following formula based on the FAO manual number 3;

$$Pe = (0.8xP) - 75 \text{ If } P > 75\text{mm/month} \ldots\ldots\ldots\ldots \text{(Equation 3)}$$

$$Pe = (0.6xP) - 75 \text{ If } P < 75\text{mm/month} \ldots\ldots\ldots\ldots \text{(Equation 4)}$$

Where;

P_e = Effective rainfall (mm/month)

P = Mean monthly rainfall (mm/month).

Therefore, total irrigation water requirement was calculated by subtracting the effective rainfall during the period from the crop water requirements as shown in appendix IV.

3.10.4.2 Defining Study Area on WEAP

Before entering data into WEAP, GIS based vector map in the form of shape file format was uploaded in the project area of the model through schematic view. The study area boundaries defined by geographical and hydrologic boundaries was set (Figure 3.6). The area has an approximately 20km^2. The map helps to orient and construct the system and refine area boundaries in the model. Then, to simulate the system, the river is divided into three zones, upstream, middle and downstream zones.

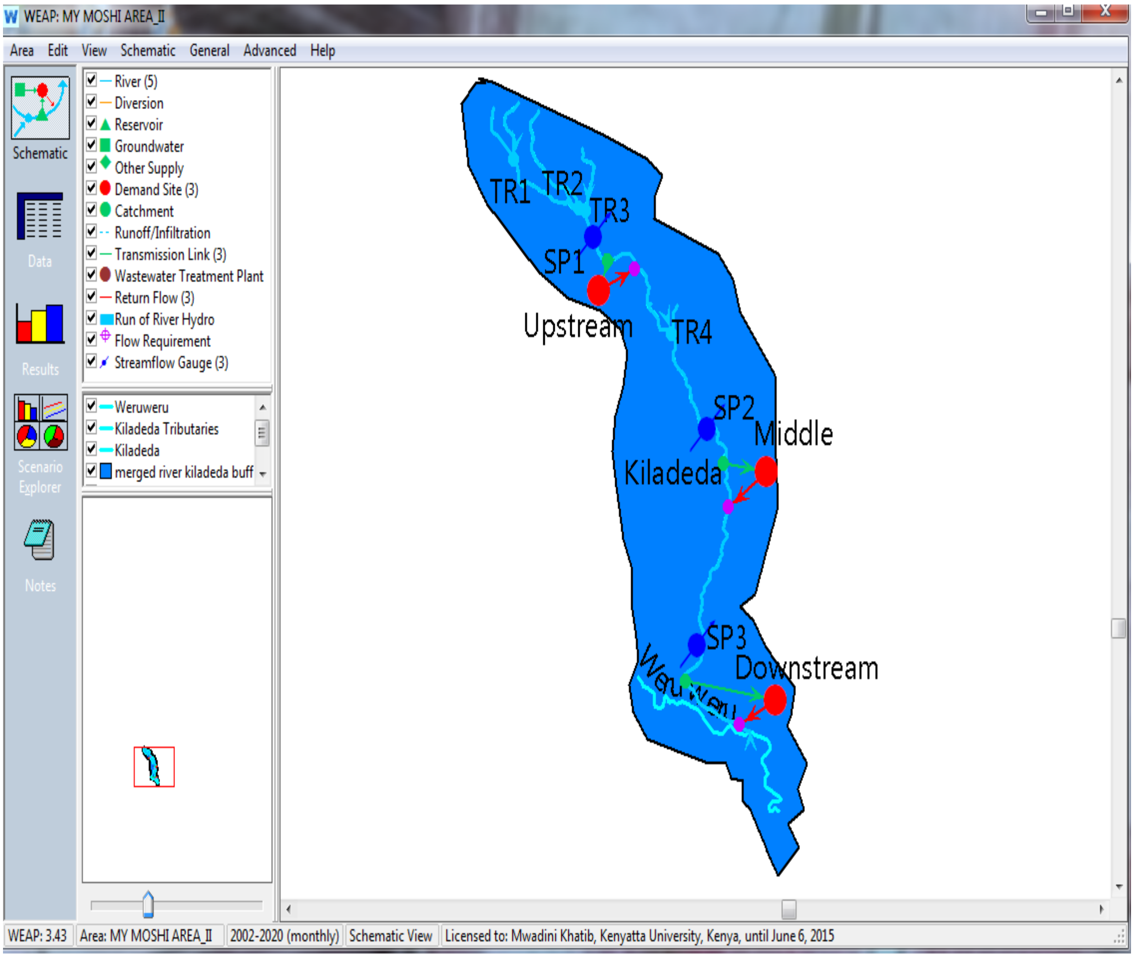

Figure 3.6: Schematic diagram of Kiladeda sub catchment in WEAP.

3.10.4.3 Setting the Period of Analysis

Afterward, the setting of current account year for water demand data was done. The base year chosen for this study was the year 2002 and the last year of scenarios was 2020. According to SEI (2012), the current account (Base year) is the year for which good demand data are available and from which future forecasts could be made. It is also the year with most current water use information and acts as the start year for period of analysis. Therefore, the year 2002 was chosen for this study to allow for 11 years historic flows data to be used in the calibration and validation (up to 2013). Also, the 2020 was chosen as last year of analysis period in order to allow projection plan of water resources for 7 years. Data files were prepared in a Comma Separated Value (CSV) format in excel and entered into the WEAP model.

3.10.4.4 Hydrology Selection

Watershed hydrology is defined as the monthly stream flow at river and local nodes in the riverine system (SEI, 2012). Selection of hydrology attributes of the sub catchment can be either the use historical flow analysis or the water year method. Thus, historical flow analysis was used in this study because the method is suitable when historical flow data is available. Therefore, historical flows from 2002 to 2013 were used in the simulation of scenarios. This was done based on the assumption that past hydrological patterns will be repeated in future.

3.10.4.5 Demand Sites

The study area has three demand sites namely; irrigation, domestic and livestock. Irrigation is the main water user and it is said to consume a lot of water compared to domestic and livestock. However, to accomplish the objective of this study; only irrigation water demands was considered.

3.10.4.6 Setting Priorities

According to SEI (2012), demand priority means the level of priority for allocation of the available water resource. Thus, demand sites with the highest priority would be supplied first before moving to lower priority sites until all the demands are met. According to the water conflicts situation in the Kiladeda sub catchment, the study assumed no upstream – downstream cooperation in irrigation water use as suggested by de Condappa *et al.* (2008). This is because water is withdrawn upstream without consideration for downstream requirements. This means first "first come, first served" basis. Therefore, priorities for irrigation demand sites in the sub catchment were set on the basis that priority increase from upstream to downstream of the sub catchment as shown in Table 3.3.

Table 3.3: Allocation Priorities for WEAP model

River zones	Irrigation allocation priority
Upstream (Njoro and Mgungani)	3
Middle stream (Shiri Matunda)	2
Downstream (Chekereni)	1

3.10.4.7 Scenarios

Scenarios are self-consistent statements of how a future system might evolve over time in a particular socio-economic setting or under a particular set of policy and technology conditions (SEI, 2012). In this study, scenarios were developed to compare irrigation water requirements for 18 years (2002-2020). The study considered only two scenarios which are;

- **Reference Scenario (2002-2020)**

The reference or business as usual scenario is the base scenario that uses the actual data to help in understanding the best estimates about the studied period (SEI, 2012). The objective of a reference scenario is to learn what likely could occur if current trend continue and to understand the real situation. Reference scenarios can also be useful for designing contingency plans where there is risk and uncertainty. The basic model built reflects the reference scenario, which replicates the real situation. The model was run for 18 years from 2002 to 2020. The years 2002 to 2013 was used in the calibration of the model and 2014 to 2020 was used in the simulation of future water demand.

- **Irrigation Expansion Scenario (2013-2020)**

Irrigation expansion scenario in this study was intended to answer the question "What if irrigation area expand to the extent that all agricultural area (204 hectares) are irrigated?" Currently the total irrigated land is 135 acres (66.2% of the total agricultural land use). The irrigation expansion scenario was assumed because irrigation water demand increase as irrigated land area increases (Schaible and Aillery, 2013).

3.10.4.8 Model Calibration and Validation

The WEAP model was calibrated using observed flow data obtained from three spot gauging stations located on the Kiladeda sub catchment. Calibration involved changing assumptions (Figure 3.7) of historic demand, altering demand priorities and improving the fit between simulated and observed flow. A period of 18 years (2002- 2020) was used for the model in which, the years 2002 to 2013 was used for calibration and 2014 to 2020 was used in the simulation of future water demand.

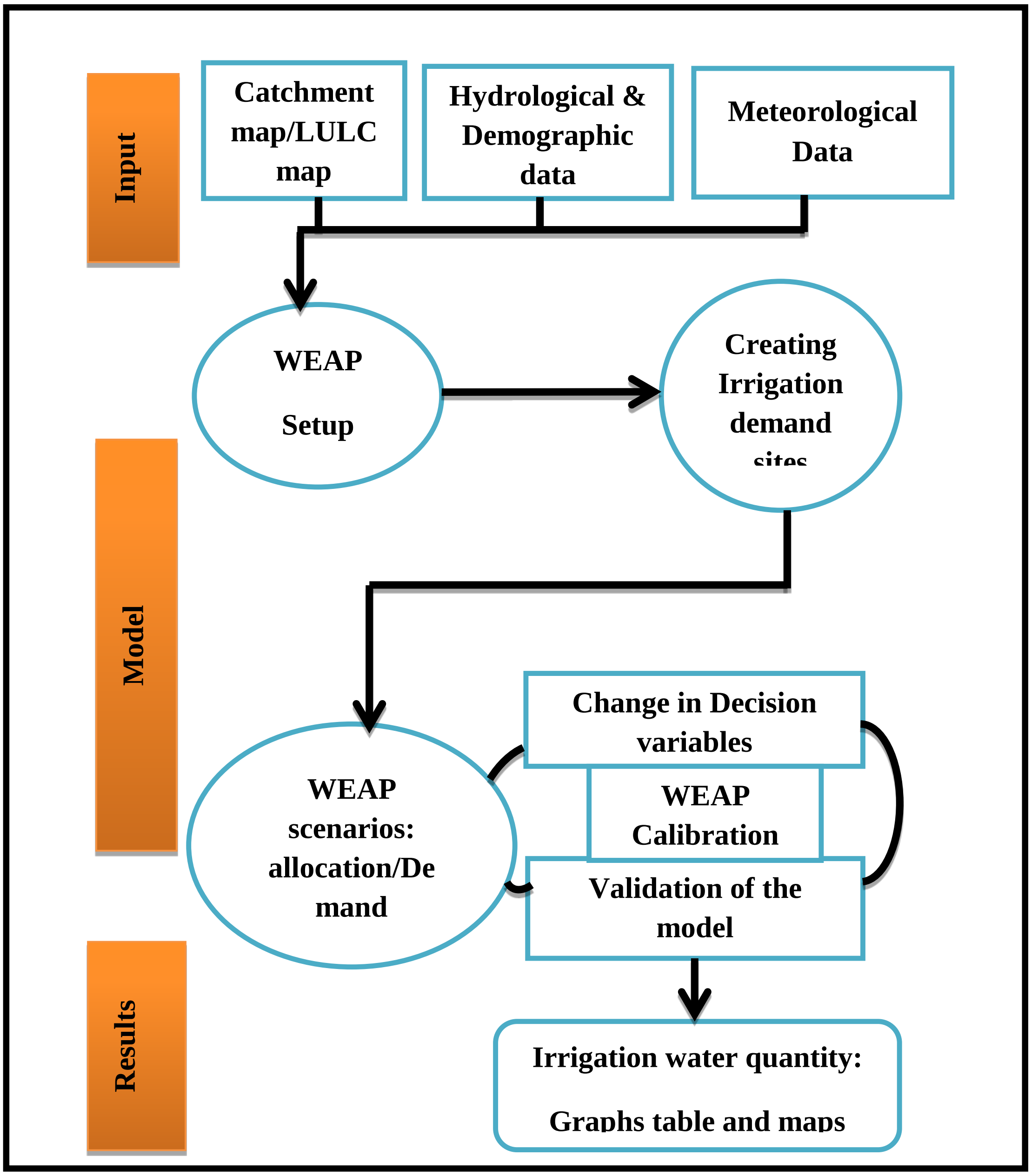

Figure 3.7: Procedures of the WEAP model (Source: Author, 2014)

Table 3.4: Variables for Data Collection and Analysis Methods

No.	Objective	Variables required	Source of Data	Type of Analysis
1	To analyse the socio-economic factors influencing irrigation water demand among farmers in Kiladeda sub catchment	Education, household size, income, gender, age, farm ownership, farm size, farm location and crop type.	Questionnaires, Observation guide and key informants	Descriptive statistics and Stepwise regression Model
2.	To examine irrigation water management practices adopted by farmers and their effects on irrigation water demand in Kiladeda Sub-catchment	Drip, sprinkler, furrows and jerry cans.	Questionnaire, Key Informant interviews and Transect walk (Observation guide)	Descriptive statistics: Cross-tabulation, percentages and frequencies. Independent sample t-test
3.	To investigate irrigation water demand and allocation among upstream, middle stream and downstream farmers in Kiladeda sub-catchment	River flow data, Rainfall data, IWR data, Evaporation, water use data	River discharge measurement, PBWO and Moshi Meteorological Station	WEAP model: Demand and allocation scenarios
4	To evaluate strategies used to mitigate irrigation water allocation disparities among farmers in Kiladeda sub catchment	Legal measures, Agronomic measures, Mechanical measures	Key informant interviews, Questionnaires and Transect walk (Observation guide)	Descriptive statistics: Percentages, frequencies and cross-tabulation; Content analysis

3.10.5 Interpretation and Presentation of Results

The findings of the research were presented in tabular form, graphic and text forms after data analysis. A triangulation of quantitative results with qualitative outputs from other literature was done in order to evaluate the pertinence of the findings. This method helped in drawing conclusions and recommending on irrigation water management practices at Kiladeda sub catchment. A final quality control of findings was made according to recent scientific knowledge.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion of the field survey conducted at Kiladeda sub catchment. Survey response indicates that all questions from farmers and key informants were successfully asked and incorporated in the research. The results of statistical analysis of socio-economic factors influencing irrigation water demand using stepwise regression model, irrigation water management practices adopted by farmers, WEAP model, and strategies for mitigating disparities of irrigation water allocation are presented and discussed in this chapter.

4.2 Socio-economic Characteristics of Farmers and Irrigation Water

A total of 150 farmers were surveyed in the sub catchment to establish the socio-economic factors affecting irrigation water demand. The characteristics of respondents that were analysed were gender, age, education level, income, house hold size, farm size, firm ownership, farm location and crop type. Therefore, the results of socio-economic characteristics of farmers affecting irrigation water demand are presented and discussed.

4.2.1 Gender and Age of Farmers

The study surveyed total of 150 farmers in Kiladeda sub catchment. The results revealed that 62.0% of farmers were male and 38.0% were female. The results of the age of farmers showed that 15.3% of farmers have an age below 20 to 35 years, 41.4% have the age between 36 and 51 years while 43.3% of farmers were over 51 years old. Three age categories were chosen to group the sampled farmers into youth, working age and elderly farmers. The gender and age results indicate that irrigation farming is male dominant in the sub-catchment and majority of the farmers are below the age of 51 years (56.7%). Old people (43.3%) were less involved in irrigated agricultural activities than young people. These results confirm the Adeoti (2009) findings in Ghana that irrigation farming is male dominated in which 94.23% of the total farmers doing irrigation in Ghana were male. He also noted that the age of the farmer has great influence on the adoption of the irrigation water management. Also, the results are in agreement with IFAD (2012b) findings that access to irrigation water in most developing countries is dominated by men compared to women.

Moreover, gender and age variables play significant role as socio-economic factors influencing irrigation water demand but they were eliminated by the model as described in section 4.2.9 of stepwise regression results. The results of gender and age distribution of farmers are shown in Figures 4.1 and Figure 4.2 respectively.

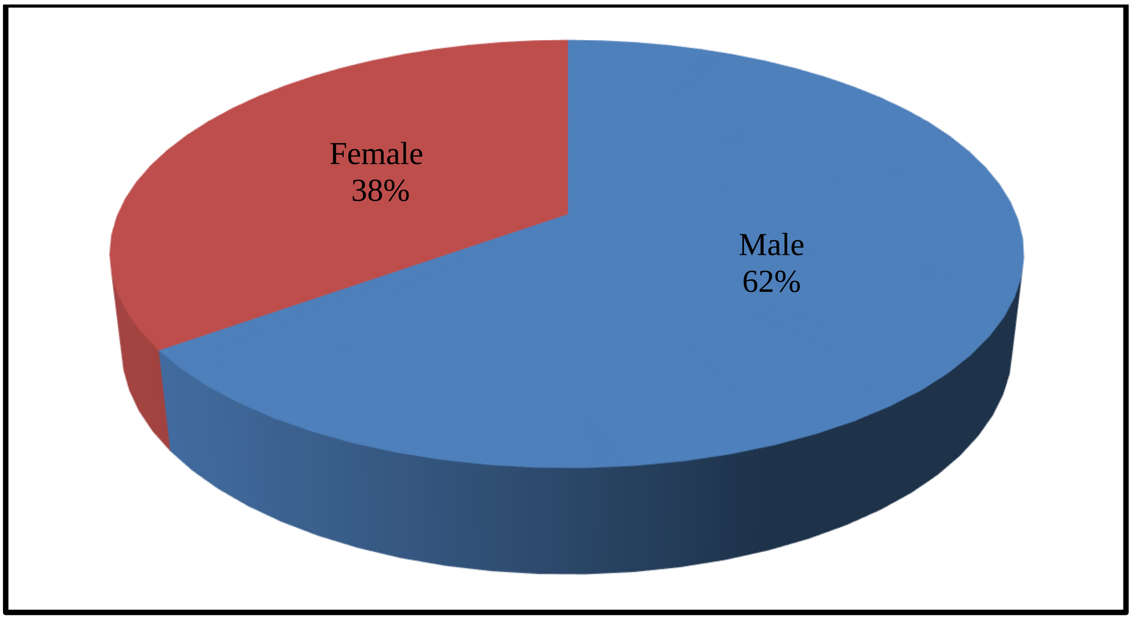

Figure 4.1: Gender of surveyed farmers in Kiladeda sub catchment

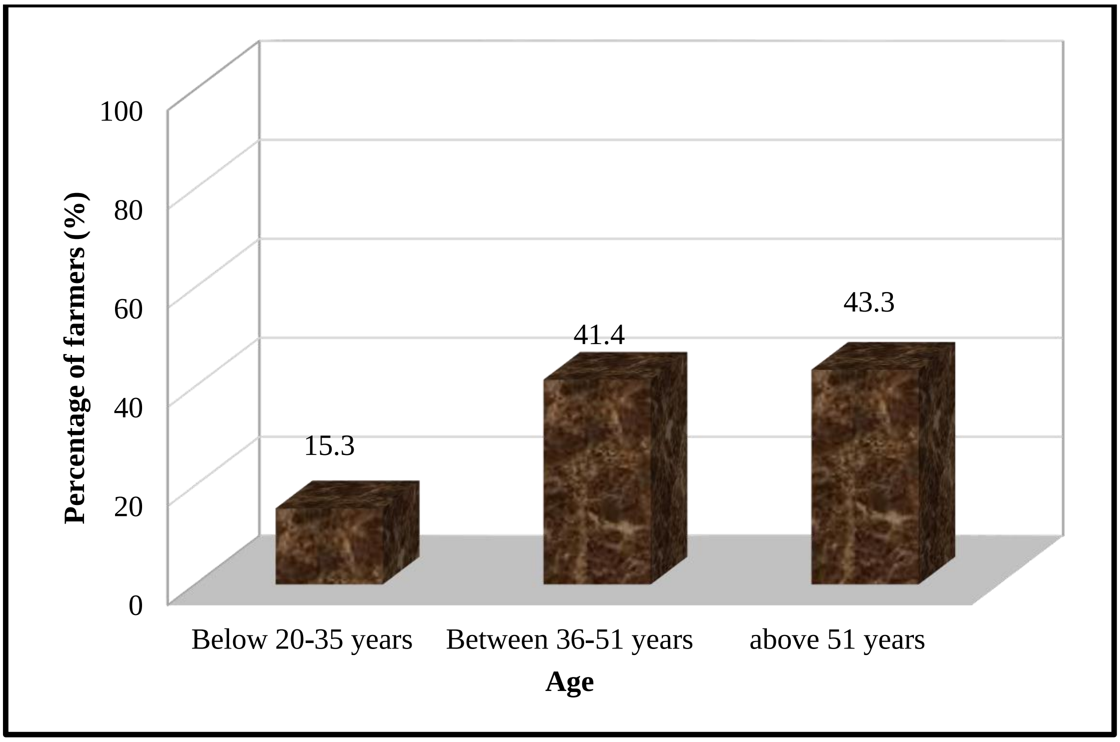

Figure 4.2: Age distribution of surveyed farmers in Kiladeda sub catchment

4.2.2 Educational Status

The study revealed that 64% of farmers attained primary school education, 10% of farmers attained secondary school education while 26% of farmers have no formal school education as shown in Figure 4.3. This implies that educated youths up to secondary school either are not interested in agriculture or end up settling in towns to look for other economic activities. It was found that farming knowledge and some water conservation measures were not properly taken by farmers. This indicates little farmers' awareness on irrigation water use and water resources protection. According to Rockaway *et al*. (2011), education is often cited as one of the factors influencing irrigation water use and enhances farmer's adoption of irrigation water management practices.

Moreover, stepwise regression model showed a negative relationship between education and irrigation water demand in the downstream of the river. This implying that farmers with low-education levels have stronger intention to conserve water than farmers with high level of education. These results contradict with Aslan *et al.* (2007) and Chebil *et al*. (2012) studies that the level of education of farmers have positive relationship with irrigation water use efficiency in Tunisia and Spain respectively. However, the negative relationship result is consistent with the Fielding *et al*. (2012) findings that household with lower education engage in more water conservation behaviours and use less water than higher-education households.

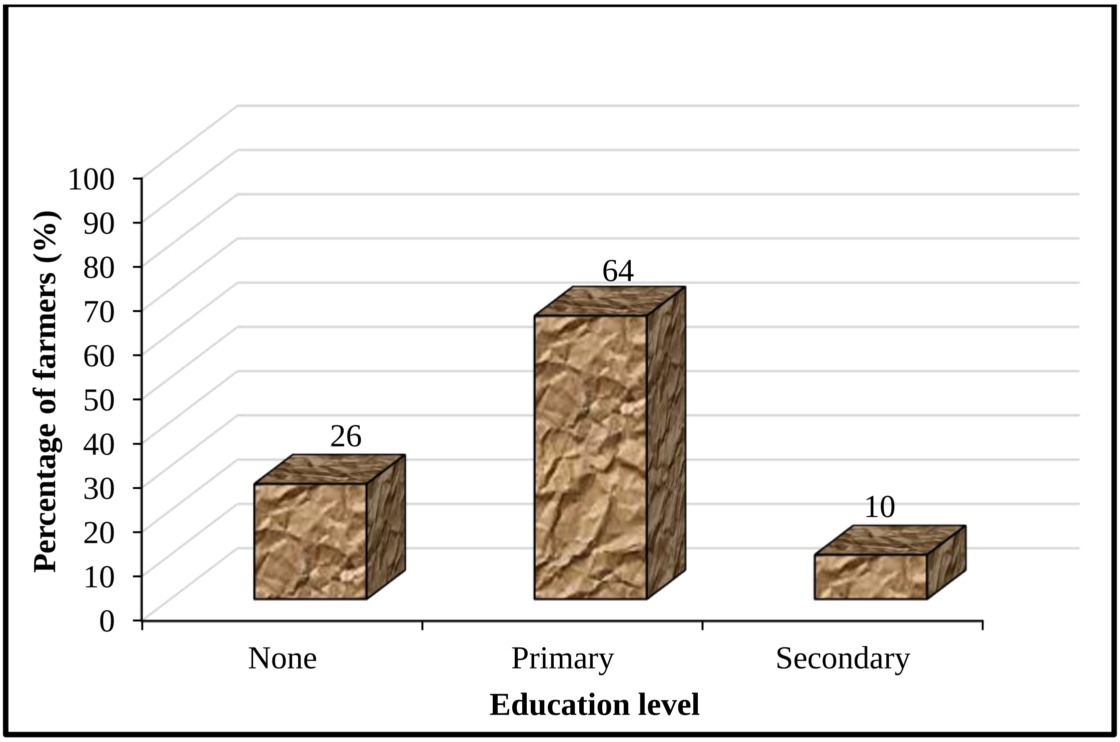

Figure 4.3: Educational attainment of surveyed farmers

4.2.3 Income of Farmers

The on-farm survey revealed that the average monthly income of farmers were 45,640 TSH (US$ 22), 40,720 TSH (US$ 19) and 44,200 TSH (US$ 21) in upstream, middle and downstream respectively. It was noted that about 63.3% of farmers have income less than 50, 000 TSH (US$ 24) per month, 34.7% have income between 50,000 and 100,000 TSH (24 to 48 US$) per month while only 2% of farmers have income of more than 100,000 TSH (48 US$) per month as shown in Table 4.1. According to 2013 Household Budget Survey of Tanzania, the per capita Growth Domestic Product (GDP) is 66,944 TSH (US$ 32) per month while the basic needs poverty line is 36,482 TSH (US$ 17) per month. Therefore, income results indicate that majority of farmers in the sub catchment are poor because their incomes fall below Tanzania growth domestic product and stick in the basic needs poverty line.

The income results of this study correlate with empirical works by IUCN (2009) and DAAD (2009) that in Kiladeda sub-catchment majority of small scale farmers are living below the poverty threshold of 1 US$ per day. Therefore, farmers are required to carry out other activities to supplement their households' income. For instance, this study established that 3.8% of farmers in the sub catchment were conducting small businesses to supplement their incomes. On the other hand, the low income of farmers can be attributed to poor irrigation methods resulting in low crop yields. Nevertheless, stepwise regression model showed a significant positive relationship between farmers income and irrigation water demand in the sub catchment. This conforms to the Adeoti (2009) that there is positive relationship between irrigation water use and income of farmers.

4.2.4 Farmer's Household Size

The study revealed that, the average household size of farmers in Kiladeda sub catchment was five (5) people. The results also show that about 26%, 16% and 20% of farmer's households have five people in upstream, middle and downstream zones respectively as in Table 4.1. It was further indicated that average of two (2) people from each farmer's household were doing irrigation in the area. This implies that the motivation to do irrigation might come from the desire to achieve food security among those with relatively higher family size as explained by Belay and Beyene (2013).

Further, the household size variable was tested in stepwise regression to determine its relationship with irrigation water demand (Table 4.3). However, it was rejected by the model. This means that household size has no significant relationship with irrigation water demand in Kiladeda sub catchment. This result contradicts the finding of Aseyehegn *et al*. (2012) who noted that household size has positive association with irrigation water use and irrigation techniques adoption as well. On the other hand, study by Zhang (2013) indicates that the number of household's members have a significant negative impact on irrigation water, thereby providing evidence that a large group size may exacerbate problems of collective action and joint irrigation water management.

Table 4.1: Summary of farmer’s demographic characteristics

Socio-economic Characteristics (N=150)		Upstream N=50	Middle stream N=50	Down stream N=50	Total (%)
Income (TSH) (%)	< 50,000 (< 24 US$)	54.0	76.0	60.0	63.3
	50,000-100,000 (24-48 US$)	44.0	20.0	40.0	34.7
	>100,000 (>48 US$)	2.0	4.0	0	2.0
Household size (%)	1	2.0	4.0	0	2.0
	2	4.0	12.0	4.0	6.7
	3	6.0	14.0	16.0	12.0
	4	26.0	14.0	22.0	20.7
	5	26.0	16.0	20.0	20.7
	6	14.0	12.0	18.0	14.7
	>7	22.0	28.0	20.0	23.4

4.2.5 Farm Size and Irrigation Water demand

The on-farm survey revealed that 28.7% of farmers have less than 1 acre of land, 64.7% have farmland of between 1 to 2 acres and only 6.6% of farmers have farm size of above 2 acres as in Figure 4.4. Farm size is an important farm characteristic which determines irrigation water demand for this study. Therefore, the regression results (Table 4.3) indicate that farm size was the factor influencing irrigation water demand in the sub-catchment with positive correlation. This result contradicts the finding of Abu-Madi (2009) that farm size has negative correlation with irrigation water demand. Also, the study established that the average farm size was 1.3 acres, ranging from 0.25 to 3 acres.

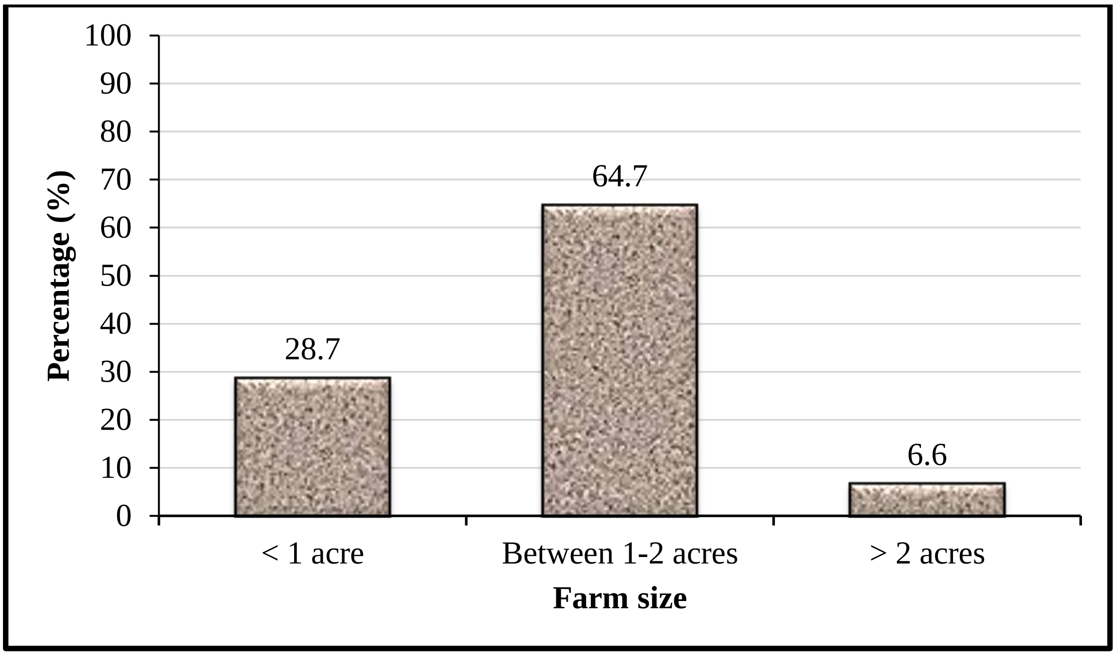

Figure 4.4: Farm size distribution in Kiladeda sub catchment

4.2.6 Farm Ownership and Irrigation Water Demand

Land ownership influences farmers' decision to adopt irrigation techniques and its water usage. The study found that land ownership in Kiladeda sub-catchment follows a customary system, though they do not have formal legal legitimacy. The study revealed that 87.3% of farmers interviewed have inherited their farmlands, 11.3% rented their farms and only 1.4% of farmers purchased their farmlands as presented in Figure 4.5. This explains the high level of adoption of irrigation water use efficiency can be practiced because, farmers who own their land tend to be careful on utilization of irrigation techniques which reduces irrigation water use compared to those who do not own the land. The stepwise regression model (section 4.2.9) also showed a negative relationship between farm ownership and irrigation water demand in downstream of the river. However, contrary to the expectation, there was no significant relationship between farm ownership and irrigation water demand in upstream of the river. This indicates that farm ownership in upstream may not motivate farmers to proper irrigation water use and therefore contradict to Belay and Beyene (2013) findings that farm ownership determines the irrigation water use efficiency.

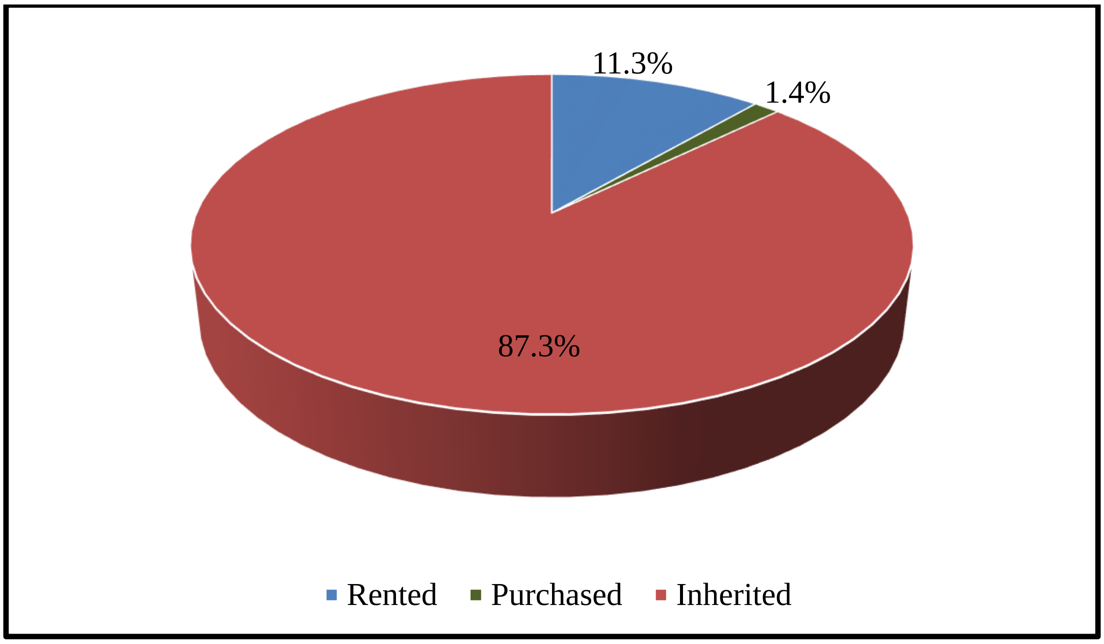

Figure 4.5: Land tenure systems in Kiladeda sub-catchment

4.2.7 Farm location and Irrigation Water Demand

The results show that farming activities were carried out close to the river (Plate 4.1). The average farm locations obtained from the field survey were 52m, 85m and 120.4m for upstream, middle stream and downstream zones respectively. Although Water Resources Management Act of 2009 of Tanzania prohibits any human activities within 60 metres from either side of the water source, it can be seen that farmers still conduct farming activities within 60 metres and therefore increase river banks encroachment. Interestingly, stepwise regression model showed positive significant relationship between farm location and irrigation water demand in Kiladeda sub catchment. Meaning that, less distant farmers utilized high amount of water for irrigation farming than those who are very far from the River. This implies that downstream farmers get less water for irrigation than Upstream. Thus, they are more sensitive to irrigation water use and allocation in the sub-catchment.

Plate 4.1: Farming activities close to Kiladeda River (Source: Author, 2014)

The results of farm location of this study are in agreement with Chiwa (2012) who observed the sub-catchment water threatened by poor farming practices in the upstream and downstream due to farming in steep slopes and right into the riverbanks without conservation measures. Similarly, Owilla (2010) findings in Mwea irrigation scheme in Kenya who found that farmers located far distance from the canal (water source) and at downstream are more vulnerable to water shortage and therefore, are less irrigating their farm.

4.2.8 Type of crops irrigated

It has been noted that maize is almost important crop grown by most of farmers in the sub catchment. This is because 40.9% of respondents were irrigating maize, 39.6% of farmers were irrigating vegetables and 18.6% of farmers irrigating beans and only 3.7% of farmers were irrigating banana, flowers and coffee as shown in Figure 4.6. The study results conform to Turpie *et al*. (2005) findings that maize was the most abundant crop, grown by most small scale farmers throughout the Pangani River Basin. However, other crops such as banana, coffee, vegetables and beans vary tremendously in the area.

Conversely, the regression analysis test confirmed that irrigation water demand in Kiladeda sub-catchment was not significantly dependent on the type of crop (Tables 4.2 and 4.3). This can be explained by the fact that there is no greater variability of crops in the three zones of the sub catchment and therefore, limits statistical performance of the model. This confirms the empirical finding of Abu-Madi (2009) in Tulkarm district, Palestine that the type of cultivated crops did not correlated to irrigation water demand.

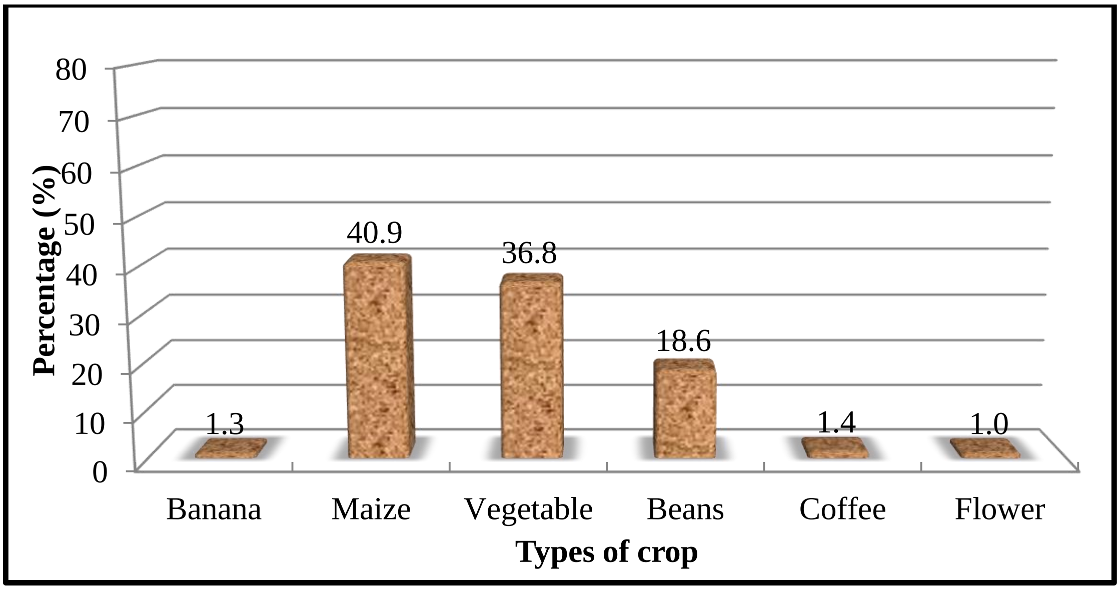

Figure 4.6: Irrigated crops in Kiladeda sub catchment

4.2.9 Hypothesis testing on socio-economic factors influencing irrigation water demand

To test hypothesis "There is no statistically significant relationship between socio-economic factors of farmers and irrigation water demand in Kiladeda sub-catchment". Nine (9) socio-economic factors were inserted in the model as independent variables (income, education, farmer's household size, farm ownership, farm size, gender, age, farm location and crop type). The variables were tested by irrigation water demand as dependent. The model output; model summary, ANOVA table and coefficients tables are presented in Table 4.2 – 4.7 respectively.

Table 4.2: Summary of Step-wise Regression Model for river zones

River zones	Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Sig. F Change
Upstream	1	0.305[a]	0.093	0.074	1.186	0.031
	2	0.445[b]	0.198	0.164	1.127	0.017
Downstream	1	0.457[c]	0.209	0.190	0.790	0.002
	2	0.553[d]	0.306	0.273	0.748	0.019
	3	0.630[e]	0.396	0.352	0.707	0.018
	a. Predictors: (Constant), Income					
	b. Predictors: (Constant), Income, Farm location					
	c. Predictors: (Constant), Farm ownership					
	d. Predictors: (Constant), Farm ownership, Education					
	e. Predictors: (Constant), Farm ownership, education, income					
	f. Dependent variable: Irrigation water demand					

For the Upstream zone, the predictor variables in the model were income of farmers and farm location from the river as shown in Table 4.2, while education, household size, farm ownership, farm size, gender, age and crop type variables were eliminated by the model. This implies that the eliminated independent variables were not predictors of irrigation water demand in upstream. The multiple correlation coefficient (R) for the relationship between the set of independent variables (income and farm location) and the dependent variable is 0.445, indicating the best combination of the independent variables which has relationship with irrigation water demand. The value of the R^2 = 0.198, implying that 19.8% of the variance in the irrigation water demand as a dependent variable was explained by the model.

For Downstream zone, the variables predicted by the stepwise regression model were; farm ownership, level of education and farmer's income while household size, farm size, gender, age, farm location and crop type were eliminated by the model. The multiple correlation coefficients (R) for farm ownership, income and education were 0.63, indicating the best combination of predictors influencing irrigation water demand as described in Table 4.2. The value of the R^2 = 0.396, indicates that 39.6% of the variance in the irrigation water demand can be accounted for by the linear combination of farm ownership, income and the level of education of a farmer. On the other hand, all nine variables in the middle stream of the river were eliminated by the model. This means that; those variables have no significant relationship with irrigation water demand. This can be attributed by the similarities of the farmers' characteristics in the middle of the Kiladeda River.

Furthermore, the stepwise regression model for the whole river was performed. The results showed that farm size and farm location were the predictor variables of irrigation water demand in the sub catchment as shown in Table 4.3. Income, education, farmer's household size, farm ownership, gender, age and crop type variables were eliminated by the model. This implies that the eliminated independent variables have no effect on irrigation water demand when the researcher considered the whole river. The value of the $R^2 = 0.135$, implying that 13.5% of the variance in the irrigation water demand was by the model.

Table 4.3: Summary of Step-wise regression model for the whole river

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.311[a]	0.097	0.091	1.357
2	0.368[b]	0.135	0.123	1.332
a. Predictors: (Constant), Farm size				
b. Predictors: (Constant), Farm size, Farm location				

Table 4.4: Results of ANOVA for the whole river

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.844	1	27.844	15.131	<0.001
	Residual	259.457	141	1.840		
	Total	287.301	142			
2	Regression	38.835	2	19.417	10.941	<0.001
	Residual	248.466	140	1.775		
	Total	287.301	142			
a. Predictors: (Constant), Farm size						
b. Predictors: (Constant), Farm size, Farm location						

The stepwise results were further validated by ANOVA test. The results in Table 4.5 indicate that the linear combination of farmer's income and farm location was significantly related to irrigation water demand at $F(2, 47) = 5.8$, $P < 0.05$ for upstream. In downstream, the linear combination of farm ownership, education and farmer's income was significantly related to irrigation water demand at $F(3, 41) = 8.974$, $P < 0.05$. The F value suggests that the model fits the data reasonably well. For the whole river, the linear combination of farm size and farm location was significantly related to irrigation water demand at F (2, 140) = 10.941, $P < 0.05$ as shown in Table 4.4.

Table 4.5: Results of ANOVA for River zones

River zones	Model		Sum of Squares	df	Mean Square	F	Sig.
Upstream	1	Regression	6.920	1	6.920	4.921	0.031[a]
		Residual	67.500	48	1.406		
		Total	74.420	49			
	2	Regression	14.731	2	7.366	5.800	0.006[b]
		Residual	59.689	47	1.270		
		Total	74.420	49			
Downstream	1	Regression	7.078	1	7.078	11.342	0.002[c]
		Residual	26.833	43	0.624		
		Total	33.911	44			
	2	Regression	10.386	2	5.193	9.271	<0.001[d]
		Residual	23.525	42	0.560		
		Total	33.911	44			
	3	Regression	13.441	3	4.480	8.974	<0.001[e]
		Residual	20.470	41	0.499		
		Total	33.911	44			
	a. Predictors: (Constant), Income						
	b. Predictors: (Constant), Income, Farm location						
	c. Predictors: (Constant), Farm ownership						
	d. Predictors: (Constant), Farm ownership, Education						
	e. Predictors: (Constant), Farm ownership, Education, Income						

The ANOVA results indicate there was significant difference in the means of the predictor variables for the upstream, downstream and the whole Kiladeda River. Nonetheless, this was not satisfactory to make a decision about the hypothesis “There is no statistically significant relationship between socio-economic factors of farmers and irrigation water demand in Kiladeda sub-catchment”. Thus, further interpretation based on the standardized and unstandardized coefficients in Table 4.6 and 4.7 was performed to determine the contribution of each predictor variables to the prediction of the dependent variable. Thus, according to the standardized and unstandardized coefficients (Table 4.6 and Table 4.7), the probability of the statistical test of the coefficients of each added individual independent variable is less than the level of significance ($p<0.05$). Therefore, there is a relationship between the selected predictors and the irrigation water demand. Hence, the null hypothesis was rejected, and therefore, the study supports the research hypothesis that there is a statistically significant relationship between the socio-economic factors of farmers and irrigation water demand in Kiladeda sub catchment.

Moreover, the *t* and Sig (p) values give a rough indication of the impact of each predictor variable (Pallant, 2011). A big absolute *t* value and small “*p”* value suggests that a predictor variable is having a large impact on the dependent variable. Also, the sign of the beta (B) coefficient indicates the direction of the relationship for the data values. If beta is greater than or equal to zero, the relationship is positive while if beta is less than zero, the relationship is negative as shown in Tables 4.6 and 4.7. In this regard, the results in Tables 4.6 and 4.7 produced the linear equations for predicting irrigation water demand in Kiladeda sub-catchment which were generated by using model coefficients (Beta weights).

Table 4.6: Factors Influencing Irrigation Water Demand for the whole river

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.137	0.233		17.726	0.001
	Farm size	0.604	0.155	0.311	3.890	0.001
2	(Constant)	3.762	0.274		13.719	0.001
	Farm size	0.600	0.153	0.309	3.936	0.001
	Farm location	0.204	0.082	0.196	2.489	0.014

Table 4.7: Factors Influencing Irrigation Water Demand in Kiladeda sub catchment

River zones	Model Predictors (Variables)		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Upstream	1	(Constant)	2.784	0.380		7.328	0.001
		Income	1.657E-5	0.001	0.305	2.218	0.031
	2	(Constant)	2.177	0.436		4.994	0.001
		Income	2.096E-5	0.001	0.386	2.866	0.006
		Farm location	0.281	0.113	0.334	2.480	0.017
Downstream	1	(Constant)	7.167	0.410		17.484	0.001
		Farm ownership	-1.167	0.346	-0.457	-3.368	0.002
	2	(Constant)	8.011	0.521		15.374	0.001
		Farm ownership	-1.213	0.329	-0.475	-3.689	0.001
		Education	-0.451	0.186	-0.313	-2.430	0.019
	3	(Constant)	7.171	0.598		11.993	0.001
		Farm ownership	-1.062	0.316	-0.416	-3.356	0.002
		Education	-0.450	0.175	-0.312	-2.568	0.014
		Income	1.532E-5	0.001	0.306	2.474	0.018

i. **Upstream of the river**

$$IWD = 2.096 \times 10^{-5}[I] + 0.281[F.L] + 2.177$$

ii. **Downstream of the river**

$$IWD = -1.062[F.O] - 0.45[E] + 1.532 \times 10^{-5}[I] + 7.171$$

iii. **The whole Kiladeda Sub catchment**

$$IWD = 0.6[F.S] + 0.204[F.L] + 3.762$$

Where;

I = Income, F.L = Farm location, F.O = Farm ownership, E = Education and F.S = Farm size.

By using linear representation from the Upstream and Downstream zone together with the mean income, farm size, farm location, education and farm ownership, it evident that the average water demand for irrigation per day for upstream and downstream are 4,752m^3 and 8,640m^3 respectively. Moreover, the regression results as shown in the above equations suggest that farm ownership and education level of farmers are inversely correlated with irrigation water demand in Kiladeda sub-catchment, whereas income and farm location are positively correlated with irrigation water demand.

4.3 Adopted Practices of Irrigation Water Management

4.3.1 Furrow Irrigation

The study investigated two main irrigation techniques employed by farmers namely, furrow and buckets irrigation techniques. According to the results obtained during the field survey, no farmer was reported to use both methods. Nonetheless, furrow irrigation was the dominant (86.7%) in the Kiladeda sub-catchment. The study revealed that 86% of respondents interviewed indicated furrows as the means of irrigation technology used in the upstream of the sub-catchment. In middle stream, 85.4% of farmers employed furrow irrigation method, while 88.9% of farmers employed furrow irrigation methods in downstream of the river (Figure 4.7).

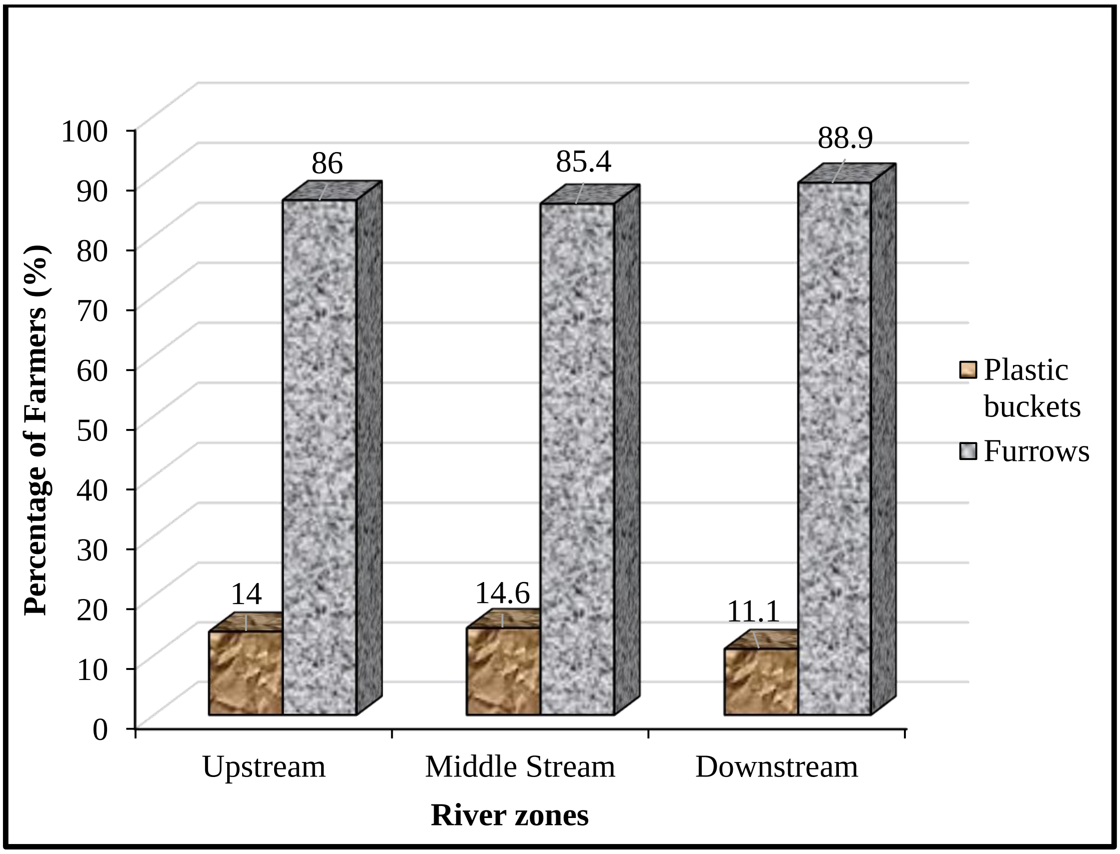

Figure 4.7: Irrigation technology employed by farmers

The study also found seven open furrows in the sub catchment. Two furrows were located in the upstream part of Kiladeda River, two in the midstream and three in the downstream zone (Figure 4.8). The furrows are divided into primary, secondary and tertiary furrows (Plates 4.2- 4.4). The primary furrows divert water direct from Kiladeda river, secondary furrows divert water from the primary (main furrows) while tertiary furrows diversions were furrows which diverted water from secondary and by gravity convey the water to the farms. The primary furrow were constructed by using cement, stones and corrugated flow surface, and well protected with abstraction control gates at the intake immediately from the river. The secondary and tertiary furrows are constructed of unlined earth and normally lose a lot of water.

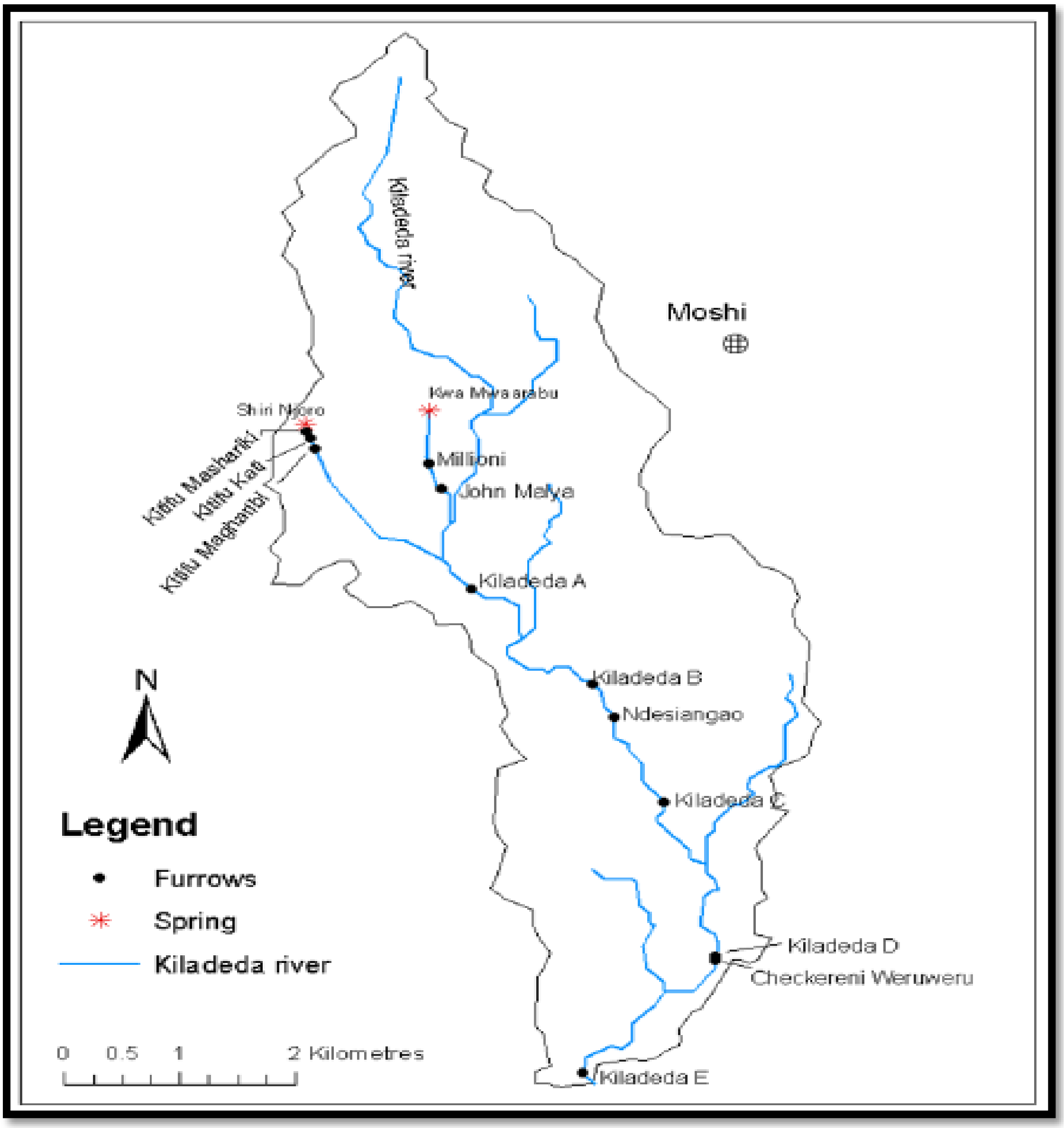

Figure 4.8: Location of spring and furrows in Kiladeda river (Komakech *et al.*, 2012a)

Furrow irrigation are shown by IUCN (2009) and Komakech and Van der Zaag (2011) that local farmers in the highland and low land areas of Kilimanjaro region have practised furrow irrigation for more than 200 years. The furrow irrigation system started around 1948 after communities settled in the area from the upper slopes of Mount Kilimanjaro. Since then the number of furrows has been increasing and accepted by the communities at present (IUCN, 2009). In his study on water management and water use in hill furrow irrigation in Kilimanjaro, Mattias (2010) observed that farmers in Kilimanjaro region utilise irrigation technology based on stream diversion canals or furrows. However, the system is less organised, technically inferior and water inefficient. Also, in Awash River, Ethiopia, the use of gravitational furrow irrigation is a common practice as noted by Wagnew (2004). Wagnew observed several leakages points from lined furrow and unlined furrow through the earthen materials and from breakages of cemented canals system.

Plate 4.2: The primary furrow in Kiladeda sub catchment (Source: Author, 2014)

Plate 4.3: The secondary furrow in Kiladeda sub catchment (Source: Author, 2014)

Plate 4.4: Existing tertiary furrow in Kiladeda sub catchment (Source: Author, 2014)

4.3.2 Plastic Buckets Irrigation

As explained above, water from the river is diverted to the irrigated farms by using an earth furrows which are poorly constructed and maintained. Therefore, farmers who have no direct access to tertiary furrows used plastic buckets to irrigate their crops (Plate 4.5). The study found that 13.3% of the total respondents used buckets for irrigation. As indicated in Figure 4.7 that 14%, 14.6% and 11.1% of farmers from upstream, middle stream and downstream zones respectively employed plastic bucket for irrigation. This can be attributed by the fact that middle stream and downstream farms were located very far from the river and furrows. Also, the higher number of farmers using buckets for irrigation in upstream was due to unregistered farmers who rented the farmlands. Interestingly, unknown quantity of water was abstracted per day and water user committee has never dealt with those farmers who illegally abstract water from the furrow.

Plate 4.5: Irrigation by using buckets in Kiladeda sub catchment (Source: Author, 2014)

4.3.3 Hypothesis testing on irrigation management practices adopted

To test hypothesis "There is no significant relationship between irrigation water management practices adopted by farmers and irrigation water demand". The study used independent samples T-test and the results were summarised in Table 4.8-4.12. The output consists of two major parts: Group Statistics (Table 4.8) and independent Samples Test (Tables 4.9, 4.10, 4.11 and 4.12). The Group Statistics output provides the sample sizes (N), means, standard deviations, and the standard error of the mean for the continuous variable (irrigation water demand), separate for each group.

Table 4.8: Results of the descriptive statistics of river zones

Group Statistics						
River zones		Irrigation techniques	N	Mean	Std. Deviation	Std. Error Mean
Upstream	Irrigation water demand	Buckets	7	2.0000	0.0001	0.0001
		Furrow	43	2.1160	0.3244	0.0495
Middle stream	Irrigation water demand	Buckets	7	3.0000	0.0001	0.0001
		Furrow	41	2.9270	0.3457	0.0540
Downstream	Irrigation water demand	Buckets	5	2.8000	0.4472	0.2000
		Furrow	40	2.9500	0.2207	0.0349
Whole Sub catchment	Irrigation water demand	Bucket	19	4.6320	1.4225	0.3263
		Furrow	124	4.9760	1.4226	0.1278

Using significance level of 0.05, an independent-samples t-test was conducted to evaluate whether furrows and plastic bucket irrigation techniques differed significantly with irrigation water demand. The test's results indicated that there was no significant difference in irrigation water demand for furrows irrigation technique (*M* = 4.976, *SD* = 1.4226) and buckets irrigation techniques (*M* = 4.632, *SD* = 1.4225; *t* (141) = -0.982, *p* = 0.328, two-tailed) in the sub-catchment (Table 4.9). The magnitude of the differences in the means (mean difference = -0.344, 95% *CI*: -1.037 to 0.349) was weak with e^2= 0.007, meaning that only 0.7% of variability in the irrigation water demand that is explained by furrows and bucket irrigation techniques.

Table 4.9: Summary of the independent t-test output in Kiladeda sub catchment

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. 2-tailed	Mean Diff.	Std. Error Difference	95% Confidence	
									Lower	Upper
Irrigation Water Demand	Equal variances assumed	0.123	0.726	-0.982	141	0.328	-0.344	0.351	-1.037	0.349

The test's results also indicated that there was no statistical significant difference between irrigation water demand and irrigation technologies adopted (furrows and buckets irrigation techniques) at *t* (46) = 0.555, *p* = 0.582, two-tailed and at *t* (4.25) = -0.739, *p* = 0.499, two-tailed) in the middle stream and downstream of the sub catchment respectively as shown in Table 4.10 and 4.11.

Table 4.10: Summary of the independent t-test output t-test in Middle stream

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. 2-tailed	Mean Diff.	Std. Error Difference	95% Confidence	
									Lower	Upper
Irrigation Water Demand	Equal variances assumed	2.615	0.113	0.555	46	0.582	0.073	0.132	-0.192	0.339

Table 4.11: Summary of the independent t-test output t-test in Downstream

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. 2-tailed	Mean Diff.	Std. Error Difference	95% Confidence	
									Lower	Upper
Irrigation Water Demand	Equal variances not assumed	5.296	0.026	-0.739	4.25	0.499	-0.150	0.203	-0.701	0.401

Conversely, there was a significant difference in irrigation water demand for furrows irrigation technique (*M* = 2.116, *SD* = 0.324) and buckets irrigation techniques (*M* = 2.0, *SD* = 0.0001; *t* (42) = -2.351, *p* = 0.024, two-tailed) in upstream of the sub-catchment. More specifically, by examining the group means and the means difference it is clear that furrow irrigation was practiced much higher than bucket irrigation techniques. The magnitude of the differences in the means (mean difference = -0.116, 95% *CI*: –0.216 to 0.017) was moderate with e^2 = 0.103, meaning that only 10.3% of variability in the irrigation water demand that is explained by furrows and bucket irrigation techniques. Even though SPSS does not provide e^2 values for t-tests, it was however calculated by using the Cohen's formula as follows (Pallant, 2011):

$$e^2 = \frac{t^2}{t^2 + (N_1 + N_2 - 2)}$$

Where;

e^2 = Eta square

t = t-test value

N_1= sample size for furrow irrigating farmers

N_2= sample size for bucket irrigating farmers

Therefore, the study accepts the null hypothesis and concludes that, there was no statistically significant relationship between irrigation management practices adopted by farmers and irrigation water demand in upstream as described in Table 4.12.

Table 4.12: Summary of the independent t-test output in Upstream

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. 2-tailed	Mean Diff.	Std. Error Difference	95% Confidence	
									Lower	Upper
Irrigation Water Demand	Equal variances not assumed	4.69	0.035	-2.351	42	0.024	-0.116	0.049	-0.216	-0.017

4.4 Water Allocation for Irrigation in Kiladeda Sub catchment

This section presents and discuss the findings of irrigation water allocation and demand among the farmers in Kiladeda sub-catchment toward improving irrigation water management.

4.4.1 River Discharge and Irrigation Water Use

The findings show that the average river discharges during wet and dry seasons were $0.44m^3/s$ and $0.11m^3/s$ respectively. This implies that the river experiences very low flows during dry season, from December to February. It was also noted that water abstraction for irrigation was critical during dry season with an average of $0.04m^3/s$ (Figure 4.9). According to Pangani Basin Water Office (PBWO), the maximum allowable water for abstraction in irrigation furrow is $0.03m^3/s$ per furrow. This means that farmers abstract water above permitted amount. Also, the study found that there was very low water abstraction rate during rainy season. The average abstraction rate was $0.02m^3/s$ during wet season. This can be ascribed by the fact that farmers are not relying on river water during rainy season. Also, the study found some control gates were closed during heavy rain in order to avoid floods (Plate 4.6).

Moreover, it was noted that upstream farmers (Kiladeda A and B) abstract more water for irrigation then downstream farmers (Kiladeda D, E and Chekereni). This situation brings water conflict between upstream and downstream farmers especially in dry season where by some downstream furrows are completely dry. For instance, Kiladeda E was completely dry during January and February, 2014 (Plate 4.7).

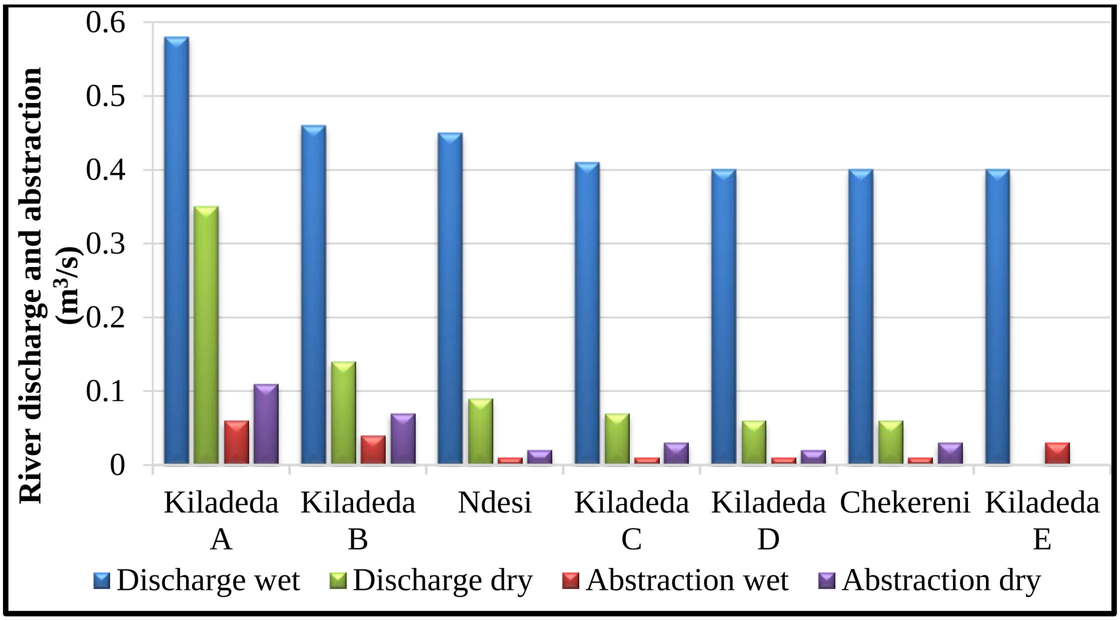

Figure 4.9: River discharge and abstraction rate of dry and rain season in 2014

Plate 4.6: Closed gates during rainy season in Kiladeda river (Source: Author, 2014)

Plate 4.7: Kiladeda E furrow during dry season, January 2014 (Source: Author, 2014)

4.4.2 Results of Model Calibration and Validation

WEAP model was calibrated with discharge data by comparing observed and simulated discharge. The Figure 4.10 shows the results of the calibration process. The results display good agreement between simulated and observed discharge of Kiladeda sub catchment. The correction coefficient (R), Nash-Sutcliffe efficiency (NSE) and the percentages bias (PBIAS) were used to assess the model performance in simulating observed discharge at the spot gauges and are shown in Table 4.13. The NSE (0.69-0.78) and R^2 (0.73-0.88) values indicate that the ability of the model was satisfactory. This is because the model is deemed to perform satisfactory if the NSE values range from 0.5 to 1.0 and percentage bias of ± 25% (Kagoda and Ndiritu, 2009).

Table 4.13: Results of the model performance of the Spot gauging stations

Gauging station	R^2	NASH (NSE)	PBIAS
Upstream	0.88	0.78	25.4
Middle stream	0.73	0.69	20.3
Downstream	0.85	0.73	22.5

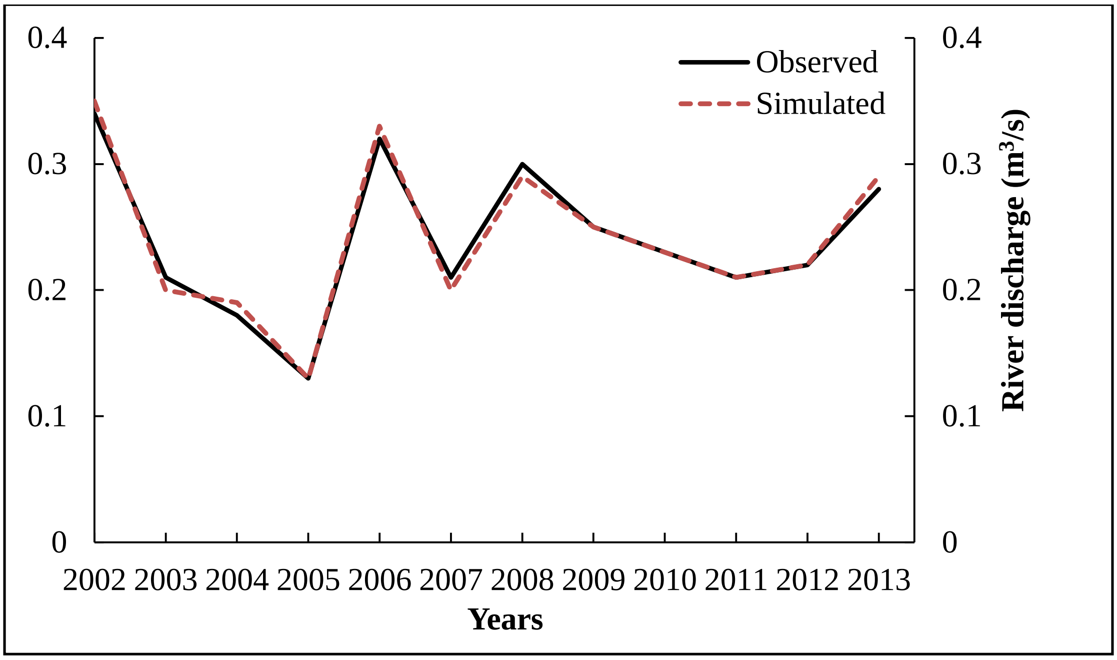

Figure 4.10: Observed and simulated discharge of Kiladeda sub catchment

4.4.3 WEAP Scenario analysis

The study used WEAP model to investigate water demand and allocation among upstream, middle stream and downstream farmers. Two scenarios were analysed namely; reference scenario and irrigation expansion scenario. The results are presented in this section.

4.4.3.1 Reference Scenario

In reference scenario, the current water demand of 2013 of Kiladeda sub catchment was calculated. The model results revealed that the current water demand in the sub catchment is 18.44Mm^3 annually (Table 4.14). The annual irrigation water demand for upstream, middle stream and downstream were 7.78 Mm^3, 4.51Mm^3 and 6.15Mm^3 respectively. The results imply that the upstream farmers use high amount of water than middle and downstream farmers. The monthly irrigation water demand for all sub catchment areas are presented in Figure 4.11.

Table 4.14: Annual irrigation water demand distribution reference scenario

River zones	Water demand (Mm^3)	Percentage (%)
Upstream	7.78	42.20
Middle stream	4.51	24.50
Downstream	6.15	33.40
Total	**18.44**	**100.00**

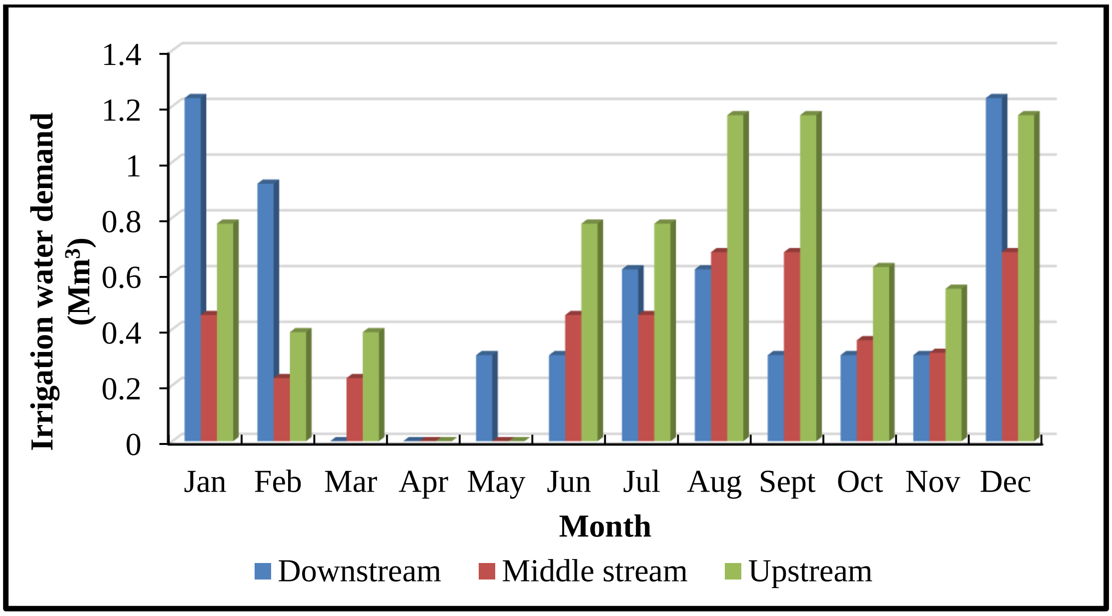

Figure 4.11: Monthly irrigation water demand in Kiladeda sub catchment from WEAP

On the other hand, unmet irrigation water demand for reference scenario was also computed. In this study, unmet water demand was considered as the amount of water that is not provided from the river during a part of the year. Unmet water demand is important for sub catchment water management and planning purposes. The results show that the current annual unmet irrigation water demand was 9.8Mm^3. This implies that only 47% of total irrigation water was met while 53% of irrigation water was unmet. Therefore, the results imply that sub catchment has water shortage of about 53% of the total irrigation water needed. The unmet demand was distributed into 3.44Mm^3, 2.33Mm^3 and 4.03Mm^3 for downstream, middle and upstream respectively. The monthly distribution of unmet irrigation water demand for reference scenario is shown in Figure 4.12.

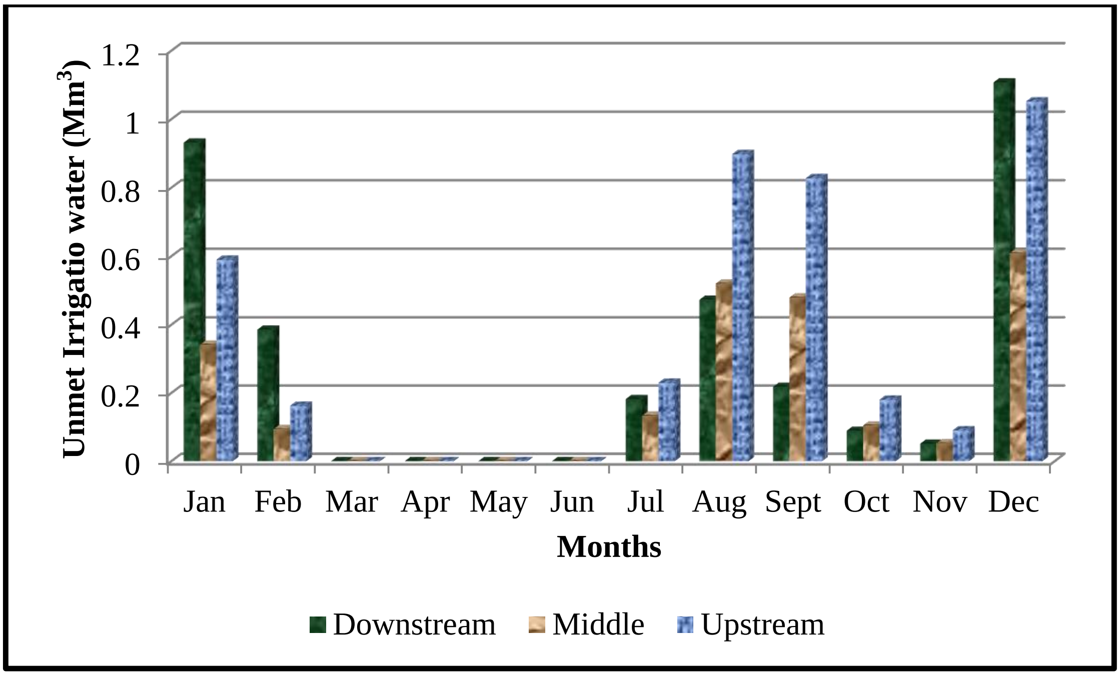

Figure 4.12: Current unmet irrigation water demand in Kiladeda sub catchment

From the Figure 4.12, it is clear that Kiladeda River has low flow when no rainfall was received in January, August, September and December in which the unmet irrigation water demand is high. During these months farmers depend on rain for irrigation purposes. However, the results show that the irrigation water demand was almost fulfilled during the months of March, April, May and June where by heavy rains occur. This is also implying that farmers are not much utilizing river water for irrigation activities. Therefore, it can be concluded that despite the fact that farmers' abstract water above the permitted level during dry season, still the current irrigation water demand remains unmet in Kiladeda sub catchment. Hence, this situation accelerates water use conflicts between upstream and downstream farmers and will increase river degradation if other alternative sources of water will not be provided to the farmers to supplement the demand.

The results are in agreement with the Ndiiri (2011) who modelled water demand for different demand sites in Mara river. She observed that agriculture sector was the least water consumer in the catchment. However, the demand for irrigated agriculture was unmet by 18%. Ndiiri (2011) found that approximately 28 Mm^3 per year should be diverted to the irrigation schemes to satisfy the demand. Moreover, Hussein and Al - Weshah (2009) found that water qualities was not sufficient to cover all the purposes for irrigation in Jordan Valley. They revealed that only 70% of the actual irrigation water demand was met with the available resources. Hence, they recommended that the raise of efficiency of irrigation practices by 10% would be appropriate for reducing unmet water demand in the Jordan Valley. Nonetheless, this study found that only 47% of total irrigation water demand was met in Kiladeda sub catchment.

In the same way, Mutiga *et al.* (2010) modelled water allocation for different sectors in the Upper Ewaso Ng'iro North Basin, Kenya. They observed that high water demand for irrigation was the main cause of excessive water abstraction particularly in the upstream catchments, giving rise to water shortages and subsequently, water use conflicts downstream. It is therefore, like in other catchment mentioned, integrate water resources approaches which consider all user's demand are needed to minimise conflicts between upstream and downstream farmers in Kiladeda sub catchment.

4.4.3.2 Irrigation Expansion Scenario

Irrigation expansion scenario in this study anticipated to answer the question "What if irrigation area expands from 135 hectares to all 204 hectares that belong to agricultural land use?" When irrigation expansion scenario was modelled, it was observed that average annual irrigation water demand in the sub catchment increased from 18.44Mm^3 to 38.24Mm^3. The total annual irrigation water distribution for sub catchment zones were 12.29Mm^3, 9.56Mm^3 and 16.39Mm^3 for downstream, middle stream and upstream zones respectively (Figure 4.13). This implies that irrigation water demand will be almost doubled in 2020 as irrigation activities increase. Hence the situation will increase water shortage in the sub catchment.

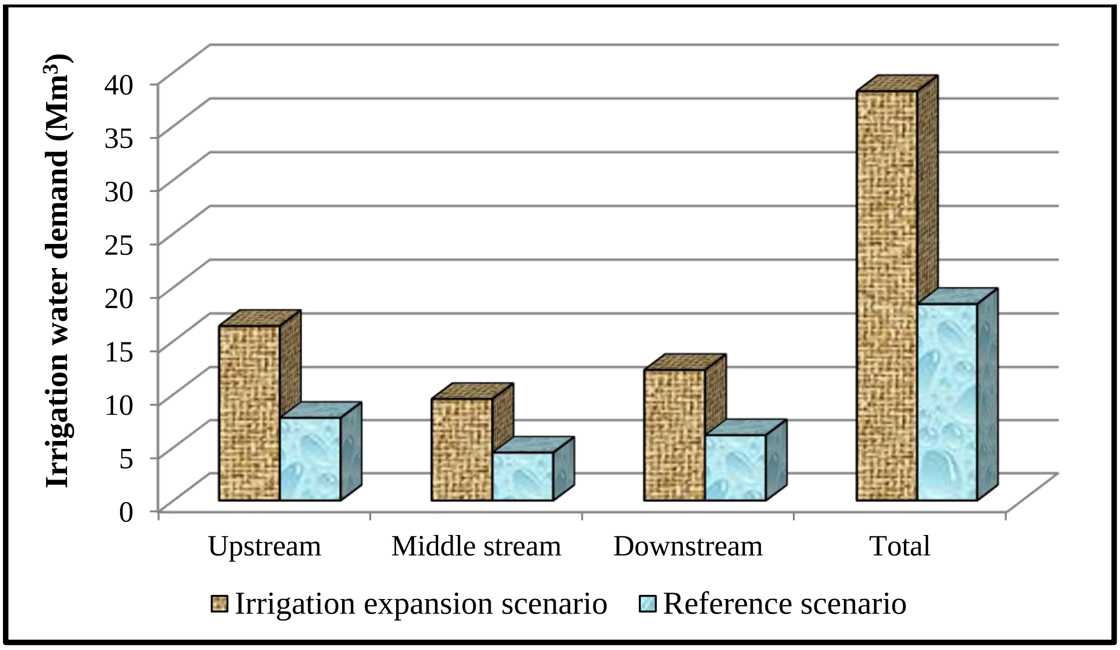

Figure 4.13: Annual irrigation water demand of irrigation expansion scenario

Also, in irrigation expansion scenario the model indicated high monthly irrigation water demand obtained in January, August and December while in the months of March to May the irrigation water demand was low as described in Figure 4.14. However, the study observed that the average annual unmet irrigation water demand was 28.34Mm^3 in irrigation expansion scenario as shown in Figure 4.15. Indeed, it can be deduced from the Figure 4.16 that irrigation water demand for March, April and May will be covered for 100% in spite of increasing irrigation needs in irrigation expansion scenario.

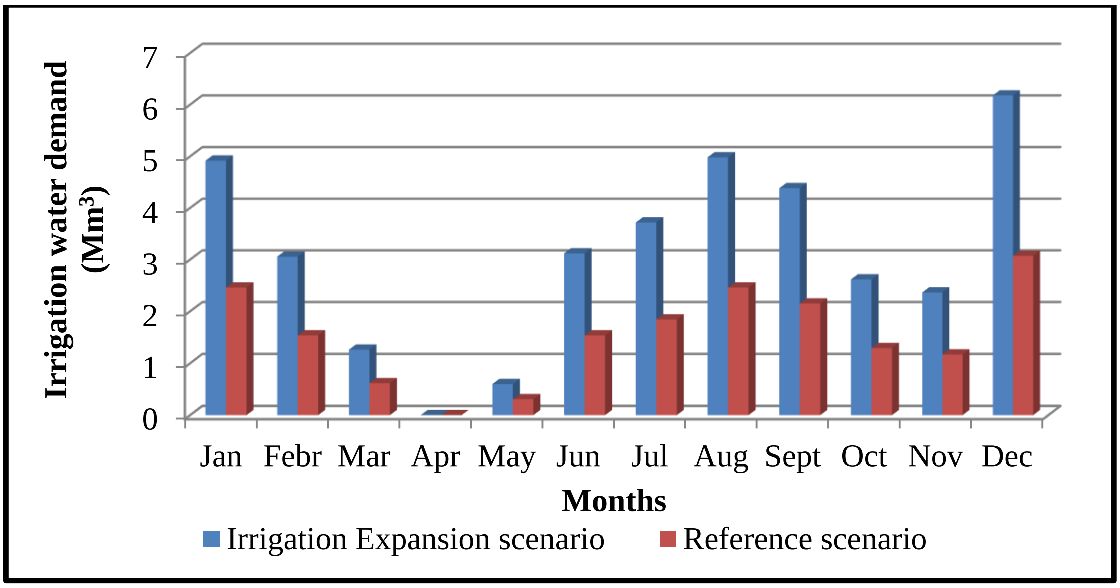

Figure 4.14: Monthly irrigation water demand of irrigation expansion scenario

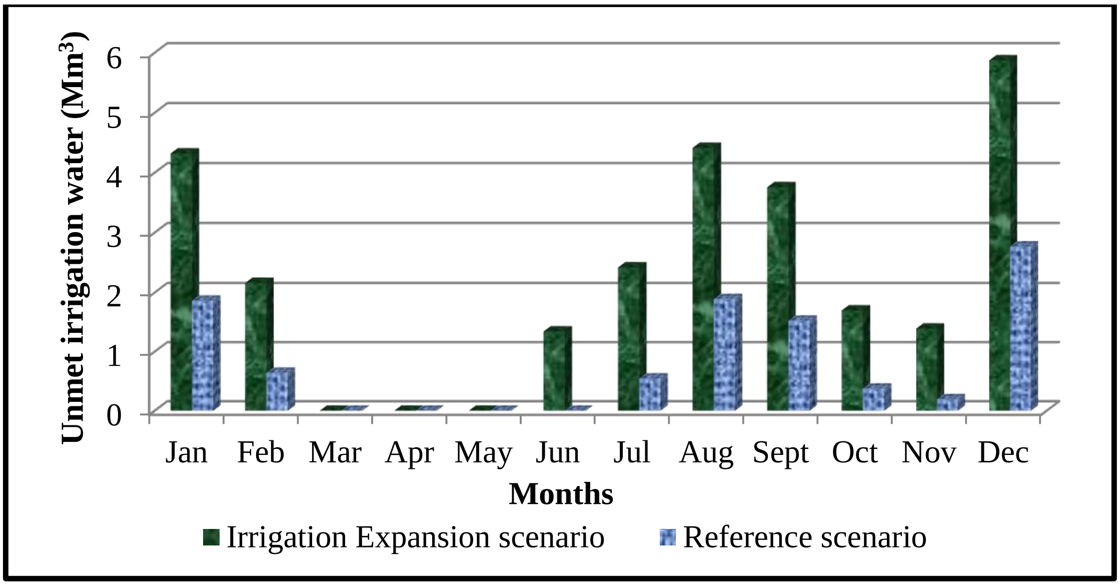

Figure 4.15: Monthly unmet water demand of irrigation expansion scenario

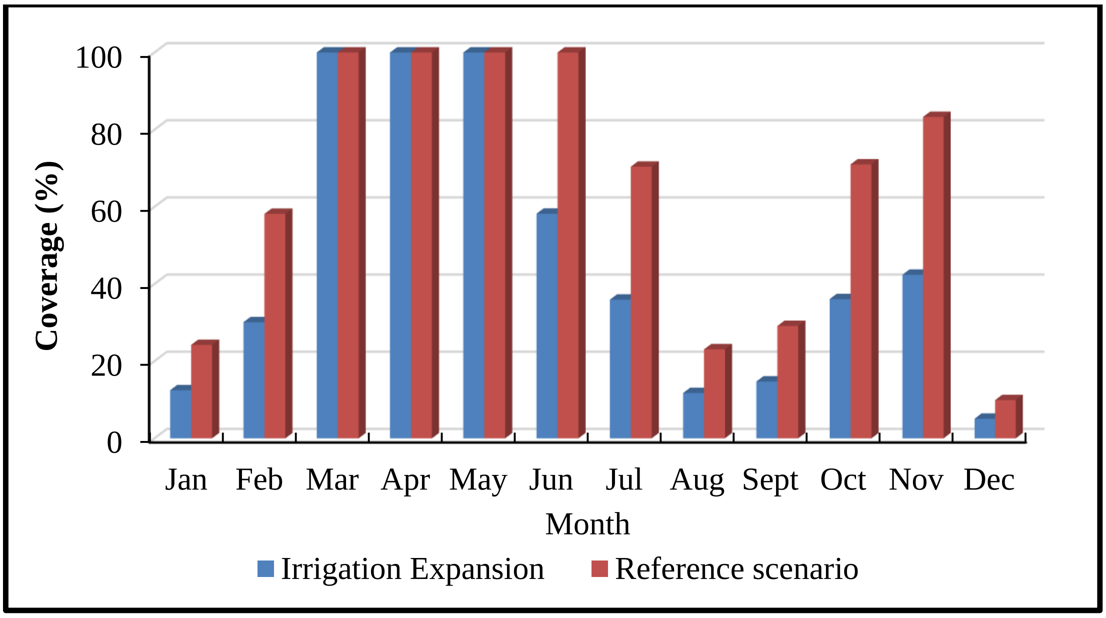

Figure 4.16: Coverage of monthly irrigation water demand in Kiladeda sub catchment.

The results of irrigation expansion scenario of this study conform to Ndiiri (2011) findings in Mara basin that the demand will increase in the future when population increases and irrigated agriculture expand. As the result shortfalls in water supply will increase especially during dry periods. Similarly, Mutiga *et al.* (2010) observed that the changes in land use such as increasing the area under irrigation resulted in an increase in water demand and consequently increasing the unmet demand in Upper Ewaso Ng'iro North Basin, Kenya.

In the same way, water demand results of this study correlate with empirical work by Mugatsia (2010) who modelled WEAP under increased water demand scenario in Perkerra catchment, Kenya. He observed that irrigation had the highest quantity of unmet demand under increased water demand scenario. This was because the flows of the river was decreasing and could not sustain the increased irrigation demand of Perkerra irrigation scheme. Therefore, this study concludes that the expansion of irrigation area in the sub catchment will increase water demand twice and therefore, it is required to implement more efficient management strategies of the available water in the sub catchment.

4.5 Strategies for Proper Water Use Allocation

Despite the fact that water shortage is a common problem in Kiladeda sub catchment and water resources are distributed unevenly, the farmers and authority have developed several strategies to reduce the impact caused by water shortage. These strategies include the formation of water users associations, water pricing, public education, reducing the farm size, water right as well as laws and regulations on water allocation. These strategies are presented and discussed in this section.

4.5.1 Formation of Water Users Association

Pangani Basin Water Office emphasized on community participation in water resources management in the respective sub catchment based on National Water Policy of 2002 and Water Resources Management Act of 2009 (URT, 2009). Therefore, irrigation water management in Kiladeda sub-catchment is managed by user-based, participatory management through sub catchment committee and Water Users Associations (WUAs). Kiladeda Water User Committee (KWUC) is responsible for arranging the water distribution to farmers belonging to their own KWUC; Water related conflicts resolution; Water permit acquisition, maintenance and conservation of water resources together with PBWO and Local Government Councils. KWUC is sub-divided into seven furrow committees (Figure 4.17), consisting of farmers having plots along the same canal. Since the farms of different farmers within the furrow area are irrigated at the same time, furrow chairman is responsible to coordinate their planting decisions and water demands.

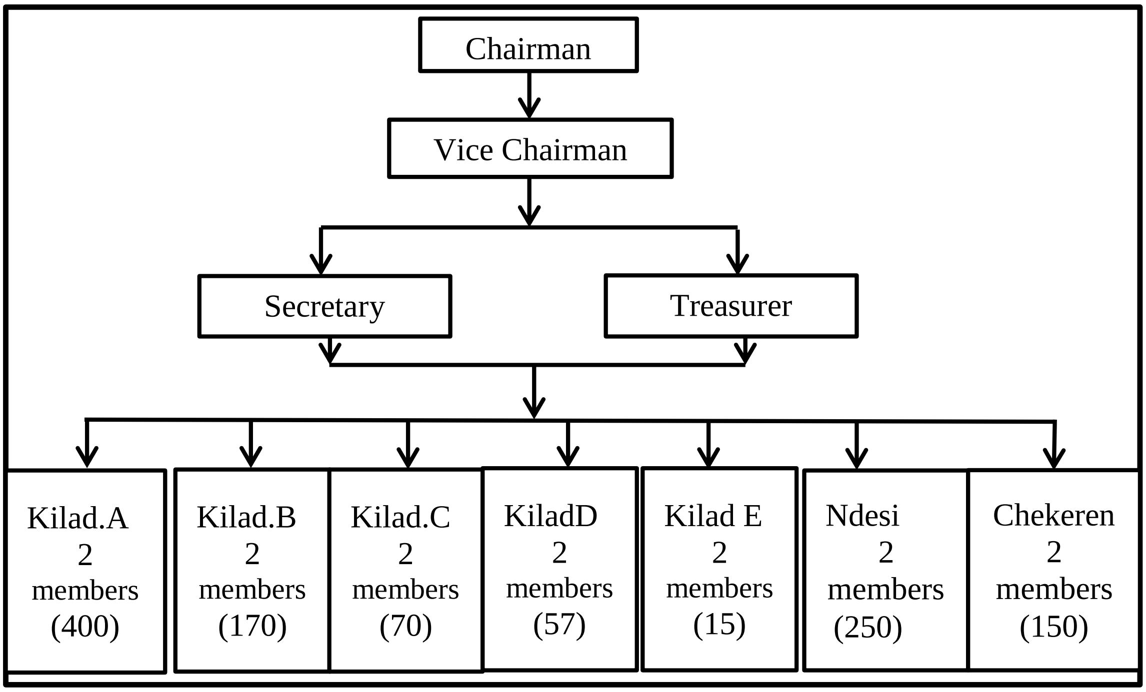

Figure 4.17: Structure of Kiladeda Water Users Committee

Moreover, in 2010, PBWO has formally established Karanga, Kikafu and Weruweru water users association called "UKAKIWE". This water users association was established by PBWO to conform to the Water Resource Management Act (WRMA) of 2009. It is responsible for catchments and their sub catchment conservation, guaranteeing equitable distribution of water and conflict resolution. UKAKIWE consists of all existing sub catchment water users committees as in Figure 4.19. The main objectives of UKAKIWE were to coordinate water users in all sub catchments and other stakeholders, to develop and oversee planned conservation measures and to encourage proper water management and conservation practices for sustainable water resources management.

However, the established WUAs are mainly active during dry seasons when there is water shortage. When farmers were asked about the effectiveness of the existing WUAs, 89.6% of the farmers responded that the association was effective in improving water availability and allocation, (61.7%) solving water related conflict (23.5%) and water source protection (4.3%). Nonetheless, about 10.4% of the farmers indicated that WUAs was not effective (Figure 4.18). This can be attributed to the fact that some farmers were not members of the association and were not aware of the WUAs.

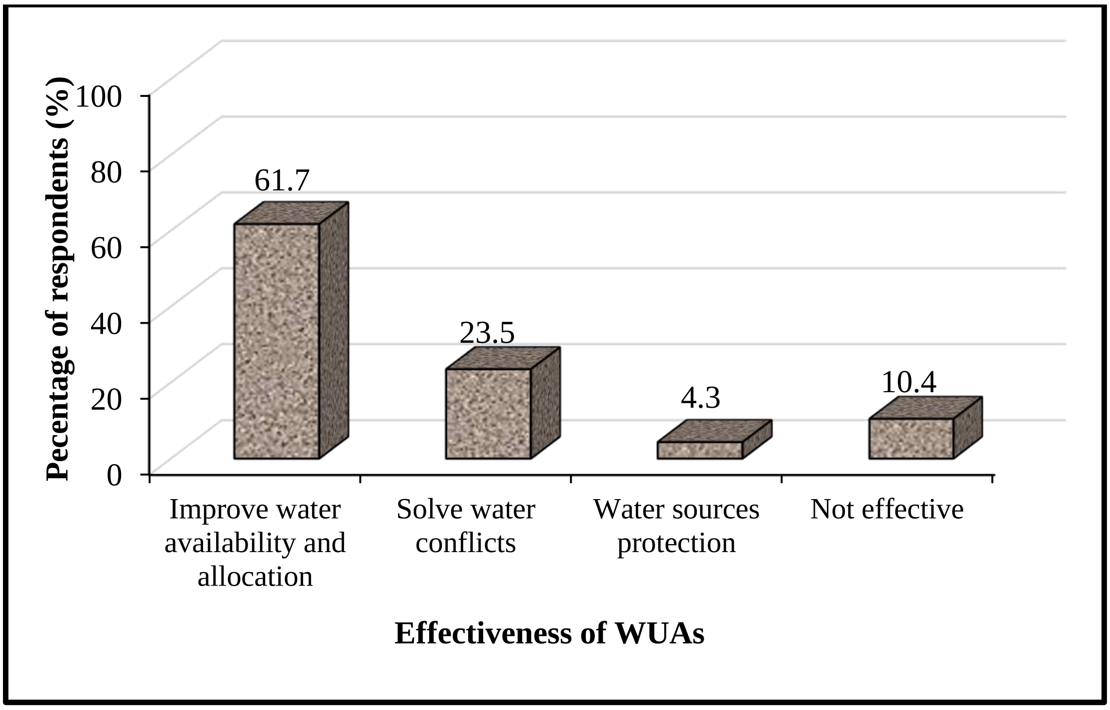

Figure 4.18: The perceived effectiveness of Water Users Association

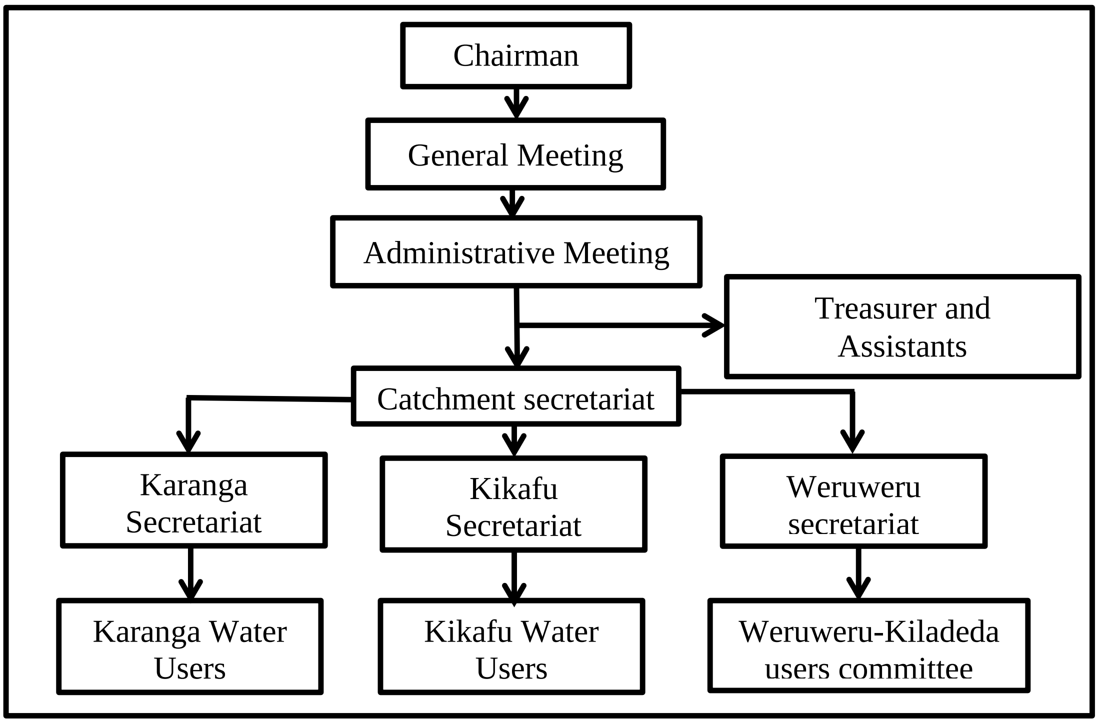

Figure 4.19: Structure of UKAKIWE Water Users Association.

According to Komakech *et al.* (2012b), the establishment of the WUAs association succeeded in minimizing water conflicts between farmers and provided an effective linkage between local arrangements and the basin water board in Pangani basin. For instance, established associations in lowland and highland of Hingilili sub-catchment have been able to solve existing water conflicts between the two sides and achieved more equitable access to and control over water resources. Again, river committees developed in Themi sub-catchment of Kikuletwa catchment have managed to structure proper water allocation and solve water conflicts between groups of water users (Komakech and Van der Zaag, 2011). Similarly, formation of WUAs would be able to promote and conserve water resource use in Upper Ewaso Ng'iro North Basin, Kenya as recommended by Mutiga *et al.* (2010). Similar strategy was noted by Nakano and Otsuka (2010) in Doho irrigation scheme, Uganda whereby water user groups were responsible for proper use, management and protection of water and related resources. For instance, they found that water user groups have been effectively contributed to irrigation water management and irrigation water availability at the plot level. They also found that water users groups clean the main sub-channels and drainage to enhance water distribution.

Study conducted by Ghazouani *et al.* (2012) about WUAs experience in Near East and North Africa, described that participation of farmers through water users groups contribute to water management, maintenance and recovering financial costs. This is because WUAs give farmers a say on issues beyond the tertiary or farm levels on seasonal water allocation at the secondary level, definition of distribution schedules and monitoring of water status. Lastly, Zhang (2013) found similar technique of WUAs formation used to mitigate irrigation water allocation conflicts in Heihe River watershed at Zhangye City in China.

Plate 4.8: Discussion with Furrows’ Chairmen (Source: Author, 2014)

4.5.2 Water Pricing

Water pricing is an economic incentive that encourages water users to adopt efficiency irrigation water use measures. The pricing strategies aimed at achieving economic efficiency and demand management which is the most important option for balancing water supply and demand in the future (Dziegielewski, 2011). Thus, Kiladeda water users committee has developed pricing mechanism in order to regulate irrigation water use. Every member of furrow contributes 3,000 TSH (US$ 1.4) per year. The money from farmer's contribution is used for operational costs of the furrows and intakes. However, other incomes of the committee are obtained through penalties which range from 50,000 to 100,000 TSH (US$ 24–48) depend on the nature of offence. Although water pricing approach provides financial resources to cover operational and maintenance costs in the sub catchment, water user committee has failed to control irrigation water use with respect to the cost imposed to farmers. This is because, in order to have equitable farmer's contribution, water should be charged volumetrically and not according to land area or number of hour used for irrigating crops (Wang *et al.,* 2010).

The study conducted by Komakech and Van der Zaag (2011) confirms similar approaches was used in Themi sub-catchment in Pangani basin. In Themi sub-catchment, every member of furrow contributes TSH 10,000 (US$ 4.8) per year for operational costs and each furrow chairman has to contribute Tshs 4,000 (US$ 2) per day for paying water guards. More so, the use of economic instruments are often promoted as strategy for not only irrigation water demand management but also domestic and other uses as explained by many scholars (Molle, 2008; Speelman, 2009). They also said to promote conservation and innovation, and provide signals to induce behavioural changes (Speelman, 2009).

4.5.3 Public Environmental Education

The study found that PBWO in collaboration with sub catchment committee and UKAKIWE has started plan of creating awareness of integrated water management to the stakeholders. Meetings with village leaders were conducted to sensitise the leaders about the need to mobilise the village members learn about integrated water management issues in their community. Moreover, the authority has established school essay competitions. One school essay competition per term at standard six levels for all primary schools in the sub catchment was conducted. The essay completion aimed at emphasizing community on the IWRM which enhance sub catchment conservation to guarantee continued water flow in the sub catchment. PBWO continues to create awareness on water resource management through mass media, social institutions, brochures and booklets. It is assumed that once the meetings have been conducted, community members help to disseminate acquired knowledge about the need to conserve water and the best conservation practices to the rest of the community. This was done in a long way in enhancing sustainability as more members enrol in the WUAs. Public education was also noted by Dziegielewski (2011) as the better means of encouraging water users to adopt and maintain long-term water conservation measures. This is because public education usually attempt to change people's behaviours associated with high water use and encouraging the use of water-saving devices and practices. Therefore, education is an instrumental in management of water resource and changing people's behaviours in Kiladeda sub catchment.

4.5.4 Reduce the irrigated acreage

To cope with the extremely water shortage, farmers were supposed to reduce the size of their irrigation farms to meet water requirement in the sub catchment (Plate 4.9). This was done especially during dry season as discharge from the river decline. The study found that 50.6% of the farmers have reduced their farmland (Figure 4.20). Nevertheless, some farmers did not completely adhere to, and tend to cultivate their entire land area.

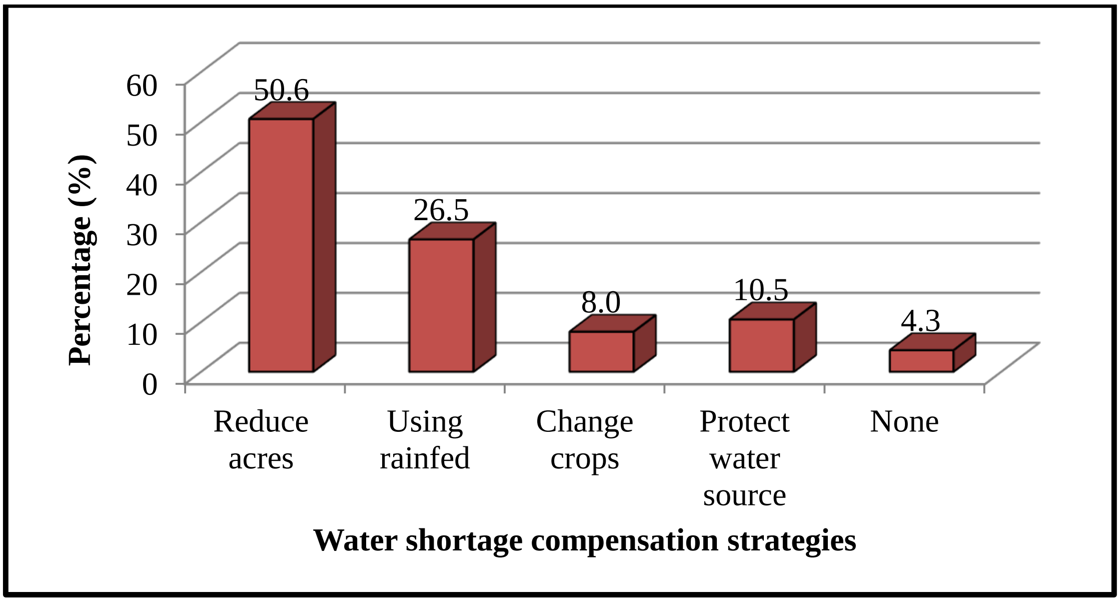

Figure 4.20: Farmer’s strategies for compensating water shortage

Plate 4.9: Reduced crop fields in dry season in Kiladeda (Source: Author, 2014)

Similar strategy was reported by Shock *et al.* (2013) when he was evaluating the strategies for efficient irrigation water use at Oregon Watershed. He found that farmers reduced irrigated acreage by leaving some land idle, and apply the saved water to high-value crops. This technique helped farmers to cope with the drought condition when water supplies were short. Again, Klock and Sjah (2011) point out that farmers turn over small farm area for irrigation in order to facilitate more efficient water management in Lombok, Indonesia. This was the common management strategy to contend with water shortage and enabled farmers to survive the lengthy dry seasons and drought periods.

4.5.5 Change in Crop Type

Changing of crops to be irrigated was one of the potential measures of reducing irrigation water demand and allocation disparities among farmers in Kiladeda sub catchment. This strategy involves shifting acreage from the high water use crops to a type of crop with lower water use requirements especially during critical period of water shortage. The study found that farmers were restricted to irrigate banana and rice during dry season of the year. The results from on farm survey show that 8% of the surveyed farmers decided to switch crops to the production of drought resistance crops to cope with the water shortage condition as described in Figure 4.20.

Findings from Mromba (2012) indicate that similar measure was used to mitigate over abstraction in the sub catchment. Besides, in analysing the impact of shifting irrigated planted acreage from high water use crops to types of crops that reduced amounts of applied irrigation, Amosson *et al.* (2005) observed similar strategy in Texas. They observed that farmers were converting irrigated corn acreage to irrigated cotton and, sorghum to soybean to reduce irrigation water use in Texas. Similarly, Evans and Sadler (2008) pointed out that farmers have shifted to crops that mature more quickly such as small grains and cool season oil seeds in United State. This farming was practiced when the amount of irrigation water delivered to farms was not enough for irrigation due to frequent season droughts. By applying this strategy, it has been assumed that this change result in water savings.

4.5.6 Water rights

In Kiladeda sub catchment, water is abstracted mainly for domestic and irrigation purposes. This was done particularly in the upstream and downstream zones where most of the demand for domestic and irrigation use of water occurs. However, livestock watering was also practiced in the sub catchment. According to Water Act of 2009, all water is vested to the Government. Therefore, one of the core functions of the PBWO is to make sure that water users at every abstraction must have a water use permit.

Therefore, all users are subjected to water permit application except livestock watering and domestic uses, irrespective to the size of their use. Water right is allocated to a certain amounts of flow by the PBWO based on a general understanding of supply and demand for water around the basin. The users are supposed to pay non-refundable fees once in life time and annual fees in each year. Normally, issuing water permit is supposed to take about a moth to get a water right processed, but it often takes longer as the water board needs to collect information from different stakeholders.

The water right issued to each furrow for which PBWO requires payment of TSH 20,000 (US$ 9.5) per year. Therefore, sub catchment committee has created regulation that each furrow's member supposed to pay a charge of TSH 3000 (US$ 1.4) per year. Some percentage goes to the respective village council and the rest remain to the furrow committee. However, farmers are not willing to pay for water right due to the notion that water is a free commodity as in previous years (Plate 4.10).

Plate 4.10: Illegal water pumping in Kiladeda sub catchment (Source: Author, 2014)

The similar approach as a measure for controlling irrigation water use has been used in many water basins in Tanzania (IUCN, 2010). Most of these basin boards have been issuing water use permits and collecting annual water fees from registered users for close to a decade (Komackech *et al.*, 2012). For instance, in Wami river basin, all abstraction must have a water use permit. Small scale users are supposed to pay 35,000 Tsh (US$ 17) while the major water users such as Morogoro water supply authority and Dar es salaam water supply supposed to pay 200,000 Tsh (US$ 95) per annum. It has been reported that revenues collected from water permits provide 40% of the finances needed for operation in Wami River Basin (IUCN, 2010).

4.5.7 Laws and Regulations on Water Allocation

Though Pangani Basin Water Office is mandated with management of water resources in the sub catchment, water users committee has responsibility of water allocation between farmers. Different laws and regulations have been adopted to mitigate irrigation water use and allocation disparities. For instance, to ensure a fair distribution, the committee introduced irrigation schedule between the furrows. The amount of water diverted to each furrow is controlled by the intake gates. The aperture size of the intakes can be adjusted as required to suit water level and flow through the furrows. Furrows chairmen are responsible for setting trend scale for each intake and also locking the intakes to avoid water allocation conflicts among farmers (Plate 4.11).

The sub catchment committee allocates water to the farmers on a roster. Farmers receive water once per week. Each farmer getting about 2 hours of flow in upstream while both middle and downstream farmers receive irrigation water for about 3 hours. According to the chairman of the committee, downstream farmers get water for three hours because water takes an hour to reach the farms.

Plate 4.11: Intake gates for water allocation in Kiladeda (Source: Author, 2014)

Apart from rotational allocation, PBWO, UKAKIWE and sub catchment water users committee have established guidelines to protect water resources and illegal water uses to conform to the Water Resources Management Act section 34 (a) of 2009. These measures are;

- A holder of a Water Use Permit shall not cause or allow water to be polluted, prevent any damage to the source from which water is taken or to which water is discharge after use, and ensuring efficient use of water.
- A Water Use Permit shall be issued taking into account water needed for maintaining environmental flow requirements.
- PBWO Prohibited irrigation activities to be conducted beyond 60 metre from Kiladeda River. Any land holder proved to have engaged in any land use within this distance is committed an offence.

In this regard, Kiladeda committee and UKAKIWE impose penalties to the users who commit offence act such as illegal practice on water abstraction and any kind of water sources destruction. Fines are also levied for offences like violating the daily water allocation schedule and damaging of operating control gates. This fines range from TSH 2,000 to 50,000 (US$ 1 to 23.8) depending on the nature of the offence.

In assessing measures being taken to mitigate the effects of water abstraction on the riparian vegetation in Kiladeda River, Mromba (2012) observed similar strategy was used. He found that the sub catchment management authority introduced penalties to those who went against the laws and regulations. These laws and regulations were used as a strong strategy in maintaining river water and ecosystem integrity.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of the study was to assess the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub-catchment for efficient and sustainable water use. Therefore, the study set the objectives of assessing the socio-economic characteristics of farmers, adopted irrigation water management practices, irrigation water demand and allocation among farmers and strategies employed to mitigate disparities of irrigation water allocation in Kiladeda sub catchment. In this regard, this chapter presents conclusion, recommendations and suggests areas for further research.

5.2 Conclusions

The study revealed that farmer size, farm location, income, farm ownership and education were the socio-economic factors influencing irrigation water demand in Kiladeda sub-catchment. Therefore, the null hypothesis on the socio economic factors of farmers affecting irrigation water demand was rejected. Hence, the study concludes that there is statistically significant relationship between socio-economic factors of farmers and irrigation water demand in Kiladeda sub-catchment.

The study also established that furrow irrigation was the main irrigation techniques employed by farmers followed by plastic buckets irrigation. The results indicated that there was no significant difference between irrigation water demand and adopted irrigation techniques in Kiladeda sub catchment. Conversely, the t-test results showed a significant relationship between two adopted irrigation techniques and irrigation water demand in upstream of the sub catchment. Hence, the null hypothesis was accepted for the whole sub catchment and therefore the study concludes that there is no significant relationship between irrigation water management practices adopted by farmers and irrigation water demand in the sub catchment.

The average discharges during wet and dry seasons were ascertained as $0.44m^3/s$ and $0.11m^3/s$ respectively. Besides, the study discovered high water abstraction rate during dry season. The average abstraction rate was $0.04m^3/s$ and $0.02m^3/s$ for dry and rain seasons, respectively. The abstraction trend shows that upstream furrows abstract large quantity of water than downstream furrows. WEAP results indicate water shortages of about 53% in the sub catchment. For all scenarios, water demand increased and hence creates greater water shortage in the sub catchment. The current annual irrigation water demand was $18.44Mm^3$ while unmet irrigation water demand was $9.8Mm^3$. The average annual water demand and unmet water demand was $38.24Mm^3$ and $28.34Mm^3$, respectively for irrigation expansion scenario. Hence, improving irrigation efficiency would significantly improve water requirements and subsequently reduce the unmet water demands in the sub catchment.

The findings of the study revealed that several measures have been implemented by Pangani Basin Water Office, Water Users Association and Sub catchment Committee to mitigate irrigation water use and allocation conflicts. These measures were such as the formation of water users associations, water pricing, public education, reducing the farm size, changing crop types and regulation on water allocation among farmers and other users. However, poor coordination and farmer’s participation on sub catchment activities was the major drawback hindering sustainable development of the sub catchment. These findings emphasize the facts that in order to achieve sustainable watershed management, institutional and economic factors should be given special consideration.

5.3 Recommendations

From the findings demonstrated throughout this research, the following recommendations might be considered for sustainable irrigation water management in Kiladeda sub catchment based on IWRM principles. These recommendations focus on the PBWO, farmers, policy makers and agricultural extension officers as the key stakeholders for irrigation activities in the sub catchment.

i. Sound intersectoral water management requires an understanding of the linkage between social and economic factors of water resource system. From the study findings, education, income, farm ownership, farm location and farm size appeared to be potential determinants of irrigation water demand in Kiladeda sub catchment. Therefore, the study recommends that Pangani Water Office should train farmers on the methods of controlling the socio-economic characteristics which exacerbate effects on irrigation water use in the sub catchment.

ii. Pangani Basin Water Office should turn to other alternative water sources. The potentiality of the existing springs along the sub catchment, ground water boreholes and rain water harvesting should be considered. This will help to cope with an increased water demand for irrigation. PBWO should also encourage farmers on the use of improved irrigation techniques the sub catchment, particularly drip irrigation. Drip irrigation would be more efficient and economical in the use of irrigation water compared to bucket and furrow irrigation techniques.

iii. The study further urged PBWO to review laws and regulations in order to conform to the current irrigated area and irrigation water requirements. Also, PBWO should review water permit for Moshi Water Supply Authority. This is because large quantity of water is abstracted from the source to urban areas.

iv. Ministry of agriculture and PBWO should provide extension services to the farmers to enhance local understanding and community responsiveness toward sustainable watershed management based on economic efficiency and social equity.

5.4 Recommendation for Further Research

This study was predominantly based on assessing the management practices of irrigation water and their effects on water allocation among farmers in Kiladeda sub-catchment for efficient and sustainable water use. For the sake of comparability, it will be worthy to extend this research by integrating the water demand of other sectors such as domestic and livestock. However, in the future, particular attention should be given to the following research topics in Kiladeda Sub-catchment;

i. An investigation of future climate change effects on water for irrigated agriculture and other sectors in Kiladeda sub catchment.

ii. Assessment of farmers’ perceptions on irrigation water management and irrigation technologies adoption in Kiladeda sub catchment.

iii. Study on efficiency evaluation of different irrigation management techniques in Kiladeda sub catchment.

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APPENDICES

Appendix I: Questionnaire

PREAMBLE

Habari yako! My name is **Khatib Mwadini.** I am a student at Kenyatta University studying M.Sc. in Integrated Watershed Management. Currently I'm conducting a research on *Irrigation water demand management practices and their effects on water allocation among farmers in Kiladeda sub-catchment.* I would like to ask you a few questions in relation to this research. The information you provide will be kept confidential and will be used only for this research.

Section A: General information: **Date of Interview: …………**

1. Interviewee information

Name of Ward /Sub ward:	
River Sub-zone:	
Name of Interviewee:	
Age:	

Section B: Socio-economic characteristics information

2. Gender of interviewee

   a) Male ☐ b) Female ☐

3. What is your level of education

   a) None ☐ b) Primary ☐ c) Secondary ☐ d) Others ☐

4. How many people live in the household? ....
5. How many are they doing irrigation in this household? ....
6. What is the size of your farm? ……………………………………..................
7. Are you the owner of the farm?

   a) Yes ☐ b) No ☐

8. If no, what type of land tenure are you engaged in?

9. What is the source of income? ....
10. How much do you earn per Month? .... (TZSH).

Section C: Water demand and allocation information

11. Which crops do you irrigate?

a) Coffee ☐ b) Maize ☐ c) Vegetables ☐ d) Others ☐

12. Which irrigation technique do you use to irrigate your crops?

a) Drip ☐ b) Sprinkler ☐ c) Furrow ☐ d) Others ☐

13. How much water do you use for irrigation purpose per day?

....

14. Does it meet your demand?

a) Yes ☐ b) No ☐

15. If No, how do you compensate for your demand? ………………………

16. How much do you pay for irrigation water per month? ....

17. What is the source of water for your irrigation farming?

a) River ☐ b) Well ☐ c) Piped water ☐ d) Others ☐

18. Who is your water supplier for irrigation?

a) MUWSA ☐ b) PBWO ☐ c) River abstraction ☐ d) Others ☐

19. How frequent do you receive water for irrigation activities?

a) Daily ☐ b)After 2days ☐ c)After 3days ☐ d) Others ☐

20. Which storage facilities do you use to store water for the case of dry season?

a) Bucket ☐ b) Semi Tank ☐ c) Dam ☐ d) Others ☐

21. How many years have you been irrigating?

a) Less than 1 ☐ b) 1-5 years ☐ c) 6-10 years ☐ d) Above 10 ☐

22. What are the benefits obtained through the use of your irrigation technique?

………………………………………………………………………………

…………………………………………………………………………………
23. What are the constraints obtained through the use of your irrigation technique?
…………………………………………………………………………...

24. Are you a member of water users association (WUA)?

a) Yes ☐ b) No ☐

25. If Yes (Question 24), how effective is it concerning irrigation water demand and allocation
....

26. If No (Question 24), Why...

27. Are there any irrigation water management bylaws in the sub-catchment?

a) Yes ☐ b) No ☐

28. If yes, how it suits/fits with the existing situation
………………………………………………………………………………………

29. What could be done by the water institutions to improve demand management in the sub-catchment?
………………………………………………………………………………………
……………………………………………………………………………………....

Thank you very much for support and kind cooperation

Appendix II: In-depth interview guide

PREAMBLE

Habari yako! My name is **Khatib Mwadini.** I am a student at Kenyatta University studying M.Sc. in Integrated Watershed Management. Currently I'm conducting a research on *Irrigation water demand management practices and their effects on water allocation among farmers in Kiladeda sub-catchment.* I would like to ask you a few questions in relation to this research. The information you provide will be kept confidential and will be used only for this research.

1. How do socio-economic characteristics affect water demand and allocation process for irrigation farming in Kiladeda River?
2. A part from socio-economic factors, what are other factors affecting water demand and allocation system for irrigation farming?
3. Which types of irrigation management technologies are practiced in the sub-catchment?
4. How do technologies affect water demand and allocation?
5. What factors are influencing the farmers to adopt irrigation technologies?
6. What are the challenges of water allocation process to meet demand for irrigation faming?
7. Which part of the river do you think farmers are highly affected by inequitable water distribution?
8. How does your office collaborate with WUAs to address water conflicts among farmers in Kiladeda sub-catchment?
9. Which measures does your office take to solve the problem of water demand allocation?

Thank you for taking time to answer these questions

Appendix III: Observation guide for transect walk

Observation by____

GPS Location ________________________________ Date ___________________

Sources of water for irrigation	River	Springs/river	Water tap	Shallow wells
Types of crops	Coffee	Tea	Maize	Banana
Nature/soil types	sand	silt	Clay	Others
Irrigation techniques	Furrow/basin	Drip	Cans	Sprinkler
Irrigation schedule/Allocation	Daily	After 2 days	After 3 days	Others
Water storage facilities	Tanks (elevated/underground)	Buckets	Others	
Water shortage coping mechanism				
Existing Laws and regulations				
Other information				

Appendix IV: Discharge and irrigation abstraction measurement

Table 1: Average discharge and abstraction rate

Measurement (2014)		Kiladeda furrow/spot gauge							
		A	B	Ndesi	C	D	Chekereni	E	Average (m^3/s)
April (Wet)	Discharge	0.58	0.46	0.45	0.41	0.4	0.4	0.4	0.44
	Abstraction	0.06	0.04	0.01	0.01	0.01	0.01	0.03	0.02
Feb (Dry)	Discharge	0.35	0.14	0.09	0.07	0.06	0.06	0	0.11
	Abstraction	0.11	0.07	0.02	0.03	0.02	0.03	0	0.04

Table 2: River discharge calculation sheet in Dry season

Gauging station: Upstream of Kiladeda								February 2014			
Distance (cm)	**Sounded Depth (cm)**	**Revised depth of obs. (m)**	**Revs. (N)**	**Time (s)**	**Revs per sec.**	**Vel. At point (m/s)**	**Velocity (m/s)**		**Area of section (m^2)**	**Discharge in section (m^3/s)**	**Accum. Discharge (m^3/s)**
							Mean vel. In vert.	**Mean vel in section**			
0.00	0.0	0.000	0	40	0.00	0.000		0.0368	0.027	0.001	0.001
30.00	18.0	0.108	4	40	0.10	0.055	0.06	0.0896	0.1095	0.010	0.011
60.00	55.0	0.330	17	40	0.43	0.124	0.12	0.1799	0.1875	0.034	0.045
90.00	70.0	0.420	36	40	0.90	0.236	0.24	0.1746	0.21	0.037	0.081
120.00	70.0	0.420	15	40	0.38	0.113	0.11	0.0949	0.204	0.019	0.101
150.00	66.0	0.396	8	40	0.20	0.076	0.08	0.5692	0.174	0.099	0.200
180.00	50.0	0.300	166	40	4.15	1.062	1.06	0.7188	0.129	0.093	0.292
210.00	36.0	0.216	58	40	1.45	0.376	0.38	0.2339	0.0975	0.023	0.315
240.00	29.0	0.174	11	40	0.28	0.092	0.09	0.1135	0.081	0.009	0.324
270.00	25.0	0.150	19	40	0.48	0.135	0.13	0.1598	0.072	0.012	0.336
300.00	23.0	0.138	28	40	0.70	0.185	0.18	0.1945	0.126	0.025	0.360
360.00	19.0	0.114	31	40	0.78	0.204	0.20	0.1360	-0.10925	-0.015	0.345
245.00	0.0	0.000	0	40	0.00	0.000	0.00	0.00	0	0	0.000
											0.345
Compiled by Brown Mwangoka and Paul Damiel							Checked by: Mwadini J. Khatib				

Table 3: River abstraction calculation sheet rate in Dry season

Gauging Station: Downstream-Chekereni											Feb-14
Distance (cm)	**Sounded Depth (cm)**	**Revised depth of obs. (m)**	**Revs. (N)**	**Time (s)**	**Revs per sec.**	**Vel. At point (m/s)**	**Velocity (m/s)**		**Area of section (m^2)**	**discharge in section (m^3/s)**	**Accum. discharge (m^3/s)**
							Mean vel. In vert.	**Mean vel in section**			
0.00	12.0	0.072	0	40	0.00	0.350		0.2334	0.01200	0.003	0.003
10.00	12.0	0.072	54	40	1.35	0.414	0.35	0.3851	0.01250	0.005	0.008
20.00	13.0	0.078	64	40	1.60	0.420	0.42	0.4201	0.01300	0.005	0.013
30.00	13.0	0.078	65	40	1.63	0.420	0.42	0.3629	0.01350	0.005	0.018
40.00	14.0	0.084	65	40	1.63	0.306	0.31	0.2930	0.01400	0.004	0.022
50.00	14.0	0.084	47	40	1.18	0.280	0.28	0.1868	0.01350	0.003	**0.028**
60.00	13.0	0.078	43	40	1.08	0.000	0.00	0.00	0	0	0.028
Compiled by Brown Mwangoka and Paul Damiel							Checked by: Mwadini Juma Khatib				

Table 3: River discharge calculation sheet in Wet season

Gauging station: Upstream of Kiladeda											April 2014
Distance (cm)	**Sounded Depth (cm)**	**Revised depth of obs. (m)**	**Revs. (N)**	**Time (s)**	**Revs per sec.**	**Vel. At point (m/s)**	**Velocity (m/s)**		**Area of section (m^2)**	**Discharge in section (m^3/s)**	**Accum Discharge. (m^3/s)**
							Mean vel. In vert.	**Mean vel in section**			
0.00	0.0	0.000	0	40	0.00	0.000		0.0686	0.1125	0.008	0.008
50.00	45.0	0.270	13	40	0.33	0.103	0.10	0.2456	0.28	0.069	0.076
100.00	67.0	0.402	60	40	1.50	0.388	0.39	0.4455	0.32	0.143	0.219
150.00	61.0	0.366	78	40	1.95	0.503	0.50	0.3915	0.2825	0.111	0.330
200.00	52.0	0.312	43	40	1.08	0.280	0.28	0.2517	0.235	0.059	0.389
250.00	42.0	0.252	34	40	0.85	0.223	0.22	0.2294	0.2275	0.052	0.441
300.00	49.0	0.294	36	40	0.90	0.236	0.24	0.2358	0.29	0.068	0.509
350.00	67.0	0.402	36	40	0.90	0.236	0.24	0.1852	0.3175	0.059	0.568
400.00	60.0	0.360	19	40	0.48	0.135	0.13	0.1347	0.09	0.012	0.580
430.00	0.0	0.000	19	40	0.48	0.135	0.13	0.0673	0	0.000	0.580
300.00	0.0	0.000	0	40	0.00	0.000	0.00	0.1020	0	0.000	0.580
Compiled by Brown Mwangoka and Paul Damiel								Checked by: Mwadini Juma Khatib			

Appendix V: Monthly irrigation water requirement

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly rainfall, P (mm)	32.8	33.3	110.7	230.7	127.6	33.5	6.8	20.3	15.6	34.7	68.2	68.2
Effective rainfall, Pe (mm)	9.7	10.0	63.6	159.6	77.1	10.1	0.0	2.2	0.0	10.8	30.9	30.9
Monthly Evaporation (mm	145	131	135	83	78	69	72	81	112	127	119	134
Crop water need, E.Tc (mm)	167	151	156	95	89	80	83	93	129	146	137	154
IWR (mm/month)	157	141	92	0	12	70	83	91	129	135	106	123
IWR (mm/day) (Kc =1.15)	**5.2**	**4.7**	**3.1**	**0**	**0.4**	**2.3**	**2.8**	**3.0**	**4.3**	**4.5**	**3.5**	**4.1**