PHYSICAL AND ECONOMIC ACCOUNTS OF WATER IN KIKULETWA CATCHMENT, PANGANI RIVER BASIN, TANZANIA

DENIS VENDELINE VAGELA

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA

2015

ABSTRACT

This study estimated physical and economic accounts of water in the Kikuletwa catchment of Pangani River Basin. Specifically the study focused on physical water supply in the catchment, water use including main users and their respective amounts and estimates of water asset accounts. The study adopted the system of Environmental and Economic Accounting of Water (SEEAW). Secondary data on rainfall, water flow, spring water, water abstraction, groundwater recharge and evapotranspiration were collected at Pangani Basin Water Office while, secondary data on livestock and crop water use in the catchment were sourced from the National Sample Census of Agriculture of 2008. Water flow data were recorded in water depth measured in cubic centimetres then computed using the established discharge equations in gauged stations to obtain water flow quantities in m^3/month. Microsoft Excel 2007 was used to analyse data. Key findings show that, the catchment received 1 024 million m^3 of water as mean monthly inflow of which 39% came from rainfall and the rest 61% contributed by groundwater spring. The catchment water supply is scarce, as most of its water is highly committed. Small scale irrigation is the main user of water in the catchment taking 49% of water set for economy. The study recommended that; the PBWA should work with irrigators and Ministry of agriculture food security and cooperatives to improve water use efficiency in the catchment, harvest rain water to offset pressure on groundwater and grow more crops with higher yield per unit water used.

DECLARATION

I, Denis Vendeline Vagela do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted in any other Institution.

... **..**

Denis Vendeline Vagela **Date**

(Msc. Candidate)

The above declaration is confirmed

... **..**

Prof. Reuben M. J. Kadigi **Date**

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

I highly thank God for granting me good health and life throughout the period of this study, without whom nothing could be accomplished. In the second place but not in order of importance, I would like to extend my sincere thanks to my supervisor Prof. Kadigi for supervision and the tireless guidance throughout the study.

I'm also indebted to the following institutions and individuals: African Economic Research Consortium for awarding me a partial scholarship at Pretoria University, all the staff of Department of Agricultural Economics and Agribusiness for their encouragement and guidance at different periods of this study, all the staff of PBWO Head Office in Arusha, District Irrigation Engineers of Arumeru DC, Arusha CC, Hai DC, Moshi Rural DC, MUWSA, AUWSA and Agricultural Irrigation Office in the Northern zone.

Lastly but not least I thank my classmates for their cooperation and encouragements in the whole process of making this study a reality. In a very special way I would like to extend my sincere thanks to my beloved wife Agness L. Ngira for her tireless tolerance and encouragement during the period of this study.

DEDICATION

This work is dedicated to my lovely parents; Mr and Mrs Vagela Wendeline, for their moral and material support, encouragement, love and tolerance during the course of accomplishing it.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

AINZ	Agricultural Irrigation Northern Zone
AUWSA	Arusha Urban Water Supply and Sewerage Authority
CC	Capital Costs
CC	City Council
CEEPA	Centre for Environmental and Economic Policy in Africa
DC	District Council
EA	Environmental Accounting
ET_0	Evapotranspiration
IUCN	International Union for Conservation of nature
IWMI	International Water Management Institute
KIA	Kilimanjaro International Airport
L/sec	Litres per Second
LMIS	Lower Moshi Irrigation Scheme
LSI	Large Scale Irrigation
Mm^3	Million cubic mitres
MUWSA	Moshi Urban Water Supply and Sewerage Authority
MVPW	Marginal Value Product of Water
NE	Natural Environment
NRA	Natural Resource Accounting
NSCA	National Sample Census of Agriculture
NWSDS	National Water Sector Development Strategy
PBWA	Pangani Basin Water Authority
PBWO	Pangani Basin Water Office

PRB	Pangani River Basin
SADC	Southern Africa Development Community
SEEA	System of Environmental and Economic Accounting
SEEAW	System of Environmental and Economic Accounting of Water
SEI	Stockholm Environmental Institute
SIWI	Stockholm International Water Institute
SNA	System of National Accounting
SSI	Small Scale Irrigation
TDV	Tanzania Development Vision
TPC	Tanzania sugarcane Plantation Company
UN	United Nations
UNEP	United Nations Environmental Programme
UNSD	United Nations Statistical Division
UN-SEEAW	United Nations System for Environmental and Economic Accounting of Water
URT	United Republic of Tanzania
WRI	World Resources Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Global water demand has been growing rapidly over the past few decades as a result of population growth as well as increasing per capita water demand. From 1940 to 2000 the withdrawal of freshwater has increased more than four times, despite improvements in water efficiency (WRI, 1996; 2005; UNWWAP, 2015). Excessive water withdrawals for agriculture and energy further exacerbate water scarcity. Freshwater withdrawals for energy production currently account for 15% of the world's total (WWAP, 2014), are expected to increase by 20% through 2035 (IEA, 2012). Studies indicate that about 748 million people do not have access to safe drinking water worldwide and water demand for manufacturing is expected to increase by 400 percent between 2000 and 2050 globally (UN, 2005; UNWWAP, 2015). In Africa the problem was worse, as it was estimated that 42% of all people did not have safe drinking water (UN, 2004). While the world is entering a period of growing water scarcity, it was estimated that by 2030, global demand for water could outstrip supply by over 40% if no changes were made (UNEP, 2012). It was foreseen that water scarcity will be the key constraint to food production under business as usual scenario (SIWI *et al.,* 2008).

Tanzania faces a water stress situation in the country, as water demands exceed available resources. Up to 2005, water scarcity had raised concerns on issues related to its use, quantity and quality (NWSDS, 2005). The Pangani basin suffered water stress situation as well, about 90% of the surface water flow is used for irrigation and hydropower generation, yet this does not meet the current demand. Water efficiency among irrigation systems is often as low as 15%, hydropower production is regularly as low as 35% of capacity and conflicts are emerging between various water users (IUCN, 2007). Dwindling water resources threaten the livelihoods dependent on irrigated agriculture and the other important contributions that the Pangani River Basin's water resources make to the national economy. Unreliable water supplies amongst irrigation agriculture dependent communities in Kikuletwa catchment, undermines Tanzania's efforts to secure livelihoods and reduce poverty levels.

The application of physical and economic water accounting was pushed by the then existing water management challenges facing Pangani river basin in which the available allocation and use contributed significantly to conflicts amongst water users. Water accounting uses a water balance approach to quantify the amount of water entering in a catchment (through precipitation and river and groundwater flows) and the amount that leaves (through evaporation, plant transpiration river and groundwater outflows) to assure the available water for the economy. Water accounting provides a clear view of water resources in a catchment, it clearly shows where water is going, how it is being used and how much remains available for future use (Lange and Hassan, 2006). Water accounting is well used to monitor the interaction between water and human activity, providing an opportunity to track changes that are taking place from time to time in the catchment (Lange *et al*., 2003). Therefore, this study intended to contribute towards filling this information gap that is: the effect of population growth, climate variability land cover and use and their effects on water management by estimating water accounts for the Kikuletwa Sub catchment of the Pangani River basin. Information from this study will provide picture on the number of water users in the catchment, how much water is available and the best alternatives to optimise the scarce water available in the catchment. This information is vital for both, planning and decision making about sustainable fresh water management in the catchment (Mbaruku, 2006).

1.2 Problem Statement and Justification

Increasing population, changing life styles of people, urbanisation and the increased pressure of economic activities to the environment have all led to various water related challenges, for instance water scarcity due to increased irrigation development, increasing stress on the water environment, reduced water quality and increased conflicts amongst water users. The water management challenges in the catchment call upon government and stakeholders to deliberately find out economic techniques to guide the optimisation of water management in the catchment. Although irrigation development has been the pivotal strategy for livelihood enhancement of the people in the Pangani River Basin; and the URT (2002), acknowledges, freshwater is a basic natural resource which sustains life and provides for various social and economic needs, there is little effort to ensure availability of the optimal alternatives in the quantification, distribution and using water especially for both planning and decision making about sustainable fresh water management (Mbaruku, 2006).

The water scarcity in the basin was the main problem that propelled the undertaking of this study. According to IUCN (2011), water was over allocated in the catchment: more water was allocated to be used than actually was available. Currently a number of modern irrigation projects located in the Kikuletwa catchment operate under capacity due to water scarcity. Citing a case from the catchment, Lower Moshi Irrigation Scheme (LMIS) receives only 600 litres per second (L/sec), which is 207 L/sec short of its design discharge allocation of 800 L/sec due to uncontrolled upstream abstraction and inefficiency water use in furrow irrigation schemes (SMEC, 2012). Therefore addressing water scarcity and management challenges is crucial for ensuring food security and economic prosperity of the people in the catchment. Also understanding the relationship between the hydrological system and the economic system is ideal for promoting cross-sectoral issues such as Integrated Water Resources Management (IWRM) that Tanzania has embraced.

Tanzania has committed itself to an ambitious poverty reduction strategy, and plans to transform itself into a middle-income country by 2025. This will require massive economic development and growth. Yet, Tanzania faces water scarcity, at least partly due to the inefficiency with which water is allocated and used. This implies that water accounting has a potential contribution to attainment of the Tanzania Development Vision (TDV) 2025 through facilitating better options of efficient water allocation and sustainable management.

The Pangani river basin is faced with various water resources management problems and challenges particularly on how to balance the available water in the basin and use in a sustainable manner. Therefore this study will contribute to the generation of information on water balance and use. The application of economic tools to water resource management issues in the Pangani River Basin is considered to be an important step towards resolving water user conflicts and improving water allocation and management processes (Turpie *et al*., 2003).

Therefore, this study is of great importance to the success of the National Water Policy, which recognises subsistence needs and environmental water requirements, as well as the needs of future generations. Therefore, determining amount of water available in the catchment and how much is due for economic use and environmental care was inevitable to implement the policy. Additionally the policy ambitiously desires to develop equal and fair procedures in access and allocation of the water resources, ensure that social and productive sectors, and the environment receive their adequate share of the water resources and ensure that water allocations and use, shall be carried out considering the principles of sustainability so that the resources remain viable for the use of the present and future generations (URT, 2002). Therefore this study generated information that would enable water resource managers in the catchment use the available water efficiently by opening up options of optimal water use.

1.3 Objectives

1.3.1 Overall objective

To estimate physical and economic water accounts of Kikuletwa catchment in order to inform planners and decision makers, on sustainable water use and management.

1.3.2 Specific objectives

Specifically the study is sought to

i) Estimate physical monthly water supply of Kikuletwa catchment

ii) Estimate monthly economic water use within the catchment.

iii) Construct water supply and use tables adopting the System of Environmental and Economic Accounts of Water (SEEAW) matrix

1.4 Research Questions

The study is guided by the following study questions

i) How much water is available for use within the catchment?

ii) Who are the major users of water in the catchment and how much do they use?

iii) What is the water use efficiency measured in terms of crop yield per unit m^3?

1.5 Organisation of the Study

This study, estimated physical and economic accounting of water in order to generate information that would inform planners, decision makers and users of water in the catchment on sustainable water use and management. The study is organised into five chapters. Chapter one introduces the concept of water demand and importance, globally, in Africa and Pangani basin; problem statement and rationale of the study, study objectives and research questions. Chapter two presents review of literature of the study in which concepts were defined as applied to this study, theoretical framework of the study, the nature and characteristics of the supply and use tables as given by SEEA-W and current (time of this study) water use in the catchment. Chapter three presents the methodology of the study, in which; an overview of the study area, the design of the study and data type and collection techniques are presented. The chapter also discusses the data analysis techniques. Chapter four presents the results of research findings. The chapter focuses onto the three objectives: physical water accounts, economic water accounts and the supply and use tables of the analysed data. Chapter five presents conclusion and recommendation of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Key Definitions

2.1.1 Environmental and natural resources accounting

Natural resource accounting is the act of tracking the interaction between the economy and the environment in the whole system of the economy within the accounting boundary and period (Charles and Jeffrey, 2004). The main purpose of environmental and natural resources accounting is to provide economic information for households, businesses and governments to measure their performance and to prepare decisions (Sève, 2002). Environmental and natural resource accounting also intends to complement the inadequacy of the conventional economic indicators Gross Domestic Product (GDP) as measures of wellbeing and sustainability of people in the country, the latter is inadequacy because it doesn't capture the effect economic activity on the non tradable natural asset (Harris and Fraser 2002).

2.1.2 Water accounting

Water accounting is the systematic process of identifying, recognising, quantifying, reporting, assuring and publishing information about water, the rights or other claims to that water, and the obligations against that water (Peter *et al*., 2010; Burrell *et al.,* 2012). Water accounting is also described as the interaction between water resources and the economy (SADC, 2010). However, in this study water accounting has been used to mean, tracking of interaction between the hydrological system and economic system for monitoring the contribution of water resources to the economy and the effect (damage) of economy to water resources.

2.2 Application of Water Accounting

Studies indicate that the current global water crisis due not only to declining water availability but sub-optimal water management. (WWC, 2000; UNESCO, 2003; UNESCO, 2006; Goldman, 2008; UNESCO, 2009 therefore, the most valuable applications for water accounting are in identifying opportunities for saving water and increasing its productive use. This is done by showing where water is being used and providing a framework of assessing its productivity. Water accounting helps to pinpoint where water can be transferred from low to higher-value uses, evaluate the scope for improving productivity of water and target interventions, and identify opportunities to reduce non beneficial evaporation, pollution or the flow of water into sinks (deep aquifers where it can't be recovered). According to this study, four ways that can be used to improve the productivity of basin water resources include; increasing productivity per unit of water consumed, tapping uncommitted outflows, reducing non- beneficial depletion and reallocating water between uses.

2.3 Theoretical Framework of SEEA

The idea of carrying out natural resources accounts came from Integrated System of Environmental and Economic Accounting (SEEA) first published in 1993, upon the UNSD Rio Easter summit which recognised the need for environmental accounts (EA) as a fundamental instrument to control the depletion rate of the natural resources (SEEA, 2003). The SEEA complements and expands the system of National Accounts (SNA) to show the existing inter relations between economy and environment (UN *et al.,* 2012). It extends the SNA asset boundary, to include environmental assets and information in physical and economic variables in a common data framework. It measures the contribution of the environment to the economy and the impact of the economy to the environment and provides policy makers with the indicators and descriptive statistics for monitoring the interactions as a prerequisite database towards attaining sustainable paths of development (UNSD, 2004; Mbaruku, 2006).

2.4 The Theoretical Framework of SEEAW and SNA in Water Resources

The SEEAW has been developed as a satellite account of the SNA where as it expands the analytical capacity of national accounting in order to address water related challenges without disrupting the central system (Raouf, 2002; UN *et al.,* 2009). The two approaches share a similar structure as both use same concepts, definitions and classifications consistent with the conventional accounts while keeping the fundamental concepts and laws of hydrology. The SNA includes only the aquifers and groundwater resources without considering the depletion rate and related consequences. The SEEAW expands the SNA asset boundary by including all water resources, surface and ground water found in the territory and measure the depletion rate. The water asset accounts in physical terms are; an elaboration of the hydrological water balance, and they describe the changes in stocks due to natural causes and human activities (London group, 2005).

2.5 The SEEAW and SEEA Frameworks

The SEEAW framework is based on the SEEA (2003), expanding what is presented in the handbook by focusing on definitions and classifications related to water, providing compilation tables and discussing data issues and suggesting indicators that can be derived from the accounts. The distinction is; SEEAW is mainly concerned with water resources only unlike SEEA which integrates accounts of different natural resources (UNSD, 2012). Mbaruku (2006), suggest that when constructing a Supply and Use Table for water resources, the SEEA implicitly takes the perspective of the economy and looking at the water exchange with the environment and within the economy. According to Mbaruku (2006), this helps to facilitate the description of the interaction between the environment and the economy.

2.5.1 The SEEAW Framework

According to SEEA (2006), water resource accounts comprise of stock and flow accounts in physical and quality accounts. Physical flow accounts are a starting point for compilation of water accounts. The central framework of the SNA contains tables in the form of matrices that record how supplies of different kinds of goods and services originate from domestic industries and imports. It also shows how, those supplies are allocated between various intermediate or final uses including export, and so does the flow account provide information on the contribution of water to the economy and the pressure exerted by the economy on the environment in terms of abstractions and emissions Figure 1.

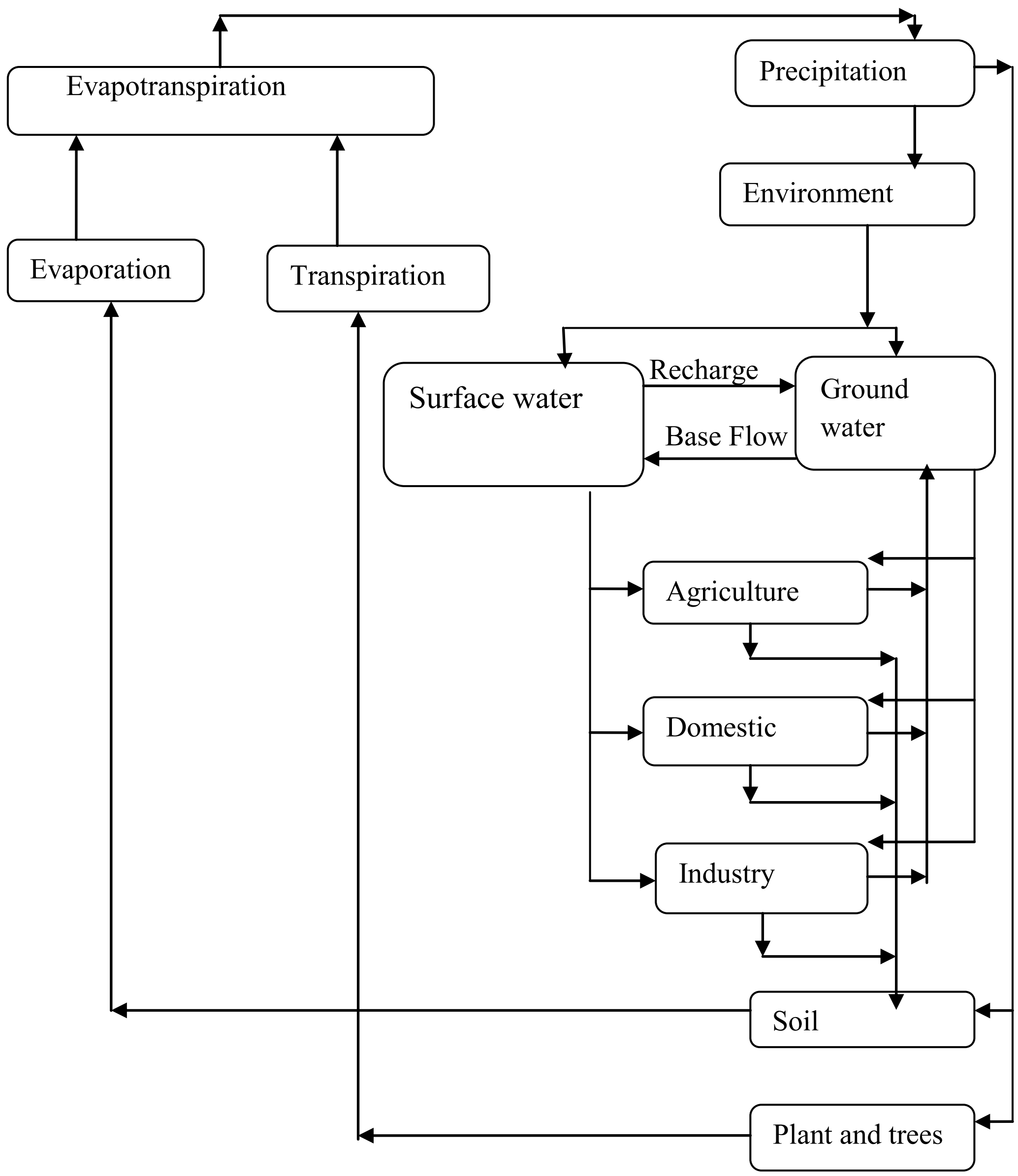

Figure 1: Interaction between the hydrology cycle and the economy

Source: (SEEA, 2006)

2.7 Physical Flows: Supply and Use Tables

The SEEAW enables compilation of triple simultaneity of flows of water. The triple flows of the physical supply table include: flows of water from the environment to the economy, flows within the economy (flows of water from one sector of the economy to another and to households) and flows from the economy to the environment (discharges of water in the environment).

The physical use table is also divided into three parts: flows received from the environment (abstraction by industry and households), use within the economy (water received from other industries and households) and the return flows to the environment. Asset accounts measure stock of water resources at the beginning and end of the accounting period as well as the changes in stock that occurs during that period. Asset accounts for water are divided into two components: produced asset which are man-made infrastructure for storage and distribution of water and natural water resources (SADC, 2010). The structures of the standard supply, use and asset tables are in Appendices 1, 2 and 3 of this report.

2.8 Current Situation of Water Use in Pangani River Basin

Productivity in the broadest sense, including agriculture, hydropower generation and environmental goods and services furnished through natural resources and nature reserves depend on an adequate supply of clean water. About 90 percent of the surface flow in Pangani Basin is used for irrigation and hydropower generation, yet this does not meet the current demand for water for these activities (URT, 2012).

Water efficiency among irrigation systems is often as low as 15 percent; hydropower production is regularly as low as 35% of capacity while conflicts are emerging between various water users (IUCN, 2011). The dwindling water resources threaten the livelihoods dependent on irrigated agriculture. This is due to the fact that 80% of the population in the basin live on irrigation agriculture; the basin also contributes 17% of power supply in the national grid. Therefore water shortage in the catchment will not only intensify conflicts but also undermines Tanzania's efforts to secure livelihoods and reduce poverty level (IUCN, 2007).

Therefore physical and economic water accounts will contribute to addressing these problems by providing opportunities for more efficient water use, opening up areas of uncommitted water and switching from growing crops which are less water efficient to more efficient water using crops.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Research Location

3.1.1 An overview of Pangani River Basin

The Pangani River Basin (PRB) covers an area of 43 650km^2 out of which 3 914 km^2 lies in Kenya. In Tanzania the basin spreads over about four regions namely; Kilimanjaro, Arusha, Manyara, and Tanga. Whereas in Kenya it covers parts of Taita-Taveta districts. Pangani river basin is one of the nine basins found in Tanzania which were formed as the result of the Government amendment (No.10) of its Water Utilization (Control and Regulation) Act No. 42 of 1981 with the sole goal of improving water resources management by sending guides of water management education closer to users.

3.1.2 Description of the Kikuletwa catchment

Kikuletwa catchment is located in the north - western of Pangani River Basin as indicated in Figure 2.The catchment covers an area approximately 6650 km^2. It also covers parts of six administrative districts and 80 administrative wards. Kikuletwa catchment is drained by approximately 15 major rivers, originating from Mount Meru and Mount Kilimanjaro. These rivers join to form the main Kikuletwa River before entering the Nyumba ya Mungu reservoir downstream. The water users include small-scale subsistence farmers, two cities (Arusha and Moshi), a number of small towns, large-scale export/commercial farms, pastoralists, mines and tourist facilities. Kikuletwa River is the main source of water for the Nyumba ya Mungu reservoir, which regulates water for electricity production further downstream (Hans and Pieter, 2013). The catchment was chosen for this study because of its high level of population. Over 50% of 1.6 million people in the Pangani basin live in the Kikuletwa catchment of which over 80% are engaged in irrigation agriculture (PBWO and IUCN (2008) ; URT, 2012).

Kikuletwa catchment with its intensive irrigation is found in the upstream of the major hydropower plants leading the catchment to be the major competitor and determinant of power generation in terms of water supply (URT, 2002).

The surface run offs to Nyumba ya Mungu have declined sharply in the past 15 to 21 years due to increased water consumption in the upstream-Kikuletwa catchment. Lastly, out of 81,000 ha of estimated irrigation area in the Pangani river basin over 50% is under small scale irrigation and concentrated in upstream (Turpie *et al*., 2003).

Therefore, this study would help to provide information that was crucial to provide solutions to the existing water management challenges in the catchment by providing opportunities for more efficient water use, opening up areas of uncommitted water and growing more efficient water using crops.

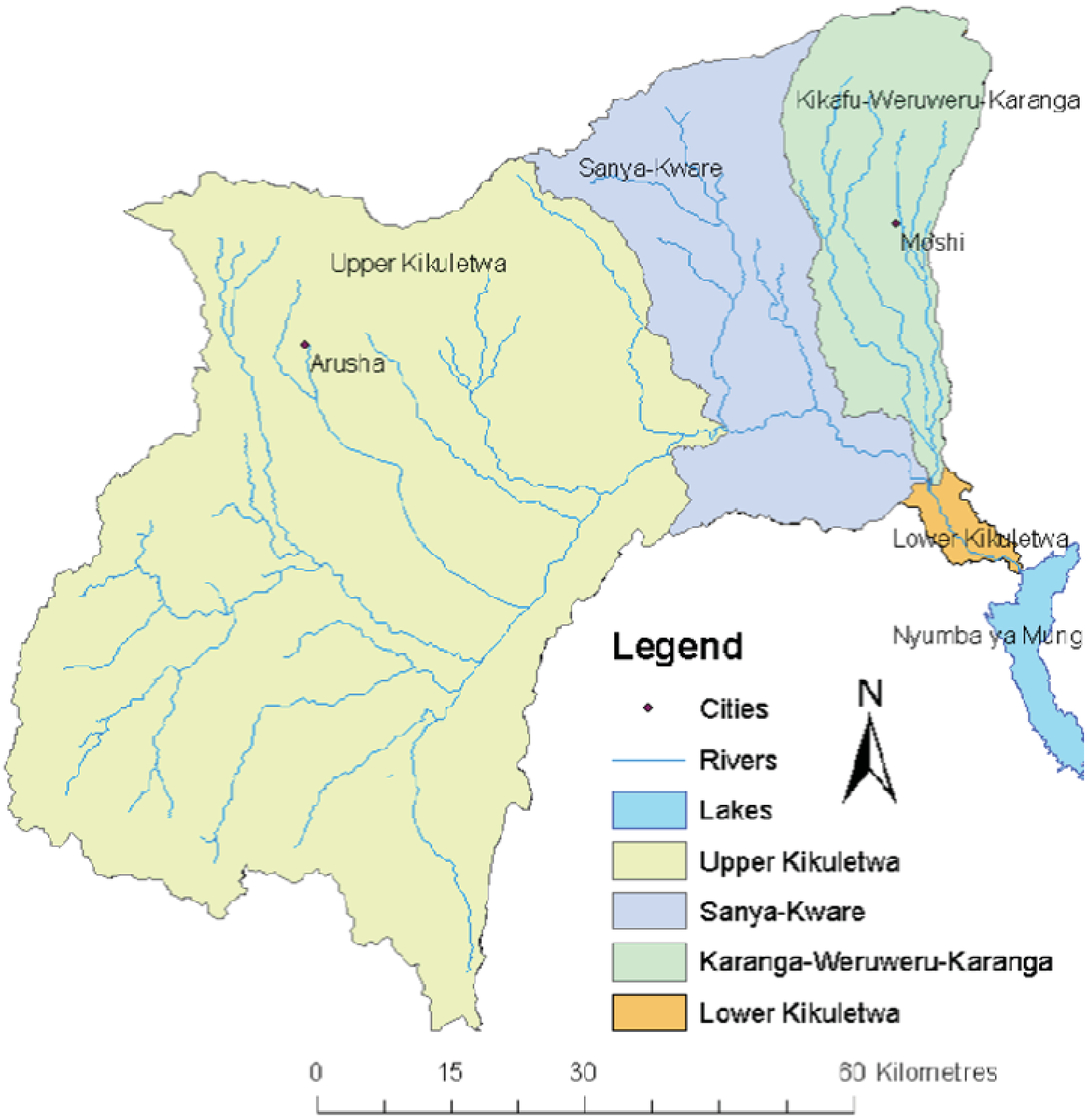

Figure 2: Map of Kikuletwa catchment showing drainage pattern
Source: (Hans and Pieter 2013)

3.2 Research Design

According to UNSD (2006), water resources accounts apply the same concepts, definitions, and classification as those applied in the internationally adopted System of National Accounts (SNA). Southern African Development Community (SADC) recommended that, studies in water accounts should adopt the modular form; that is, countries, river basins or accounting catchments can start with certain standard water accounts depending on their data availability situation and policy priorities. The normal practice is to start with physical water supply and use accounts followed by asset accounts then economic accounts. Very often both cross sectional and time series data are used in compiling water resources accounting (SADC, 2010).

3.3 Data Collection

Physical and economic accounts of water require well balanced data acquisition from both the hydrology and the economy. The water accounting framework can in principle be compiled at any level of geographical disaggregation of a territory, the options are usually to compile the accounts either at the level of administrations, river basins, or accounting catchments depending on the objective of the analysis (SADC, 2010). In this study, mainly secondary data were used to analyse the hydrological and economic interaction in the Kikuletwa catchment in 2012. In addition, few one to one discussions with heads of institutions and department of the water supply and management authorities were done guided by questionnaire in Appendix 11 to cross check reliability, suitability and adequacy of the secondary data. Data on livestock and crops water use especially number of livestock in the catchment were collected from National Sample Census of Agriculture 2008, while water consumption of each animal per day was obtained from literature published by the Centre for Environmental and Economic Policy in Africa (CEEPA). Details of the type of data acquired sources obtained and the units reported are given in Table 1.

Table 1: Data sources, type and corresponding units

Data source	Type of data	Units
PBWO (Head Office)	Rainfall	Mm/day
PBWO (Head Office)	Flow	M^3/s
PBWO (Head Office)	Evaporation	Mm/day
AUWSA, MUWASA, AINZ	Abstraction	M^3/day
AINZ, CEEPA, (NSCA,2008)	Livestock, crops	Litre/day, litre/ha
PBWO (Head Office)	Springs	M^3/s
PBWO (Head Office)	Groundwater recharge	Mm/day

3.4 Data Analysis

In this study, the Microsoft excel 2007 was used to analyse data. Rivas (2003), defines water balance as the balance between the income of water from precipitation and snowmelt and the outflow of water by Evapotranspiration, groundwater recharge and stream flow. Analysis in this study was converting the units of figures recorded and aggregating them before inserting into the Natural water balance equation. Therefore empirically Natural Water Balance (NWB) is given by:

$$NWB = P - E + R + \Delta S \qquad (1)$$

Whereby

P=precipitation, E=evaporation, R=run off and ΔS=change in storage can be positive or negative.

3.4.1 Precipitation

There are several methods of measuring rainfall distribution, they include: Arithmetic mean, spatial mapping (theissen+) and Isohyetal to mention a few (Statistics New Zealand, 2004). However, in this study only the Arithmetic mean method was used to analyse amount of water entering Kikuletwa catchment from precipitation (rainfall).

3.4.2 Stream flow

River flow data can be used to establish the volume of water entering or leaving the basin (Statistics New Zealand, 2004). In this study, secondary data on stream flow in the Kikuletwa catchment were obtained at the Pangani Basin Water Office (PBWO) in terms of height of the water depth, measured in centimetres cubic (cm^3). The height records were then computed in the established discharge equations in gauged stations to obtain stream flow quantities in m^3/month.

3.4.3 Ground water recharge

The ground water recharge was estimated using adhoc norm of rainfall infiltration. In Kikuletwa, the geology is volcanic; semi consolidated, friable and porous, in which according rainfall infiltration scale the percentage correlation of ground water recharge is between 10 and 15 percent (Mbaruku, 2006). Therefore in this report groundwater recharge was estimated to be 15% of total rainfall received in the catchment in 2012.

3.4.4 Evaporation and evapotranspiration

Computation of Evapotranspiration was carried out according to the formula given in Equation 2. In this study, the pan coefficient of 0.6 was used as Hess (1996), recommends the use of 0.6 as a first estimate for practical purposes if no additional information is available.

$$ET_0 = K_p \times E_{pan} \qquad (2)$$

Where K_p= Pan coefficient and E_{pan} = pan evaporation (mm/day).

3.4.5 Domestic water demand analysis

According to WATERNET (2003), the bottom line of water consumption can be defined as the lifeline per capita water consumption. Therefore, domestic water use was derived using the formula given in Equation 3; where lifeline per capita water consumption was multiplied by the population of settlements in the catchment.

$$Q = q` P_n \qquad (3)$$

Where Q= water demand, q` = per capita demand and P_n = population.

3.4.6 Analysis of crops and livestock water requirement

To calculate the total amount of water used for growing crops and keeping up animals in the catchment for the year 2012, water requirement per crop per day, and livestock water requirement per day were important. Land area and time duration for the crops until harvest were also taken into account to quantify water use in these agriculture subsectors in the catchment. Therefore to get the amount of water used for livestock: multiplied number of water per day by total number of days in the year and number of livestock in the catchment, while for crops amount of water per unit area multiplied by number of days until harvest times number of hectares.

3.4.7 Analysis of water use efficiency

In order to estimate how well was water input converted to useful economic activity or product output in a system or activity, the formula in Equation 4 was used. Amount of water used to grow the selected crops was recorded from PWBO and amount of crops obtained from Agricultural Irrigation Northern Zone for modern irrigation and from National Sample Census of Agriculture for traditional irrigation

Water use intensity/ Efficiency = $\frac{Volume\ of\ water\ used}{Output}$……………….. (4)

3.4.8 Analysis of water returns flow

Return flow in this study, were water flows from the municipal water use and from the irrigation sectors. According to Linsley (1972), the quantity of domestic and industrial waste water is taken as 60 to 75% of the water used whereas as in the irrigation return flow is taken as 20% of the total water supplied according to field data.

3.4.9 Analysis of water productivity

Water productivity in this study, included water uses, depletion and value in the water catchment and was analysed using formula indicated in equation 5.

Water productivity = $\frac{Output}{Volume\ of\ water\ used}$…………………………...... (5)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 The Physical Water Accounts of Kikuletwa

Physical water accounts comprise water resource data on water supply and discharge (SADC, 2010). Table 2 shows the results of analysis for different components in million m^3 in the period of study (Jan. – Dec. 2012) namely: total inflows, rainfall, outflows, ground water recharge and return flows. The following sub sections examine independent components as indicated in Table 2 and the analysis done.

Table 2: Water resource estimates (Jan- Dec 2012) in Mm^3/Month

Catchment analysed Components/Mon	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Net annual rain fall (Mm^3/Month)	2	292	211	1058	1402	82	40	255	15	108	880	422
Amount transfers out (Mm^3/Month)	24	28	29	29	26	26	26	39	44	41	33	32
Return flows from the Economy (Mm^3/Month)	26	26	26	26	26	26	26	26	26	26	26	26
Total groundwater recharge (Mm^3/Month)	0.22	43	32	159	210	12	6	38	2	16	132	63

Mm^3 = Million cubic mitres

Source: (URT, 2012; AINZ, 2012)

4.1.1 Rainfall analysis

The catchment receives rainfall ranging from 276.8mm at Kahe rain fall station to 1544mm recorded at Kibosho mission rainfall station leading to an annual average of 687mm (Appendix 4). High rainfall was recorded in highland of the catchment such as Kibosho mission, Lyamungo Agro vet and Moshi Maji 600-1500 mm per year; where as in plain lands such as Kia, Kahe, and Nyumba ya Mungu and Moshi airport observing massive reduction of rainfall ranging from 300-500mm per year. Kibosho mission and Lyamungo Agro vet rainfall stations though not located within Kikuletwa catchment but were included in the analysis in order to capture the rainfall distribution effect.

The monthly trend of rainfall has high fluctuations. Months; April, May and November recorded the highest rainfall in the catchment while January and September recorded the lowest rainfall amount in the year. This rainfall trend conforms to the catchment's hydrological characteristics whereby the catchment receives two rain seasons per year; the long rain season (*Masika* rains) which marks its pick between April and May and short rain season (*Vuli* rains) which marks its pick between October and November.

Spatial distribution of rainfall within Kikuletwa catchment was also highly fluctuating, for instance highlands stations such as Kibosho mission and Lyamungo agro vet recorded highest rainfall while plain lands such as Kia, Kahe and Nyumba ya Mungu recorded lowest rainfall. Though, the annual rainfall recorded in 2012, (687mm) seemed to be exceptionally low, it was beyond the scope of this study to study the inter-annual rainfall trend including effect of climate variability. Rainfall data from various stations in the catchment are presented in Appendix 4 of this report. The annual rainfall was then converted to volume measured in cubic metres and aggregated to quantify amount of water entering the catchment from rainfall.

4.1.2 Groundwater recharges analysis

Table 2 presents in part the ground water recharge analysis in Kikuletwa catchment. The analysis was done based on the monthly total rainfall received in the catchment. Groundwater recharge was estimated by adhoc norms of rainfall infiltration (Mbaruku, 2006). The adhoc norms method proposes that, ground water recharge system depends on rain fall intensity, duration and the existing geological formation of the accounting area. Literature on geology formation in the study area suggests that the soils are: volcanic, semi-consolidated, friable and porous. Such formation characterises the percentage correlation of 10 to 15% of the rainfall. Therefore the total monthly recharge for the year was 40 Million m^3 equivalents to 5.75%% of the total monthly rainfall received in 2012. The total amount of water in the aquifer was not covered, although some scholars argue that it is not necessary to know total amount of water in the aquifer, according to Lange and Hassan (2006), the most important is the amount of water that can be abstracted and used preferably in a sustainable manner. The sustainability condition requires that the annual abstraction does not exceed recharge. This condition is not satisfied in the Kikuletwa catchment as abstraction rate is far beyond recharge which implies well fields are likely to run dry under business as usual scenario.

4.1.3 The analysis of amount of water flows out

The total amount of water transfers out from the catchment during the accounting period was 380 Million m^3, equivalent to 44% of the total inflow. This is the total discharge through surface runoff measured at Kikuletwa power station. Some 595 Million m^3 is supplied to the economy equivalent to 68% of the total annual inflow.

The other amount of water equal to 269 Million m^3 is supplied to domestic use equivalent to 31% of the total annual inflow in the catchment. This analysis indicated that agriculture sector receives higher amount of water than domestic use sector; more water is discharged outside the catchment than water used for domestic purposes. In addition, water recorded at end use, exceed the total annual inflow recorded at production points. This scenario indicated that there were unlicensed abstractions around the catchment which were not registered by Pangani Water Basin Authority (PWBA).

4.1.4 Return flow analysis

According to analysis total amount flows to the environment during the accounting period was 312 Million m^3. Irrigation contributed 112 Million m^3 equivalents to 36% of the total annual return flow; domestic contributed 161 Million m^3 equivalent to 52% of the total annual return flow and industrial sub sector contributed 39 Million m^3 equivalent to12%. The amount of water that flows back to the environment is significantly huge; therefore if the water is contaminated with poisonous chemicals it poses danger to the ecosystem health in the catchment. To reduce this danger government and institutions must encourage recycling of used water and construct water treatment plants.

4.1.5 The analysis of natural water loss

The rate of evapotranspiration in the catchment was 384 Million m^3 during the accounting year (2012). This is equivalent to the monthly average of 32 Million m^3 of water loss. This amount is more than the total supply of water for domestic and other sectors in Arusha and Moshi Municipals for one year. Figure 3 shows the relationship between evapotranspiration and rainfall in mm^3/month. In the Figure evapotranspiration is higher than rainfall in all months except in May because evapotranspiration involves evaporation and transpiration. January and October have higher margins of difference because during the two months farmers clear farms ready for cultivation hence expose wider area for evaporation.

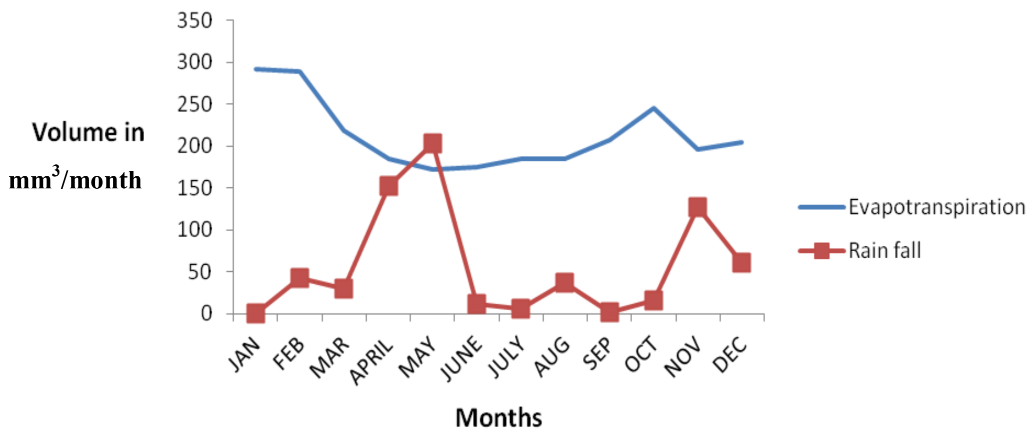

Figure 3: Evapotranspiration and rainfall in Kikuletwa catchment for the period of 12 months

4.1.6 Analysis of water available in the catchment

The available water is defined by Mbaruku (2006), as the total quantity of water that can be available for practical application to desired uses. It includes the yield from surface water, groundwater and return flows from the non consumptive use of water as well as water transferred out. Table 3 shows the water balance in the catchment based on total inflow – outflow analysis. According to the analysis two overdraft months from the groundwater were observed in January and September in 2012 denoted by negative balances. Generally the catchment was under stress as majority of months have very little balances accept few months of May, April, November and December because the months fall during long and short rain seasons respectively.

Table 3: Water available in the catchment considering total inflow and outflow

Months	Inflow (Mm^3)	Outflow (Mm^3)	Available water (Mm^3)
Jan	628.57	663.19	-34.62
Feb	919.23	695.79	223.44
Mar	838.5	677.71	160.79
Apr	1685.34	757.03	928.31
May	2030.07	786.68	1 243.39
Jun	709.11	654.92	54.19
Jul	667.01	652.07	14.94
Aug	881.85	687.28	194.57
Sep	641.86	671.68	-29.82
Oct	735.01	683.84	51.17
Nov	1506.65	744.82	761.83
Dec	1049.37	700.14	349.23

Mm^3= Million cubic mitres

Source: (PWBO/IUCN, 2008)

4.2 The Economic Accounts of Water in the Catchment

Economic accounts of water describe how well water is used to produce outputs. In accounting terms it includes the monetary analysis that shows the rational existence of various economic activities in the catchment. The components of economic accounts analysed include: water abstraction, water use and water productivity. The analyses of major components of economic accounts are presented in the following subsections.

4.2.1 The analysis of water abstraction

Based on water permit data provided by the PBWO Table 4; an analysis was conducted to determine the status of water rights allocation in the Kikuletwa catchment. More particularly, it was deemed essential to establish the relationship between the allocations granted against the calculated demand. The analysis on water allocations covers all types of water use in Kikuletwa catchment in an effort to determine the indicative relative weight of irrigation water demand in the catchment with the inclusion of disenfranchised permits and those water abstractions that have no water rights, a total of 2 360 water uses were listed.

Of this, only 426 or 18%, with a total allocated amount of 12.5 Cubic metres (cumecs) have been granted full water rights, while some 23.3 cumecs have been provisionally allocated to some 388 schemes of various water use categories. Some 156 water permit applications are pending with the PBWO with an equivalent rate of 4.18 cumecs. It is surprising to note that most of these, if not all, are operational and uncontrolled.

Most alarming are the abstractions without approved water rights, enumerated by the PBWO to be 1 078 in number. Unrealistically, an estimated amount of 3.55 cumecs is assigned to represent overall abstraction requirements as most of these are smallholder’s irrigation (village, individual or small groups) with accompanying abstractions for domestic and livestock use. This is a very conservative rate and is estimated to be only 25% of the actual usage/demand. If all abstractions are considered active, an estimated water demand would surpass the 50-cumec mark which is way above the estimated inflow into the Nyumba ya Mungu reservoir at 44 cumecs**.** Table 4 shows the breakdown of all water use per allocation category in the catchment.

Table 4: Water use per allocation category in Kikuletwa catchment

S/n	Allocation category	Number	Water use permits percentage	Allocation litres/s	Water allocation percentage
1	Granted final	426	18.05	12541	24.69
2	Granted provisional	388	16.44	23310	45.89
3	Application	156	6.61	4181	8.23
4	Expired	11	0.47	76	0.15
5	Cancelled	24	1.02	1385	2.73
6	Deferred	2	0.08	105	0.21
7	Withdrawn	11	0.47	258	0.51
8	Abandoned	172	7.29	2721	5.36
9	Dormant	62	2.63	2278	4.48
10	Refused	8	0.34	257	0.51
11	Superseded	15	0.64	121	0.24
12	Unknown	7	0.30	16	0.03
13	Without WR	1078	45.68	3549	6.99
Total		**2360**	**100.00**	**50798**	**100.00**

Source: (SMEC, 2012)

Small scale agriculture is the major user of water in Kikuletwa catchment. Over 49% of the total water allocated for economic use goes into small scale irrigation. Findings from this study further indicated that water use in this sector was inefficient. And the worst of all is that 45% of water abstraction permits for small scale irrigation is unregulated. Under increasing demand for irrigated agriculture, increasing population and unemployment rates in urban centres; the overharvest of water in the catchment would intensify conflicts amongst water users.

4.2.2 Analysis of water use

The analysis of water use in the catchment is presented in Table 5. According to the table small scale irrigation in the major water user in the catchment taking 49.78% of all the water allocated for economic use. Generally the water use in the catchment is disaggregated as large scale agriculture 22.19%, domestic rural 12.73% industries 10.29%, livestock 1.80%, domestic urban 1.52%, flowers 0.88% agricultural rain fed 0.43% and commercial and institutions taking 0.38% of water in the catchment. From the findings small scale irrigated agriculture is the major water user in the catchment, the subsector also employs a larger share of the population in the catchment. The total depletion of water for the economy is 68%, this depletion fraction is determined by taking total depletion for the economy dividing by the gross inflow in the catchment. The distribution of water use in the catchment was good as larger share of the water was allocated to economic purposes.

Table 5: Water depletion in the catchment

Uses	Volume(Mm^3)	% total water used
Large scale Irrigation	132.00	22.19
Flowers	5.23	0.88
Small scale irrigation	296.10	49.78
Agricultural rain fed	2.55	0.43
Livestock	10.70	1.80
Industrial	61.20	10.29
Commercial +Institutions	2.27	0.38
Domestic urban	9.05	1.52
Domestic rural	75.75	12.73
Total	**594.85**	**100**

Mm^3 =Million cubic metres

Source: (URT, 2008; AINZ, 2012)

4.2.3 The analysis of water use efficiency

To find out how well water is used to produce outputs in different economic uses, an analysis was done relating production (output) from the economy and the amount of water used. Findings from this study indicated that large scale irrigation under improved irrigation systems have higher crop yield per unit water use than traditional small scale irrigation using furrow systems. For purposes of comparison analyses of sampled crop (maize) yield per unit water use from the two types of irrigations were done and results as shown in Figure 4. Mean crop yield per unit of water use in large scale irrigation was larger than in small scale irrigation. Field observations indicated that most large scale irrigation have technical assistants for irrigation engineers and technicians from Northern irrigation zone and districts. Unlike small scale irrigation, where participants are many and not assisted by technicians leave alone their scattered distribution. Therefore any intervention designed to improve water use should target small scale irrigation in the first place.

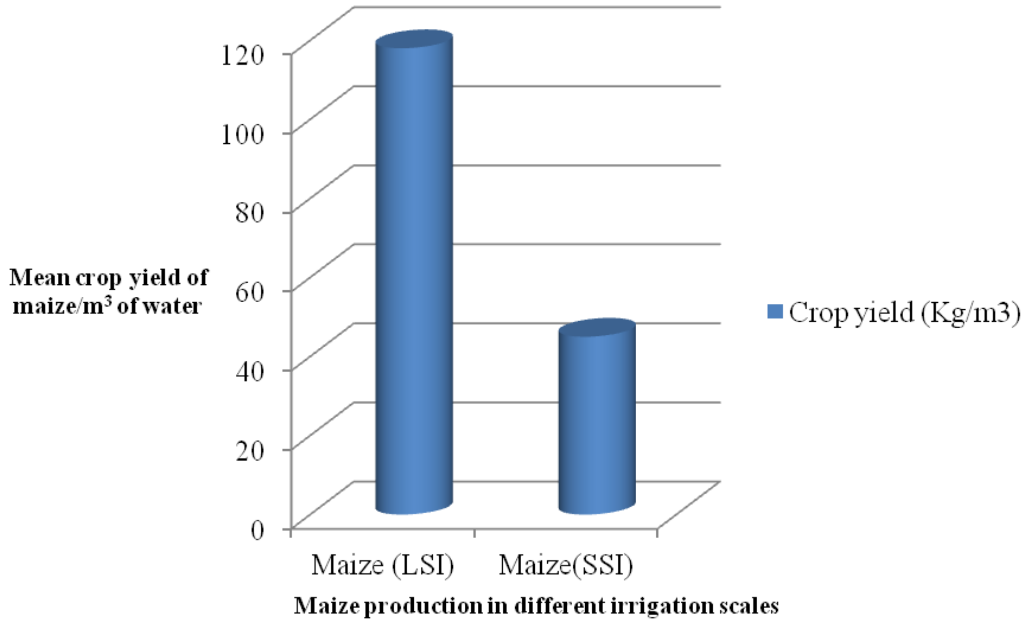

Figure 4: Mean yield of maize per unit use of water between large scale irrigation and small scale irrigation in Kikuletwa catchment

Appendix 5 shows water supply and billing efficiency in Arusha and Moshi municipalities. The two municipalities produced a total of 23 million m^3 combined in 2012. Of this amount 15 million m^3 equivalents to 65% reached the target clients and was successful billed. A total 8 million m^3 equivalents to 36% of water was lost on the way between production and final end user. Comparing the performance of the two municipalities in terms of amount of water supplied and billing efficiency; AUWSA supplied more water than MUWSA, 14 million m^3 equivalents to 59% of the total water produced by them combined, while MUWSA supply 10 million m^3 equivalents to 41%. MUWSA has higher billing efficiency 70% than AUWSA 61%. Despite the difference in the billing efficiency between the two municipalities the mean billing efficiency for combined production is within the international acceptable ranges of 64%.

Table 6 presents the amount of water that goes into livestock sub sector in the catchment. The livestock water use was estimated on the basis of number of animals and their average daily water requirements. Data on the number of animal species available in the catchment was obtained from national sample census of agriculture 2007/08 (URT, 2012). Although it was likely that the census might have missed some animals especially in the communal areas but this was the best estimate available. Water for livestock was supplied by the PWBA. According to analysis, 946 m^3 was supplied for livestock while field water use showed that 11 million m^3 was used per annum as indicated by Table 6. The difference between water supplied to sub- sector in the catchment and real water used according to daily water requirements by animals was assumed to be amount of water supplied by self providers in the commercial farms and communities. Total water supplied to livestock in the catchment is 1.8% of total water allocated for economic use in the catchment.

Table 6: Livestock water requirements, 2012 Kikuletwa catchment

Animal	Water consumption		Numbers of animals 2012	Total water consumption (m^3)
	Daily water requirements (litres)	Annual water per (m^3)		
Cattle	45	16.43	427 947	7 029 029
Sheep	10	3.65	387 714	1 415 156
Goats	10	3.65	454 425	1 658 651
Donkeys	15	5.48	18 443	100 975
Pigs	25	9.13	39 448	359 963
Poultry (per 100 units)	23	8.40	1 051 135	88 242
Dogs	3	1.10	39 604	43 366
Total	**131**	**47.815**	**2 418 716**	**10 695 384**

Source: (URT, 2012; Lange *et al*., 2003)

4.2.4 Analysis of water productivity

According to Lange and Hassan (2006), water productivity is an indicator often used to compare the performance of industries over time and they define water productivity as the value of output (in constant prices) from each sector divided by the water use in the sector. This study analysed the total yield harvested in terms of tons or kilograms against water used. Although it is argued that the economic value of water depends on the user as well as on the use to which it is put. This analysis was used to infer crops with higher output from water used. The economic assumption underlying this analysis is the value of water for agricultural purpose is the marginal value product of water (MVPW), referred to as an additional value through a unit of water supplied or used in production.

The analysis as indicated in Appendices 6 to 10, suggest that maize has the highest marginal value of Tshs 738 per m^3 of water supplied compared to the rest in the sample of crops involved in the analysis. The next crop is banana with the marginal value of Tsh 340 per m^3 of water supplied. Tomatoes have the marginal value of Tshs 317 and the last one was vegetables with the value of Tshs 252 per m^3 of water supplied. According to this analysis if all other factors are kept constant then under the current arrangement respective authorities need to encourage production of maize as it produced more value per unit m^3 of water. Otherwise more attention should be directed to efficient use of water in the production of vegetables.

4.3 The Supply and Use Tables on Analysed Data

The physical supply table describes the flow of water within the economy and flows from the economy to environment as discharge of sewage to water bodies. The physical use table describes flows of water from the environment to the economy (water abstraction by water utility) and flows within the economy (e.g. water received from another industry). Both supply and use tables provide information on the contribution of water to the economy and the pressure exerted by the economy on water resources in terms of abstraction and pollution. Upon accounting for water supply and use, the monetary analysis is also done to show the rational existence of various economic activities in the accounting domain. All the same monetary accounting was not done due to limited data; instead economic analysis was done for selected crops from irrigation agriculture as main water user in the catchment.

4.3.1 The catchment water balance

The concept of catchment water balance provides an indication of demand and supply situation in the catchment in an attempt to establish whether the catchment is open or closed with respect to water availability. A catchment becomes open if there is an uncommitted utilizable outflow and becomes closed if all its outflows are fully committed. The water balance analysis in the catchment show that ground water is 15% of the net annual rain fall; the amount of water wasted through Evapotranspiration is 8.1% of the total rainfall while 8% of the water from the catchment transfers out down to Nyumba ya Mungu dam and groundwater spring make 60% of total inflow in the catchment.

The monthly mean water balance of the catchment as indicated in Fig. 5 is under stress meaning there is less water in the catchment than demanded by human use and eco system use. The catchment experienced both open and closed durations in the accounting period. According to analysis, there was overdraft of water abstraction in January and September, where as the rest of months in the catchment, there were positive balances of varying amounts marking maximum amounts during May and April and November and December during long and short rain seasons respectively. Attention is to be taken when defining overdraft abstraction; it does not mean draining out all water in the catchment, but tapping even the minimum amount of water required to support the bio system in the catchment. This amount of water is technically known as Ecological reserve and is not supposed to be harvested. Because harvesting this water means denying life to bio nature.

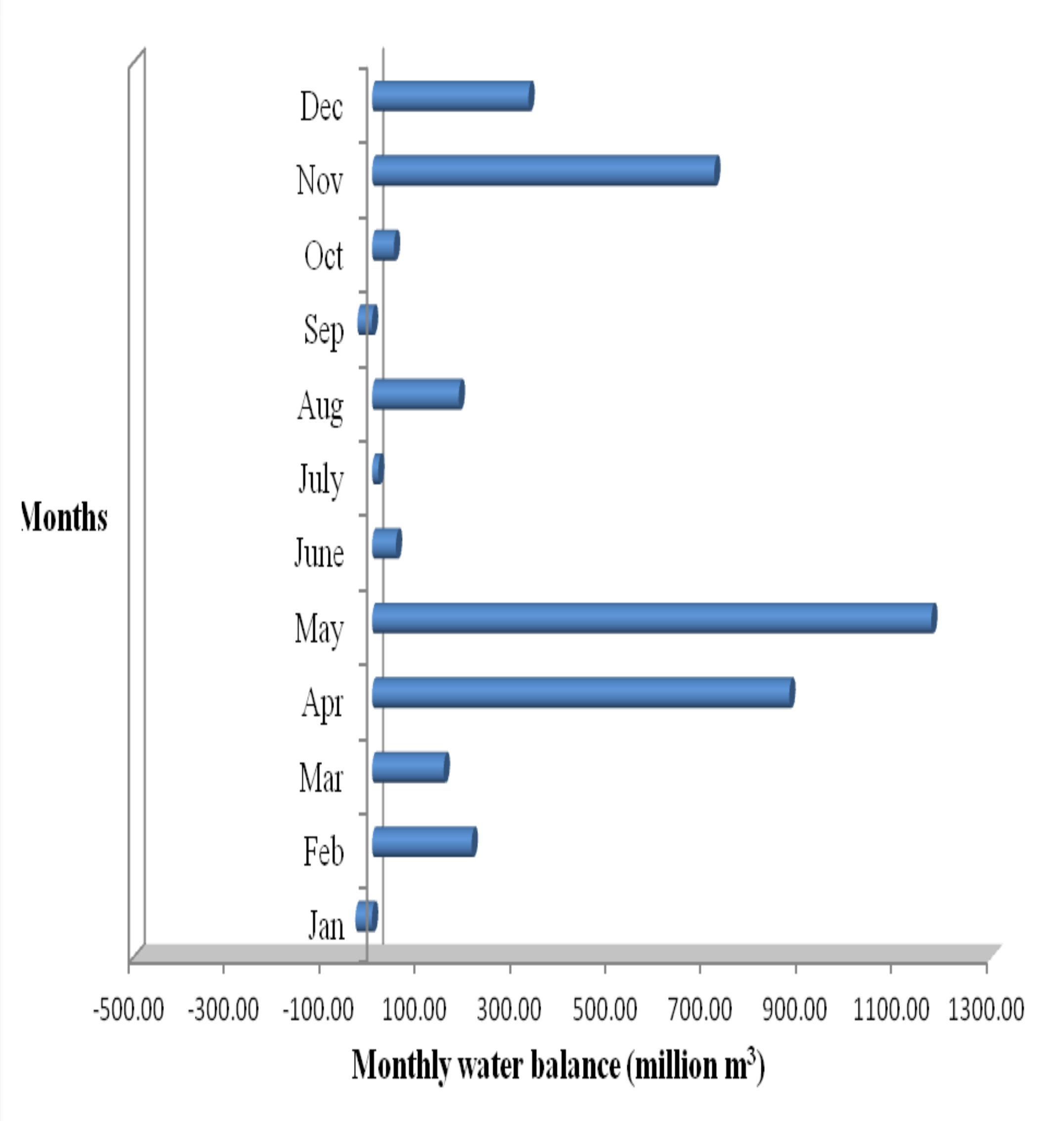

Figure 5: The water balance of the Kikuletwa catchment (Mm^3)

4.3.2 The physical water flow accounts for the catchment

The water supply and use tables were constructed for the year 2012 involving 12 months of the calendar year. The tables constructed adapted the UN-SEEAW structure as discussed earlier. The water flow accounts were undertaken for the purpose of interpreting the water stock in the catchment by looking into inflow and outflows and put the information into matrix. The UN- SEEAW structures modified by the standardised methodologies recommended by SADC were adopted. These tables were designed into three levels namely: environment, distribution and production. The environment refers to the hydrology and its characteristics of inflow and outflow in the catchment, the distribution refers to available institution and their role of drawing and supplying water to the economy. The production level focuses on economic units taking part in the catchment for the production activities. The three levels (environment, distribution and production) of the matrices have been kept throughout regardless there was data or not for the purpose of keeping the key flow features.

4.3.2.1 Water supply

Table 7 shows the summary of water flow from the atmosphere (precipitation) and from the groundwater to the environment. According to that analysis, the supply section of the matrix showed Kikuletwa catchment receives an average inflow of 1 024 Mm^3/month from atmosphere and ground storage. Out of it, 984 Million m^3/month is translated into net inflow after deducting ground water recharge. From the net inflow 595 Mm^3/month was set for economic use. Amount transfers out was 31 Million m^3/month and non beneficial process was 32 Million m^3/Month. This distribution leaves some 326 Million m^3 as catchment water balance. Precipitation supplied 397 Million m^3 (39%) of water in the catchment per month while, 601 Million m^3 (59%) come from groundwater and 26 Million m^3 (2%) from economy as return flows. The catchment has no other inflows to replenish the stock.

Table 7: The water supply matrix

Water resources Kikuletwa- Monthly Average 2012 in million m^3						
Supply		Environment				
		Atmosphere	Spring	Natural (NE)	Surface water	Ground water
Environment	Atmosphere					
	Spring					
	Natural Environment (NE)	397	601			
	Surface water			595		
	Groundwater			40		
	Evapotranspiration			32		
	Amount transfers out			31		
Distribution	PRB (total inflow)				595	40
	Irrigation authorities					
	Individual institutions					
	Municipalities					
Production	Large scale irrigation					
	Flowers					
	small scale irrigation					
	Agricultural rain fed					
	Livestock					
	Households					
	Industrial					
	Commercial					
	Domestic rural					
	Domestic urban					
Total supply		**397**	**601**	**698**	**595**	**40**

Source: (SEEA, 2006; SADC, 2010)

4.3.2.2 Water use

The use table shows the amount of water received by various economic activities from the environment and water received from other economic units (flow within economy). The use table also demonstrates water in volume wise used by different economic activities.

Table 8: The water use matrix

Water resources Kikuletwa- Monthly Average 2012 in million m^3							
Use Table		Environment					
		Atmosphere	Spring	Natural (NE)	Surface water	Ground water recharge	
Environment	Atmosphere						
	Spring						
	Natural Environment (NE)	397	601				
	Surface water			595			
	Groundwater			40			
	Evapotranspiration			32			
	Amount transfers out			31			
Distribution	PRB (total inflow)				595	40	
	irrigation authorities						
	Individual institutions						
	Municipalities						
Production	Large scale irrigation				132	8.58	
	Flowers				5.23	0.34	
	small scale irrigation				296.1	20.73	
	Agricultural rain fed				2.55	0.18	
	Livestock				10.7	0.75	
	Households				0	0	
	Industrial				61.2	4.28	
	Commercial				2.27	0.16	
	Domestic rural				75.75	5.30	
	Domestic urban				9.05	0.63	
Total Use		**397**	**601**	**698**	**594.85**	**40.95**	

Source: (SEEA, 2006; SADC, 2010)

4.3.2.3 Institutions available and water distribution network in the catchment

Table 9 shows the water institutions available and the amount of water they supply in percentage. Analysis shows that Pangani Water Basin Authority is the main custodian distributing 72% for irrigation authorities, 27% for municipalities and 2% for individual institutions.

Table 9: Water used by institutions percentage of total

Use Table		Distribution sectors			
		PRB	Irrigation Authorities	Individual Institutions	Municipalities
Environment	Atmosphere				
	Spring				
	Natural Environment (NE)				
	Surface water				
	Groundwater				
	Evapotranspiration				
	Amount transfers out				
Distribution	PRB (total inflow)				
	Irrigation Authorities	72%			
	Individual Institutions	2%			
	Municipalities	26%			
Production	Large scale irrigation		22%		
	Flowers		0.0%		
	small scale irrigation		50%		
	Agricultural rain fed				
	Livestock				2%
	Households				
	Industrial			2%	10%
	Commercial				0
	Domestic rural				13%
	Domestic urban				2%
Total		**595**	**428**	**10**	**155**

Source: (SEEA, 2006; SADC, 2010)

4.3.2.4 Water use by activity

Table 10 shows the water used by various production activities in the catchment. According to the analysis detailed information was estimated using the exact amount of water abstracted in volume and percentage. Uses are disaggregated into large scale irrigation, small scale irrigation, livestock and households. The analysis shows that large scale irrigation agriculture use 132 Million m^3 /month equivalent to 22%, small scale irrigation using 296 Million m^3 /month equivalent to 50% while livestock use 11 Million m^3 month equivalent to 1.8% and household used 156 Million m^3/Month equivalent to 26% of water allocated for economy. According to this analysis small scale irrigation was the chief consumer of water in the catchment as it used over 50% of all water set for economic use. This implies that any intervention designed to improve water use in the agricultural sector should address the small scale agriculture in the first place.

Table 10: Water use by production activities

Water used by production activities		Water received by different institutions for economic use				
		PRB	Irrigation Authorities	Municipalities	Total water received	
Sectors	**Crops/sub-sectors**				**Quantity**	**% of total**
Large scale irrigation	coffee	126.77			126.77	21.31
	Flowers	5.23			5.23	0.88
	Total	**132**	**0**	**0**	**132**	**22.19**
Small scale Irrigation	Maize		72.10		72.1	12.12
	Paddy		89.00		89	14.96
	Bananas		38.00		38	6.39
	Vegetables		51.00		51	8.57
	Tomatoes		46.00		46	7.73
	Total	**0**	**296.1**	**0**	**296.1**	**49.78**
Livestock	cattle			7.03	7.03	1.18
	Goats			1.7	1.7	0.29
	Sheep			1.4	1.4	0.24
	Donkeys			0.1	0.1	0.02
	Pigs			0.36	0.36	0.06
	Poultry			0.09	0.09	0.02
	Dogs			0.04	0.04	0.01
	Total	**0**	**0**	**10.72**	**10.72**	**1.80**
Households	Industry			61.2	61.2	10.29
	Commercial			2.27	2.27	0.38
	Domestic urban			9.05	9.05	1.52
	Domestic rural			75.75	75.75	12.73
	Transport losses			7.76	7.76	1.30
	Total	**0**	**0**	**156.03**	**156.03**	**26.23**
TOTAL		**132**	**296.1**	**166.75**	**594.85**	**100.00**

(Source: SEEA, 2006; SADC, 2010)

4.3.2.5 Natural water stock and changes

Table 11 shows the natural water stock in the catchment and the related changes. The gross inflow is made up of rainfall, groundwater spring and return flow. Net inflow is given by gross inflow minus the groundwater recharge. The process of depletion comprises of water use by productive activities while non beneficial process refers to natural water loss. Amount transfers out is termed as outflow. The balance therefore is called uncommitted water (Mbaruku, 2006). According to analysis the Kikuletwa catchment receives an average inflow of 1 024 Million m^3/month from atmosphere and ground storage. Out of it 984 Million m^3/month is translated into net inflow after deducting groundwater recharge. From the net inflow 595 Million m^3/month is set to carter for economic use. Amount transfers out was 31 Million m^3/month and non beneficial process was 32 Million m^3/month while the water balance in the catchment was 326 Million m^3/month.

Table 11: Natural water stock and changes

Monthly changes to stock	**Mean monthly values in Mm^3**
A. Precipitation (+)	397
A2. Net ground water recharge (-)	40
A3. Monthly Evapotranspiration (-)	32
A4. Total abstraction by economy (-)	595
A5. Return flows from the economy (+)	26
A6. Net groundwater springs (+)	601
A7. Amount transfers out (-)	31
Net water volumes stock (BALANCE)	**326**

Mm^3=Million cubic mitres

Source: (SEEA, 2006; SADC, 2010)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The monthly mean inflow in the catchment is 1 024 Million m^3, 397 Million m^3 (39%) from precipitation and 601 Million m^3 (59%) from groundwater spring and 26 Million m^3 (2%) return flows. The mean inflow figure (1024 Mm3) implies that per capita water consumption in the catchment is less than 1000 per person per year which means the catchment experiences acute water scarcity. Therefore, if no immediate measures are taken to address this situation the welfare of 80% of farmers in the catchment, engaged in irrigation farming would deteriorate and the major hydropower plants downstream will be seriously affected.

Only 426 permits of water abstractions equivalent to 18% of all water abstractions in the catchment are granted final permits by Pangani Water Basin Authority (PBWA). Of the total 2 360 permits 388 (16%) were given provisional permits, 156 (6.6%) applications are submitted, while 1078 (45%) are abstractions operating without permits. The rest, 312 abstractions are either, cancelled, refused, expired, deferred, withdrawn, abandoned, dormant, refused, superseded or unknown. In view of the findings that only426 (18%) of water abstractions in the catchment are granted final permits, it is concluded that, if the responsible authority (PWBA) does not intervene to regulate the water abstraction in the catchment, the catchment is in high risk of running dry due to uncontrolled water abstractions.

Small scale agriculture is the major user of water in the catchment taking (49.78%), followed by large scale agriculture (22.1%), industrial (10.29%) and livestock (1.8%). in view of this finding, small scale irrigation is the major user of water in the catchment.

Large scale irrigation has relatively larger crop mean yield per unit m^3 of water than small scale irrigation agriculture: 45kg/m^3 for small scale irrigation and 118 kg/m^3 for large scale irrigation using maize as the sample. Based on this findings it was concluded that; communities need to be mobilised to venture into large scale irrigation through income generating groups where they share the cost in order to improve water use efficiency and crop yield per unit cubic of water.

About 68% of all water that enters the Kikuletwa catchment is set for economic use. Despite the good distribution of water, majority of the economic sectors have low water use efficiency especially small scale irrigation which employs larger section of the population in the catchment.

The catchment has monthly stock balance of 326 Mm^3 to sustain the ecosystem. However there is limited evidence to support whether the amount is adequate, because there was no scientifically set evidence on the minimum amount of water required to sustain ecosystem in the catchment at the time of this study.

5.2 Recommendations

5.2.1 Recommendation to policy makers

Based upon the conclusion that, the water accounting (WA) is appropriate tool to deal with the water scarcity and water management challenges by providing data on the amount of water and optimal alternatives for measurement; it is recommended that WA is practicable concept in any level of territory division as it has high ability to integrate the physical and flow accounts on water supply and use for the management of water resources. Amendment of policy for the purpose of including guidelines that attach economic and monetary value to water is also recommended.

In view of the conclusion that Kikuletwa catchment has per capita water consumption less than 1000 per person per year it is recommended that set a rule that require every person to harvest rain water for use in the catchment.

5.2.2 Recommendation to water supply and management authorities

Based on the conclusion that small scale irrigation is the major user of water in the catchment, the sub sector is also less efficient in water use, it is recommended that a deliberate strategy is undertaken to improve water use efficiency in small scale irrigation including exploring uncommitted sources of water such as harvesting rainwater.

Given that, very few water abstractions in the catchment are regulated by water management Authorities (18%) this study recommends, strengthening of Water User Associations (WUA) in the catchment so that they disclose all illegal water abstractions in their neighbourhood.

5.2.3 Recommendation to Individuals and institutions

In view of the conclusion that the catchment overcommitted ground water resources (59% of all water in the catchment), it is therefore recommended that; more investment be directed to harvesting rainwater at household level or individual institutions to offset the pressures of over committing groundwater resources.

5.2.4 Recommendation to farmers

According to the conclusion that crops in the catchment have different yield per unit of water and some crops have high yield while others have low. The study recommends that; farmers should be encouraged to produce crops with high yield per unit of water under all other factors remained constant.

REFERENCE

Agricultural Irrigation Northern Zone (AINZ) (2012). Tanzania Irrigation Database, Northern zone, Kilimanjaro, Pp34

Burrell, M., Moss, P., Nguyen, K., Petrovic J. and Ali, A. (2012). *General Purpose Water Accounting Report 2011-2012: Lower Darling Catchment*, NSW Department of Primary Industries, Sydney Pp 1

Charles, P. and Jeffrey, R. V. (2004). Natural resource accounting and economic development theory and practice. *The Journal of Developing Areas,Vol 38 (1) 213-215*

Goldman, S. (2008). The Top Five Risks Conference: Key Takeaways. [http://www.academia.edu/432849/The_Top_Five_Risks_Conference_Key_Takeaways] site visited on 20th August, 2014.

Harris, M. and Fraser, I. (2002). Natural resource accounting in theory and practice: A critical assessment. *Australian Journal of Agriculture and Resource Economics*, Vol. 46 (2) 139-192

Hans, C. K and Pieter, Z. (2013). Polycentrism and pitfalls: the formation of water users forums in the Kikuletwa catchment, Tanzania, *Water International Journal,* Vol.38 (3) 231-249

Hess, T. (1996). Evapotranspiration estimates for water balance scheduling in the UK, Silsoe College, and Cranfield University, MK45 4DT, UK. [https://dspace.lib.cranfield.ac.uk/bitstream/1826/1675/1/ATMOM.pdf] site accessed in May, 2013

Integrated System of Environmental and Economic Accounting (SEEA) (2003). A Handbook Manual [http://unstats.un.org/unsd/envAccounting/ seea2003.pdf] site visited in July, 2006.

Integrated System of Environmental and Economic Accounting (SEEA) (2006). A Review Handbook Manual [http://unstats.un.org/unsd/envAccounting/ seea2006.pdf] Site visited in July, 20013

International Energy Agency (IEA) (2012). The IEA Model of Short- term Energy Security (MOSES) Primary Energy Sources and Secondary Fuels. Working Paper. Paris OECD/IEA. [http://www.unesco.org/open-access/terms-use-ccbysa-en] Site visited in October, 2013.

International Union for Conservation of Nature (IUCN) (2011). Building Consensus on Water Allocation and Climate Change Adaption: Water and nature initiative (WANI) case study [https://www.iucn.org/about/work/ programmes/water/wp_our_work/wp_our_work_wani/] Site visited on 20th August, 2014.

Lange, G. and Hassan, R. (2006). *National water accounts in Namibia technical report*. [http://unstats.un.org/unsd/envaccounting/ceea/archive/Water/

Lange, G. M, Hassan, R. M and Hamilton, K. (2003). *Environmental Accounting in Action- Case studies from Southern Africa,* Edward Elgar Publishing. [http://www.amazon.com/Environmental-Accounting-Action-Studies-Southern/dp/1843760762] site visited in May, 2013

Linsley, R. K. and Franzini, J. B. (1972). *Water resource Engineering Book* [http://ascelibrary.org/action/doSearch?AllField=Linsley] Site visited in May 2013

Mbaruku, G. (2006). Physical and Economic water accounts of the Kikuletwa sub catchment of the Pangani River basin, Unpublished Dissertation for Award of MSc Degree of University of Dar es Salaam, Tanzania. Pp 28

National Water Sector Development Strategy (NWSDS) (2005). *Water Resources Availability, Utilisation and Demand in* National Water Sector Development Strategy 2005-2015, Ministry of Water, United Republic of Tanzania. Pp 9

Pangani Basin Water Office/International Union for Conservation of Nature (PBWO/IUCN) (2008). *Pangani River System – State of the Basin Report – 2007*. PBWO, Moshi, Tanzania and IUCN Eastern Africa Regional Program, Nairobi, Kenya [www.panganibasin.com]site visited in June 2013

Peter, D., Godfrey, J. and Hanley S. (2010). *Opinion Accounting for Water* [http://www.companydirectors.com.au/director-resource-centre] site visited September, 2014.

Raouf, M. A. A. (2002). Theoretical Framework for Environmental Accounting Application on the Egyptian Petroleum Sector [http://www.erf.org.eg/CMS/uploads/pdf/1185352882_S-P_Mohamed_Raouf.pdf] Site visited on August 2014.

Rivas, E. M. A. A. and Emannuel, F. D. V. (2003). Water balance and observed Flows in the anllons river basin (nw Spain), [http://eurekamag.com/research/034/225/034225205.php] site visited in July 2013

Sève, J. I. (2002). *A Discussion Paper on Environmental and Natural Resources Accounting and Potential Applications in African Countries* [www.tnrf.org/en/node/5612] site visited in December, 2013

Snowy Mountains Engineering Corporation (SMEC) (2012). *Preparation of Pangani basin integrated Water resources management and Development Plan*: Irrigation Inventory, Agricultural irrigation zone office, Kilimanajro. Pp 56

Southern Africa Development Community (SADC) (2010). SADC *Economic Accounting of water use project*: Standardised Methodologies for Economic Accounting of water in SADC [http://www.sadc wateraccounting.org/_system/ writable/DMSStorage/851en/ SADC-EAW%20Training%20Manual.pdf] site visited on June, 2013

Statistics New Zealand (2004). Water: Physical Stock Accounts [http://www.stats.govt.nz/environment/default.htm] site visited on 12th January, 2006.

Stockholm International Water Institute (SIWI); International Water Management Institute (IWMI) and Stockholm Environmental Institute (SEI) (2008). "*Saving water: From Field to Fork- curbing losses and wastage in the food chain*" Quarterly Newsletter of the IWMI, Stockholm [http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf] site visited September, 2014

The London Group (2005). *United Nations Commission for Environmental Accounting*: Proceedings and Papers. [http://www4.statcan.ca/ citygrp/london/london.htm] Site Visited in June 2013 .

Turpie, J. K., Ngaga, Y. M., Karanja, F. K. (2003). *A preliminary Economic Assessment of water resources of the Pangani River basin, Tanzania: Economic value, Incentives for sustainable use and mechanisms for financing management;* IUCN – Eastern Africa Regional Office &

Pangani Basin water Office [www.panganibasin.com] site visited May, 2013

United Nations (UN) Millennium Project (2005). *Investing in Development: A practical plan to achieve the Millennium Development Goals.* London: Earth scan. [www.unmilleniumproject.org/reports] Site visited April 2013.

United Nations (UN) Millennium Task Force on water and Sanitation (2004). *Health, Dignity and Development, What will it take*? New York: Stockholm International Water Institute and UN Millennium Project. [http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf] site visited in March, 2013

United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2003). United Nations World Water Development Report: Water for People, Water for Life. [http://www.un.org/esa/sustdev/publications/ WWDR_english_129556e.pdf] Site visited on 10th September, 2014

United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2006). *United Nations World Water Development Report: Water, a Shared Responsibility*."[http://unesdoc.unesco.org/images/0014/0014

United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2009). United Nations World Water Development Report: *Water in a Changing World.* [http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/] Site visited on 10th September, 2014.

United Nations Environmental Programme (UNEP) (2012). *Measuring water use in a green economy, A Report of the Working Group on Water Efficiency to the International Resource Panel*. McGlade, J., Werner, B., Young, M., Matlock, M., Jefferies, D., Sonnemann, G., Aldaya, M., Pfister, S., Berger, M., Farell, C., Hyde, K.,Wackernagel, M., Hoekstra, A., Mathews, R., Liu, J., Ercin, E., Weber, J.L., Alfieri, A., Martinez-Lagunes, R., Edens, B., Schulte, P., von Wirén-Lehr, S., Gee, D. [http://www.unep.org/resourcepanel/Portals/24102/Measuring_Water.pdf] site visited in May, 2013

United Nations Statistical Division (UNSD) (2006). *Handbook of Integrated Economics and Environmental Water accounting 2004 SEEAW*: draft for discussion [http://unstats.un.org/unsd/envaccounting/seea.asp] site visited January, 2013

United Nations Statistical Division (UNSD) (2012). *System of Environmental and Economic Accounting for Water*. United Nations, New York. [http://unstats.un.org] Site visited in July 2013

United Nations World Water Assessment Programme (UNWWAP) (2015). *The United Nations World Water Development Report 2015: Water for a*

Sustainable World. Paris UNESCO [www.unesco.org/open-access] site visited on 27th October 2015.

United Nations, European Commission, Food and Agriculture Organization, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank (2012). *System of Environmental-Economic Accounting Central Framework*. White cover publication, UNSD, New York. Pp 8

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank (2009). *System of National Accounts 2008*. New York. [http://unstats.un.org/ unsd/nationalaccount/docs/SNA2008.pdf] Site visited on 10 September, 2014.

United Republic of Tanzania (URT) (2002). *The National Water Policy*, Dar es Salaam. Public press Pp 28

United Republic of Tanzania (URT) (2012). *National Sample Census of Agriculture 2007/08 report*, Ministry of agriculture food security and cooperative, Government press, Dar es Salaam Pp 123

United Republic of Tanzania (URT) (2012). *Population and housing Census*, National Bureau of statistics, Government press, Dar es Salaam. Pp 256

WATERNET (2003). IWMI: *Principles of Integrated Water Resources Management, Agricultural water demand*. [https://intranet.iwmi.org] site visited February, 2013

World resources Institute (WRI) (1996). *World resources* 1996 Washington: WRI [www.wri.org] site visited on 12th January, 2013

World resources Institute (WRI) (2005). *World resources* 1996 Washington: WRI [www.wri.org] site visited on 12th January, 2013

World Water Assessment Programme (WWAP) (2014). *The United Nations World Water Development Report 2014*. Water and Energy, Paris UNESCO [http://www.unesco.org/open-access/terms-use-ccbysa-en] Site visited in October, 2015.

World Water Council (WWC) (2000). World Water Vision: Making Water Everybody's Business. [http://www.worldwatercouncil.org/index .php?id=961&L=%20onf...blurLink%28this%29] Site visited 10th September, 2014.

APPENDICES

Appendix 1: The structure of the supply table

Supply			**Agriculture**	**A forestation**	**Energy**	**Mining &Bulk industry**	**Urban**	**Rural**	**Ecological reserve**
From the environment	**S1**	**Total Abstractions**							
		From Surface water							
		From groundwater							
		From other water							
		For own use							
		For delivery							
Within the economy	**S2**	**Total supply of distr. water**							
		Water supplied to users							
		Of which recycled water							
		Waste water to sewerage							
To the environment	**S3**	**Total residuals**							
		To inland water							
		Return flows							
		Treated waste water							
		Untreated waste water							
		Cooling water							
		Water used for the hydropower							
		Water lost in transport							
Total supply									

Appendix 2: The structure of water use table

Supply			**Agriculture**	**A forestation**	**Energy**	**Mining &Bulk industry**	**Urban**	**Rural**	**Ecological reserve**
From the environment	**S1**	**Total Abstractions**							
		From Surface water							
		From groundwater							
		From other water							
		For own use							
		For delivery							
Within the economy	**S2**	**Total supply of distr. water**							
		Water supplied to users							
		Of which recycled water							
		Waste water to sewerage							
To the environment	**S3**	**Total residuals**							
		To inland water							
		Return flows							
		Treated waste water							
		Untreated waste water							
		Cooling water							
		Water used for the hydropower							
		Water lost in transport							
Total supply									

Appendix 3: The structure of asset account table

	Reservoirs	Lakes	Rivers	Ground water	Total
Opening stocks					
Abstraction from water resources (-)					
Return to water resources (+)					
Precipitation (+)					
Inflow (+)					
Evapotranspiration/ evaporation (-)					
Outflows (-)					
Other volume changes:					
Discovery (+)					
Others					
Closing Stocks					

Appendix 4: Monthly data for rainfall (mm) of various stations in the Kikuletwa sub catchment (Jan-Dec 2012)

Months/ Met. station	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec.**	**Total**
Nyumba ya Mungu	0.00	72.00	14.40	111.10	1.60	0.00	0.00	29.20	0.00	36.40	178.50	45.60	488.80
Kahe	0.00	15.70	17.10	0.00	0.00	0.00	0.00	31.50	0.00	1.40	150.40	60.70	276.80
Moshi Airport	0.00	62.50	21.20	123.20	56.00	0.00	2.10	43.60	1.10	6.20	104.50	42.70	463.10
Kia	1.50	9.80	33.40	137.00	51.90	0.70	0.00	2.10	0.00	13.10	111.20	31.30	392.00
Kibosho Mission	0.00	56.80	23.90	298.90	797.10	50.90	30.20	44.60	9.00	27.80	143.30	61.10	1543.60
Moshi Maji	0.00	54.20	42.00	166.20	132.80	3.00	2.00	61.00	0.00	7.00	84.50	86.00	638.70
Lyamungo Agro vet	0.00	24.10	61.50	232.50	377.60	28.10	5.90	45.20	4.80	17.10	116.00	99.10	1011.90
Average	**0.21**	**42.16**	**30.50**	**152.70**	**202.43**	**11.81**	**5.74**	**36.74**	**2.13**	**15.57**	**126.91**	**60.93**	687.84

Appendix 5: Monthly water supply and billing efficiency in Arusha and Moshi Municipalities

Months	AUWSA				MUWSA			
	Total supply (m^3/months)	Total water billed (m^3)	Total water not billed (m^3)	Billing Efficiency (%)	Total supply (m^3/Month)	Total water billed (m^3)	Total water not billed (m^3)	Billing Efficiency (%)
Jan	1 036 699	627 323	409 376	61	818 400	607 219	211 181	74
Feb	1 013 446	618 202	395 244	61	765 600	608 455	157 145	79
Mar	1 104 524	684 805	419 719	62	792 000	538 444	253 556	68
Apr	1 094 350	662 738	431 611	61	792 000	546 870	245 130	69
May	1 234 190	733 973	500 217	59	818 400	492 746	325 654	60
Jun	1 323 797	750 551	573 246	57	792 000	528 327	263 673	67
Jul	1 262 233	741 770	520 463	59	818 400	542 326	276 074	66
Aug	1 262 233	711 489	550 744	56	818 400	565 538	252 862	69
Sep	1 111 554	700 813	410 741	63	792 000	546 554	245 447	69
Oct	1 076 912	731 778	345 134	68	818 400	587 358	231 042	72
Nov	1 099 599	699 131	400 468	64	792 000	592 338	199 663	75
Dec	1 109 731	715 056	394 675	64	818 400	558 734	259 666	68
Total	**13 729 267**	**8 377 628**	**5,351 639**		**9 636 000**	**671 4908**	**2 921 092**	
Mean	**1 144 106**	**698 136**	**445 970**	**61**	**803 000**	**559 576**	**243 424**	**70**

Appendix 6: Average gross value per m^3 of water used per output of maize

Crop	Name of the scheme	Amount of water supplied (m^3/ha)	Area under irrigation (ha)	Productivity (Kg/ha)	seasons of production	Production (Kg/ha)	Crop value (Tsh/kg)	Crop value (TSh/ha)	Crop value per m3 of water (Tsh/m^3)
Maize	Nzeganzega	67924	65	2800	2	364000	150	54600000	804
Maize	Jophari	67924	85	2700	2	459000	150	68850000	1014
Maize	Ngomeni	67924	65	2700	2	351000	150	52650000	775
Maize	Semendo	67924	43	2800	2	240800	150	36120000	532
Maize	Palestina	67924	45	2800	2	252000	150	37800000	557
Maize	Mohamed King'oso	67924	45	2800	2	252000	150	37800000	557
Maize	Mpenda Roho	67924	75	2800	2	420000	150	63000000	928
Average									**738**

Appendix 7: Average gross value per m^3 of water used per output of banana

Crop	Name of the scheme	Amount of water supplied (m^3/yr)	Area under irrigation (ha)	Productivity (Kg/ha)	seasons of production	Total Production last season (kg)	Crop value per (Tshs/kg)	Crop value (TShs/ha)	Crop value per m3 of water used(Tshs/m^3)
Bananas	Kengele A&B	13515	70	7000	1	490000	1100	7700000	570
Bananas	Lauwo	47304	20	6500	1	130000	1100	7150000	151
Bananas	Mriri	23652	40	6500	1	260000	1100	7150000	302
Bananas	Ntenga	23652	40	6500	1	260000	1100	7150000	302
Bananas	Mawisi	14555	65	7000	2	455000	1100	7700000	529
Bananas	Kitukure	15768	60	7000	1	420000	1100	7700000	488
Bananas	Masway	18922	50	7000	1	350000	1100	7700000	407
Bananas	kashi/ Matotoo	15768	60	7000	1	420000	1100	7700000	488
Bananas	Nkwatele	23652	40	7000	1	280000	1100	7700000	326
Bananas	Mesawa	15768	60	7000	1	420000	1100	7700000	488
Bananas	Kisina	31536	30	7000	1	210000	1100	7700000	244
Bananas	Manguruwe	21024	45	7000	1	315000	1100	7700000	366
Average									**340**

Appendix 8: Average gross value per m^3 of water used per output of Tomatoes

Crop	Name of the scheme	Amount of water supplied (m^3/ha)	Area under irrigation (ha)	**Productivity (kg**/ha)	seasons of production	**Production (Kg**/ha)	**Production (Kg**/ha)	Crop value per (Tsh/kg)	Crop value (TSh/ha)	**Crop value per m3 of water** (Tsh/m^3)
Tomatoes	Olevolosi	20183	100	68000	2	136000	12400	650	8060000	399
Tomatoes	Sasi	19710	80	40000	2	80000	1200	650	780000	40
Tomatoes	Maridadi	17520	180	68000	2	136000	8160	650	5304000	303
Tomatoes	Meshorori	21024	150	70000	2	140000	7000	650	4550000	216
Tomatoes	Maroroi	21024	150	75000	2	150000	11250	650	7312500	348
Tomatoes	Nduruma kati	21024	150	75000	2	150000	20000	650	13000000	618
Tomatoes	Kimnyaki	21024	120	65000	2	130000	3900	650	2535000	121
Tomatoes	Sakaya	22935	110	50000	2	100000	2500	650	1625000	71
Tomatoes	Marurani kati	21024	120	50000	2	100000	2800	650	1820000	87
Tomatoes	Oleiguruno	12129	130	68000	2	136000	12000	650	7800000	643
Tomatoes	Ilkidinga	13140	120	68000	2	136000	11700	650	7605000	579
Tomatoes	Manyire	28067	200	70000	2	140000	16800	650	10920000	389
Average										**317**

Appendix 9: Average gross value per m^3 of water used per output of Vegetables

Crop	Name of the scheme	Amount of water supplied (m^3/ha)	Area under irrigation (ha)	Productivity (kg/ha)	seasons of production	Production (Kg/ha)	Crop value per (Tsh/kg)	Crop value (TSh/ha)	Crop value per m^3 of water used(Tsh/m^3)
Vegetable	Nzeganzega	339618	13	5600	3	72800	650	47320000	139
Vegetable	Johari	169809	26	5500	3	143000	650	92950000	547
Vegetable	Ngomeni	169809	26	5500	3	143000	650	92950000	547
Vegetable	Semendo	441504	10	4500	3	45000	650	29250000	66
Vegetable	Palestina	339618	13	5600	3	72800	650	47320000	139
Vegetable	Mohamed king'oso	315360	14	7300	3	102200	650	66430000	211
Vegetable	Mpenda roho	441504	10	5600	3	56000	650	36400000	82
Vegetable	Mtambo	477818	33	6000	3	198000	650	128700000	269
Vegetable	Ismail	315360	20	6500	3	130000	650	84500000	268
Average									**252**

Appendix 10: Average gross value per m^3 of water used per output of Paddy

Crop	Name of the scheme	Amount of water supplied (m^3/ha)	Area under irrigation (ha)	Productivity (Kg/ha)	seasons of production	Production (Tonnes/ha)	Crop value per (Tshs/kg)	Crop value (Tshs/ha)	Crop value per m^3 of water (Tshs/m^3)
Paddy	Soko	17280	400	5000	2	1250	2000	2500000	145
Paddy	Lower moshi	103680	2300	6000	3	5574	2000	11148000	108
Paddy	Mawala	86400	1425	5000	2	3645	2000	7290000	84
Paddy	Musa Mwinjanga	30240	250	4250	2	1063	2000	2125000	70
Paddy	Kikafu Chini	60480	151	4250	2	642	2000	1283500	21
Paddy	Mtambo	43200	200	4000	2	800	2000	1600000	37
Paddy	Ismaili	17280	150	4000	2	600	2000	1200000	69
Average									**76**

Appendix 11: Questionnaire administered to heads of water management authorities and institutions in Kikuletwa catchment

SOKOINE UNIVERSITY OF AGRICULTURE
Department of Agricultural Economics and Agribusiness
Questionnaire for the Research on
Physical and economic water accounts of the Kikuletwa sub catchment of Pangani River basin, Tanzania.
By
VAGELA, Denis Vendeline
Msc. (Agricultural and Applied Economics) vageladenis@yahoo.com

A1: Coffee, Sugar and Vegetables questionnaire

Type of crop	Estimated water consumption (m^3/ha)	Number of hectares under irrigation	Crop yield (tons/other units per hectare	Crop value per ton/other unit (Tsh/ton)	Value per hectare (Tsh/ha)	Estimated average value (Tsh/m3
	(1)	(2)	(3)	(4)	(5) =(3) x(4)	(6) =(5)/(1)
LSIUF Coffee estate						
LSIUMI Coffee Estate						
LSIUF Sugar estate						
LSIUMI Sugar estate						
LSIUF Vegetables estate						
LSIUMI Vegetables estate						

Where LSIUF = Large scale irrigation using furrow
LSIUMI = Large scale irrigation using modernised irrigation

Other questions:

1. Indicate investment cost
2. Indicate total size of the farm
3. Indicate land value
4. Indicate operation and maintenance cost including taxes
5. Indicate volume of water right given to you
6. Indicate type of modern irrigation in use
7. Any other information

A2 Irrigation agriculture questionnaire form

Type of crop	Type of crop/irrigation		Estimated water consumption (m^{3}/ha)	Number of hectares under irrigation	Crop yield (tons/other units per hectare	Crop value per ton/other unit (Tsh/ton)	Value per hectare (Tsh/ha)	Estimated average value (Tsh/m3)
			1	2	3	4	5=4x3	6=5x1
Paady								
Maize								
Onion								
Banana								
Vegetables								

Where SSIUF = Small scale irrigation using furrow
LSIMI = Large scale Irrigation using modernised irrigation

Other Questions are:

1. How much volume of water is used for each crop per hectare?
2. How much commercial farms use furrow irrigation and what percentage share of the cultivated land per hectare?
3. How much commercial farms use modern techniques and what percentage share of the cultivated land per hectare?
4. How much non commercial irrigation farms use furrows and what percentage share of the cultivated land per hectare?
5. How much non commercial irrigation farms use modern techniques and what percentage share of the cultivated land per hectare?
6. What is the water requirement for traditional furrow irrigation for each crop (l/ha)?
7. What criteria to recommend for large or small scale irrigation?
8. Return flow discharge.

Small- scale farming using furrow irrigation

Crops	Water needed per hectare	2006		2007		2008		2009		2010		2011		2012	
		Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3
Paddy															
Maize															
Tomatoes															
Bananas															
Vegetable															

Small-scale farming using modern irrigation

Crops	Water needed per hectare	2006		2007		2008		2009		2010		2011		2012	
		Ha	M	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3	Ha	M^3
Paddy															
Maize															
Onions															
Bananas															
Vegetable															

A3 Livestock Questionnaire form

		Total water use = Average daily requirement x 365 days x number of animals						
Livestock species	Average daily water requirement (M^3/day)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Cattle								
Goats								
Sheep								
Horses								
Donkeys								
Pigs								
Chicken								
Others								

Other questions are

1. How much land is used as a ranch? If yes
2. What livestock are being grazed?
3. What are the other types of grazing?
4. How much volume of water is required for livestock?
5. What is the number of livestock grazed?

A4 Urban/ Rural questionnaire form

1. What is the total volume of water billable for domestic use monthly in 2012
2. What is the total volume of water billable for commercial use monthly in 2012
3. What is the total volume of water billable for industrial use monthly in 2012?
4. What is the total production cost including taxes monthly in 2012?
5. What is the total revenue monthly in 2012
6. Indicate type of sources (ground water, river water, etc.) and supply capacity for each.
7. What are the total annual water losses?

8. Indicate other businesses and households obtaining their own water? Clearly showing volume of water uses and type of sources.
9. Indicate total water demand volume wise.
10. List down 10 biggest consumers in volume wise.

	Total	**%**
Houses served		
Yard connections		
Public taps		
Area population		

A5 Hydropower station

1. What is the maximum discharge required to achieve optimal production?
2. What is the minimum designed flow and can produce how much kWh?
3. What is the production cost per $1m^3$ of water supplied?
4. What is the unit charge of one kilowatt produced and related production cost?
5. What is the capacity of the dam?
6. Operation and maintenance coast.
7. How much water loss

A6 Meteorological station

Data for calculation of Evapotranspiration values in the basin (2006-2012)

Station	Air humidity	Temperature	Solar radiation	Air wind speed	Sunshine
Lyamungu					
TPC Langasani					
KIA					
Moshi Airport					
Arusha Airport					

Appendix 12: List of persons contacted in the field during data collection

Name	Title	Office	Contact
Muchunguzi	District irrigation officer	Arumeru DC	0759620301
Solomon G.	DALDO		0754659306
Mr Urio	Assist DALDO	Arusha DC	0754334686
Mr. Kajigili	District irrigation officer	Hai DC	O754277925
Dr. Kweleke	DALDO		0757581681
Eng. I. J. Macha	Hydrologist	PBWO	0754560650
F. Masawe	District irrigation officer	Moshi Rural DC	0755403560
M. Kessy	Extension officer		0754461362
Eng. Moshi G.R.	AINZ Consultant	AINZ	0754379513
Mr Peter Kiwelu	hydrologist	PBWO-Arusha	0755242438
Eng. Kibasa	Operational Manager	MUWSA	0784451165
Eng. Mohamed I.	Operation and Maintenance Eng.	AUWSA	0767229514/0784229514
Mr. kalulu	IT staff	AUWSA	0754281219

Appendix 13: Water accounts definitions

Available water: the amount of water available to a service or use, which is equal to the inflow less the committed water

Closed basin/catchment: A basin or catchment where utilization outflows are fully committed

Committed water: the part of outflow that is reserved for other uses

Depleted fraction: the fraction of inflow or available water that is depleted by process and non process uses

Domain: the area of interest where accounting is to be done bounded in time and space

Fully committed basin/catchment: a water basin that has been developed to the extent that all water has been allocated or in other words all outflows are committed

Gross inflow: the total amount of inflow crossing the boundaries of the domain

Net inflow: the gross inflow less the change in storage over the time period of interest within the domain. Net inflow is larger than gross inflow when water is removed from storage.

Non-depletive uses of water: uses where benefits are derived from an intended use of water without depleting water

Non-process depletion: depletion of water by uses other than the process that the diversion was intended for

Open basin: a basin where uncommitted utilization outflows exist

Process depletion: that amount of water diverted and depleted and depleted to produce an intended good

Productivity of water: the physical mass of production or the economic value of production measured against gross inflow, net inflow, depleted water, process depleted water, or available water

Uncommitted outflow: outflow from the domain that is in excess of requirement for downstream uses.

Utilizable water: outflow from a domain that could be used downstream