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Institute of Water
and Energy Sciences

**PAN AFRICAN UNIVERSITY**

Institute of Water and Energy Sciences (Including Climate Change)

# ASSESSING THE ROLE OF WATER USER ASSOCIATIONS ON RESTORATION OF THE DECREASED ENVIRONMENTAL FLOW AND DEGRADED FRESHWATER ECOSYSTEM IN TANZANIA.

**Happyness Ngonyani**

**31/July/2018**

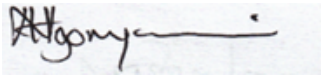
**Master's in water policy**

**Supervisor: Dr. Khaldoon A. Mourad**

**THESIS SUBMITED FOR FULFILMENT OF MASTER OF SCIENCE IN WATER POLICY**

## DECLARATION

I, HAPPYNESS NGONYANI, declare that; this research proposal is my own work and has not been presented and will not be presented by any other person, at any other University for similar or any other degree award.

Signature 

Date **31/July/2018**

## CERTIFICATION

I the undersigned, certifies that; I have read and hereby recommends for the acceptance by the University of Pan African University Institute of Water and Energy Sciences as a master thesis entitled: “Assessing the role of water user associations in the restoration of the decreased environmental flow and the degraded ecosystems in Tanzania” for the fulfilment of the requirements for the Master of Science degree in Water Policy.

Signature

Dr. Khaldoon A. Mourad

PhD (Water Economics)

Date **30 July 2018**

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## DEDICATION

To my mother Mrs. Thecla Ngonyani, for sending me to school, my husband Mr. Abubakary Mgaya Ramadhan, my son Joachim and all members of Ngonyani's Family for their prayers and encouragement throughout the whole period of my research writing.

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## ABBREVIATIONS

| | |
|---|---|
| ASDP | Agricultural Sector Development Program |
| AWF | African Wildlife Foundation |
| CH4 | Methane |
| CO2 | Carbon dioxide |
| DO | Dissolved Oxygen |
| DV | Dependent Variable |
| EMA | Environmental Management Act |
| EIA | Environmental Impact Assessment |
| FGD | Focus Group Discussion |
| FNPP | FAO Netherlands Partnership Program |
| GHGs | Green House Gases |
| GRR | Great Ruaha River |
| IUCN | International Union for Conservation of Nature |
| IV | Independent Variable |
| IWRM | Integrated Water Resource Management |
| l/sec/m | Litres/second/meter |
| l/sec/ha | Litres/second/hacter |
| m | meter |
| $m^3$/se | meter cubic/second |
| $Mm^3$ | Million meter cubic |
| NAWAPO | National Water Policy |
| NAP | National Agricultural Policy |

| | |
|---|---|
| NGOs | Non-governmental Organizations |
| N2O | Nitrous oxide |
| SDG | Sustainable Development Goal |
| RBWB | River Basin Water Boards |
| RIPARWIN | Raising Irrigation Productivity and Releasing Water for Intersectoral Needs |
| SMUWC | Sustainable Management of Usangu Wetland and its Catchment |
| SPSS | Statistical Package for Social Science |
| USAID | United States Agency for International Development |
| WARMA | Water Resource Management Act |
| WB | Water Basin |
| WUAs | Water User Associations |
| WWF | World Wildlife Fund |

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# ABSTRACT

Mkoji sub catchment is the populated and intensified sub catchment in Tanzania while being the uppermost sub catchment of the Rufiji basin with the downstream users being critical users like domestic, wetlands, national parks and hydropower generation. Public participation through the use the water user associations established in the basin as per National Water Policy as one of the stakeholders in the integrated water resources management, influences sustainable management of the resource and its environment in general. Despite the efforts made by governmental and non-governmental organizations in forming and supporting Water User Associations, little is known about their role on water resources management and the extent to which the formation of WUAs restored the environmental flows or improved water resources management. The study aimed to assess the role of water user associations on restoration of decreased environmental flow and degraded aquatic ecosystems in Tanzania, with the case study of Mkoji sub catchment of Rufiji basin. Six water user associations of Mkoji Apex: Upper Mkoji, Mambi, Gwiri, Mlowo, Mpolo and Mswiswi associations were assessed. The study aimed to assess their strategies on restoration, influence of the land use on the flow decrease and ecosystem degradation, evaluation of the climate factors on flow and ecosystem as well as their role in climate change and variability mitigation strategies for the restoration activities. Both primary and secondary data were collected and analysed for this study. Primary data were collected from various sources using interviews, focus group discussions and questionnaires, summarized, tabulated and narratively presented and the secondary data were obtained from various institutions reports and documents, reviewed and analysed. Statistical Package for Social Sciences (SPSS) was used on the analysis of the secondary data with spearman correlation test to seek the relationship between the flow and the aquatic ecosystem (fisheries catch used as the aquatic ecosystem representative of the study). Statistical results showed there were no any correlation between the flow and the aquatic ecosystems. It was also identified that, land use management restoration strategy, water resource restoration strategy and are the ecosystem restoration strategies used for the restoration by the water user association. 89% of the sample population accepted the decrease of the flow and then while 75% accepted the decrease of the fish catch as the freshwater ecosystem of the study. It was also reported on the deforestation and their sources which identified being agriculture, fuel and other activities with

the scored percentages being 54%, 32% and 14% respectively for being the influential on decrease on the flows and the degradation of the aquatic ecosystems. The statistical rainfall data showed not much differences in rainfall, though the primary sources reported on the change of the patterns in time and intensity while on the other hand water user associations and villagers reported on being aware of the condition and taking some of the precaution measures on the situation by using the climate and hydrological information in management of the water resources and restoration of the flow and ecosystems through environment management actions. Based on the results obtained it was concluded that Water user associations are doing greater job in management and restoration while politics and other factors like funds water permits are holding them back in their work regardless of them formed as apolitical organ. With these findings the study recommended: The government should consider measure and put the environmental flows for all the rivers in each basin and sub-catchment starting with the most congested basins and that needs environmental attention so that environmental degradation can be reduces in the sub catchments. It is advisable to involve animal keepers in the WUAs rather than marginalizing them despite being rightful user while land use planning can help in reducing the conflicts between farmers and animal keepers for water and pasture and between downstream and upstream users in quality and quantity as well as time of irrigation for the rotations Negotiations between the government and land owners near water sources on how to use a particular land should be considered with the helps from water user associations on how that land can be used sustainably but only after 30m from water sources. To sustainably use the freshwater ecosystem aquaculture development should be used as there is still potential in the area instead of illegal fishing or extensive use of the

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Water resource management is a complex and multi-sectoral issue with different dimensions. Competing for water resources among different users in water basins creates challenges in managing and allocating these resources. According to Brisbane Declaration of 2007, environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystem flows (Forslund et al., 2009). The definition took a broad view including the transboundary resources. In this regard, in the shared water basins, the degradation of a flow (in quantity, quality or time) in a country or a state will eventually affect the status of the water resources of the other states.

The pressure of water uses has deteriorated both quality and quantity of the resources and worsened the environmental flow situation in many rivers over the world, which highlighted the need to a better sustainable management to make rivers suitable for sustaining human beings' life and the environment including fresh water flora and fauna.

In 1981, Tanzania adopted the River Basin Management and established the River Basin Water Boards (RBWB) to manage its surface and ground waters resources. Water policy went through a reform process and took into consideration rising awareness at the local level and resource management for the environmental flow. Managing water resources in RBWB is based on an Integrated Water Resource Management IWRM plan that depends on comprehensiveness, subsidiarity and economic approaches. Formal and informal community participation are recognized in Tanzania (Sokile and Koppen, 2004). Participatory approach was achieved the formation of the Water User Associations that are based on the National Water Policy (NAWAPO), which has been established in 2002. Water Use Associations (WUAs) have a vital role in the management and allocation of water resources for the environmental purposes. The participation part of the NAWAPO has not given any direct engagement of the other stakeholders in planning water uses (especially public), because the minister has had all the power in the water plans. It has a big difference from the management practices in Florida Water Management Policy, for example, where in some of the regions public has the right to engage

directly in the planning of their water users (Hirji and Davis, 2009). In addition, NAWAPO emphasizes in the management of the environmental flow for the sake of the health and viability of the riverine no matter of the activities that are done in the area using various scientific data collection tools. Ndelwa (2014), reported on the role of the water user associations in the management of the water conflicts in the basins, a research conducted at Ilonga sub-catchment of Wami-Ruvu basin in Tanzania. It was identified that; river water is the main water source for agriculture and 22% of conflicts identified before the formation of WUAs and 4% after the formation in the area. Moreover, equitable distribution of water resources to users was a good way for conflict resolution in the basin. Still climate change is a challenge to WUAs.

## 1.2 Statement of the research problem

Mkoji sub-catchment, one of the populated sub catchment in Tanzania; is characterized with its multiple users of water resources like hydropower production, agriculture, livestock and other land use. The growth of the area as the Southern Agriculture zone in Tanzania for the production of agricultural stuffs for food in the country has increased conflicts between water users at the upstream, middle and downstream users; it has also increased the conflicts among the agriculturalists and livestock keepers. Having multiple users and intensive water use in the sub-catchment has increased the abstraction and the encroachment of the reserved areas like forests which in its turn have led to deforestation and an increase in the $CO_2$ emissions as poor agricultural activities have supported climate change and variability in the area).

All of the above-mentioned components have influenced the environmental flows of the river in the sub-catchment. According to WWF (2010), the issues of decreased environmental flows, water user conflicts, and the decrease in the size of the wetland in the sub-catchment contributed to the decrease in the flow of rivers and affected downstream users. Various programs have been initiated for the restoration of the environmental flow and the degraded aquatic ecosystems taking public participation approach into account. The establishment of water user associations in the basin plays a vital role in the integrated water resources management plan. Encouraging public participation in management influences sustainable management of the resource and its environment in general.

Despite the efforts made by governmental and non-governmental organizations in forming and supporting WUAs, little is known about their role on water resources management.

Furthermore, the extent to which the formation of WUAs restored the environmental flows or improved water resources management is also unknown.

Engaging farmers in the management and the decision-making increases water productivity and increases transparency and accountability in the management (Zhang, 2013). WUAs play various roles in the management of the water resources. Therefore, this study will assess the role of WUAs in the restoration of the decreased environmental flow and the strategies that are being used in Mkoji sub-catchment in Tanzania.

**General objective**

The main goal of this research is: To assess the role of water user associations on the restoration of the reduced environmental flow and the degraded freshwater ecosystems taking Mkoji sub-catchment as a case study from Tanzania.

**1.3 Specific objectives**

1. To evaluate the methods/strategies used by WUAs in Mkoji sub-catchment of the Rufiji basin for the restoration of the environmental flow and the degraded ecosystem;
2. To analyze the influence of land uses in decreasing the environmental flow and degrading the ecosystem;
3. To analyze climate change effects and variability on the environmental flow and the degraded ecosystems; and
4. To assess the role of WUAs in influencing climate change mitigations strategies for the restoration and management of water and biodiversity in the Mkoji sub-catchment.

**1.4 Research questions**

i. What are the methods used by the associations in the basin on the restoration of the environmental flow?

ii. What are the possible effects brought by climate change and variability on the flow and the degraded ecosystems?

iii. What is the influence of land use in the decrease of the environmental flow and ecosystem degradation?

v. What is the influence of the WUAs on climate change mitigations strategies for the restoration and management of the water resources in the basin?

### 1.5 Significance of the study

The significance of this study is to know the role of the water user associations, as stakeholders in the IWRM plan, in the restoration of the decreased environmental flow and the degraded freshwater ecosystems. The study assessed the status of the environmental flow and its rehabilitated degraded ecosystems in the water basin. The findings of this study helped in highlighting the knowledge of the WUAs about climate change, variabilities on the water resources and the different impacts of land uses. The study also, assessed how WUAs disseminate the information (advices) to the population according to the IWRM approach to consider efficiency, effectiveness and sustainability in using water resources for the development of the country and for the ecosystem. The findings also suggested on how water basins authorities can support and contribute to the capacity building and rising awareness to these associations on managing water resources for the benefit of all water users according to the IWRM principles.

### 1.6 Scope of the study

#### 1.6.1 Study Area

The study was conducted in Mkoji sub-catchment of Ruaha River Basin in Tanzania that covers an area of about 3400 $km^2$. It is located in Southwest of Tanzania between the latitudes $8^0$ 10' 0"and $9^0$ 5' 0" South, and longitudes $33^0$ 35' 0" and $34^0$ 10' 0" East**.** It is one of the uppermost sub-catchments of the Rufiji river basin, its upper zone receives water from Poroto and Chunya mountains. The Poroto and Chunya escarpment forms the sources and tributaries of most of the major rivers in the Mkoji sub-catchment. The Mkoji sub-catchment is drained by the Mkoji River and four other major perennial rivers as well as several seasonal streams flowing towards the central plain (Steven, 2004). Mkoji sub-catchment is characterized by various number of water users from upstream to downstream, which intensified the water resource, and to some extent caused water conflicts between users especially during the dry season. Due to the frequently occurred of the water user conflicts and decrease in the environmental flows, which affected downstream users including Ruaha National Park wild animals and Ihefu swap. WUAs have been established to tackle these problems. The study was conducted in three months from March to June 2018.

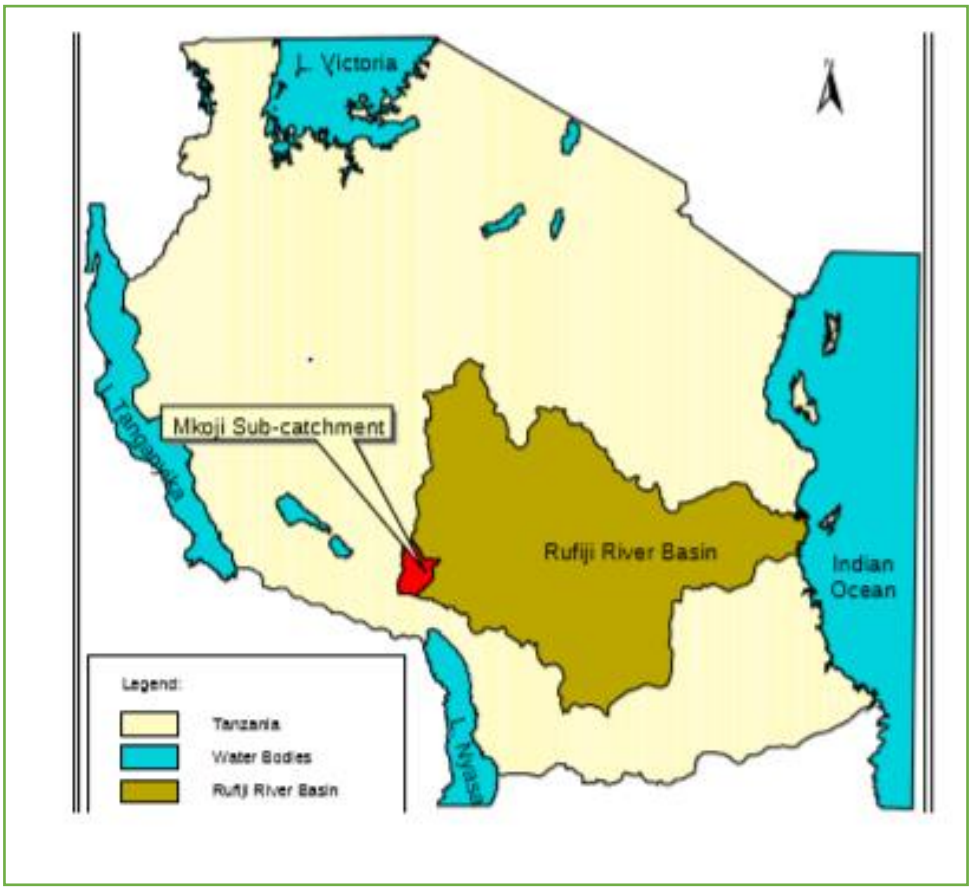


Figure1. The map of Tanzania showing Rufiji basin and allocation of Mkoji sub-catchment (Rajabu,2007)

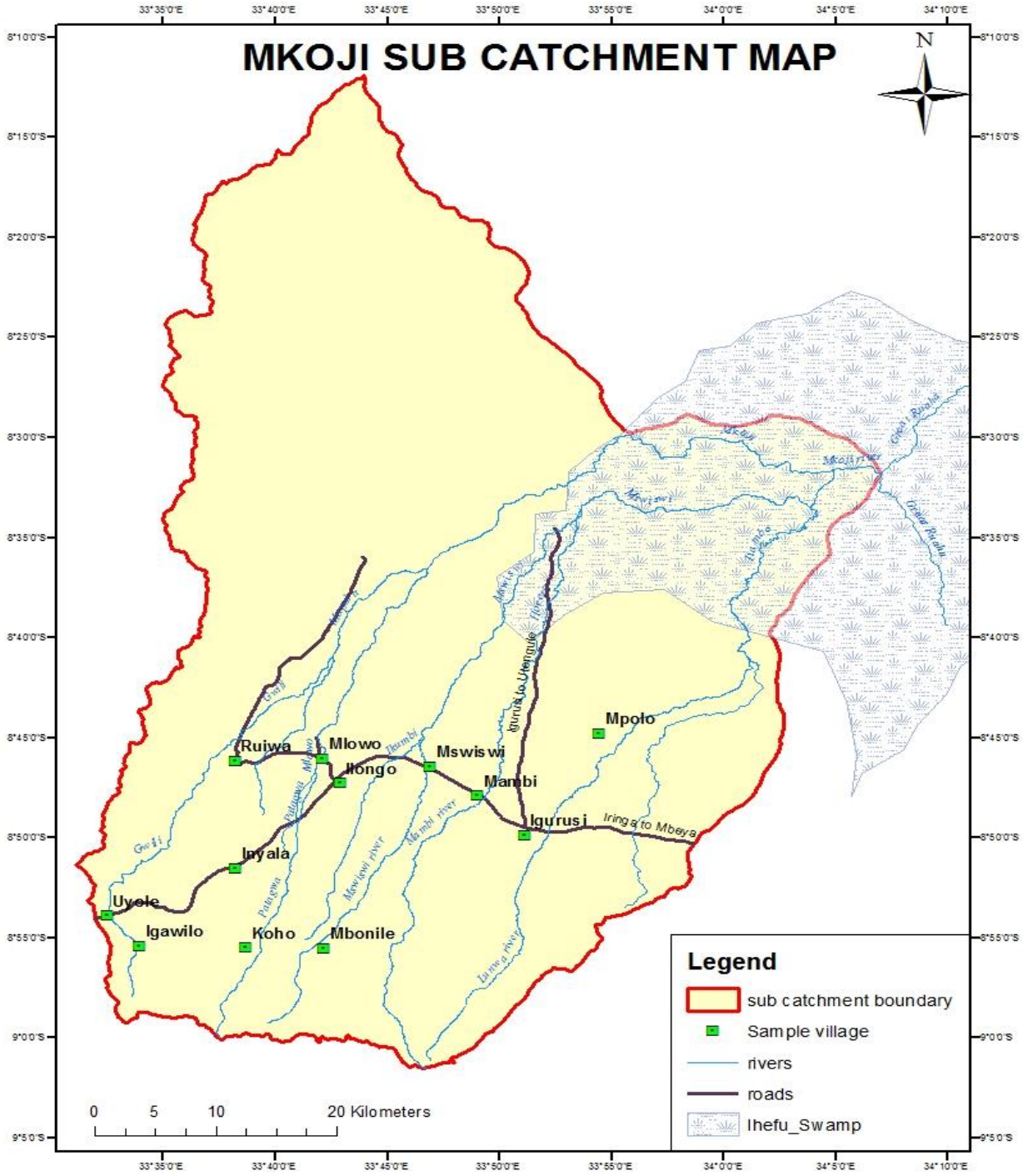


Figure2. A map of Mkoji sub-catchment showing the sampling villages

### 1.6.2 Climate

The climate of the studied area is unimodal, with two seasons, one rainfall season between November and April and one dry season between May and October. The annual rainfall range is 600 mm to 800mm in the lowlands and 1500mm in the highlands. Rainfall ranges within the zones of the sub catchment. With upper zone of the sub catchment receiving high rainfall while middle and lower zones receive small amount of rainfall annually.

### 1.6.3 Population

The studied area has a high population density due to the fertile soil that favors agriculture and livestock. Its population size approximated to be 146,000 with its annual growth rate about 2.4 % (Water for Future report, 2011 and RIPARWIN report, 2004). High population density of the area is along Southern highlands and Tanzania-Zambia highway.

### 1.6.4 Socio-economic activities

Socioeconomic activities in the area are agriculture (both crop production and livestock keeping), fishing**,** business, industries. Agriculture practiced in the area is both rainfed and irrigation agriculture while the local irrigation methods like diversion of the rivers, pumping of water from the rivers and the use of furrows being predominant to most smallholders over the modern irrigation approaches.

### 1.6.5 Water resources and uses

Mkoji sub-catchment has surface water and groundwater. Various rivers drain in Mkoji sub-catchment as shown in the Figure 3 below. Immediately downstream of the sub catchment there are important wetlands, Ihefu wetland which is part of the Usangu plain, while the water uses in the sub catchment being domestic, irrigation, livestock and brick making. (Lusuva,2004) reported that the major water uses in Mkoji sub catchment are irrigation with 76%, livestock with 6% and 18% for domestic use. In 2000/2001 it was estimated the water availability in Tanzania per capita was ~2,700 $m^3$/year (World Resources Institute, 2000/2001). The available water resource during the rainy season in the Mkoji sub catchment estimated to be 3190$Mm^3$. During the wet season, domestic water uses were found to be 0.8 $Mm^3$. The total water used under supplementary irrigation was estimated to be 35.37 $Mm^3$. The total water requirement to grow crops under rainfed conditions in MSC is 42.6 $Mm^3$.The total amount of water consumed by livestock for the whole Mkoji sub-catchment was about 1.47 $Mm^3$.The total amount of water used under dry season

irrigated agriculture in MSC was estimated at 12.4 $Mm^3$. The volume of water used for domestic purposes the whole of Mkoji sub catchment during the dry season was thus 0.96 $Mm^3$.The quantities of water consumed by livestock in the dry season were estimated of total amount of water used for livestock in the whole of Mkoji Sub-Catchment was 1.13 $Mm^3$. The water used for brick making in Mkoji Sub-catchment was estimated at 0.053 $Mm^3$ with much of it being used in the upper and middle zones of Mkoji. An average water consumption in Mkoji sub catchment estimated to be 21.28l/person/day in dry season 20.57 l/person/day in wet season (Rajabu,2007).

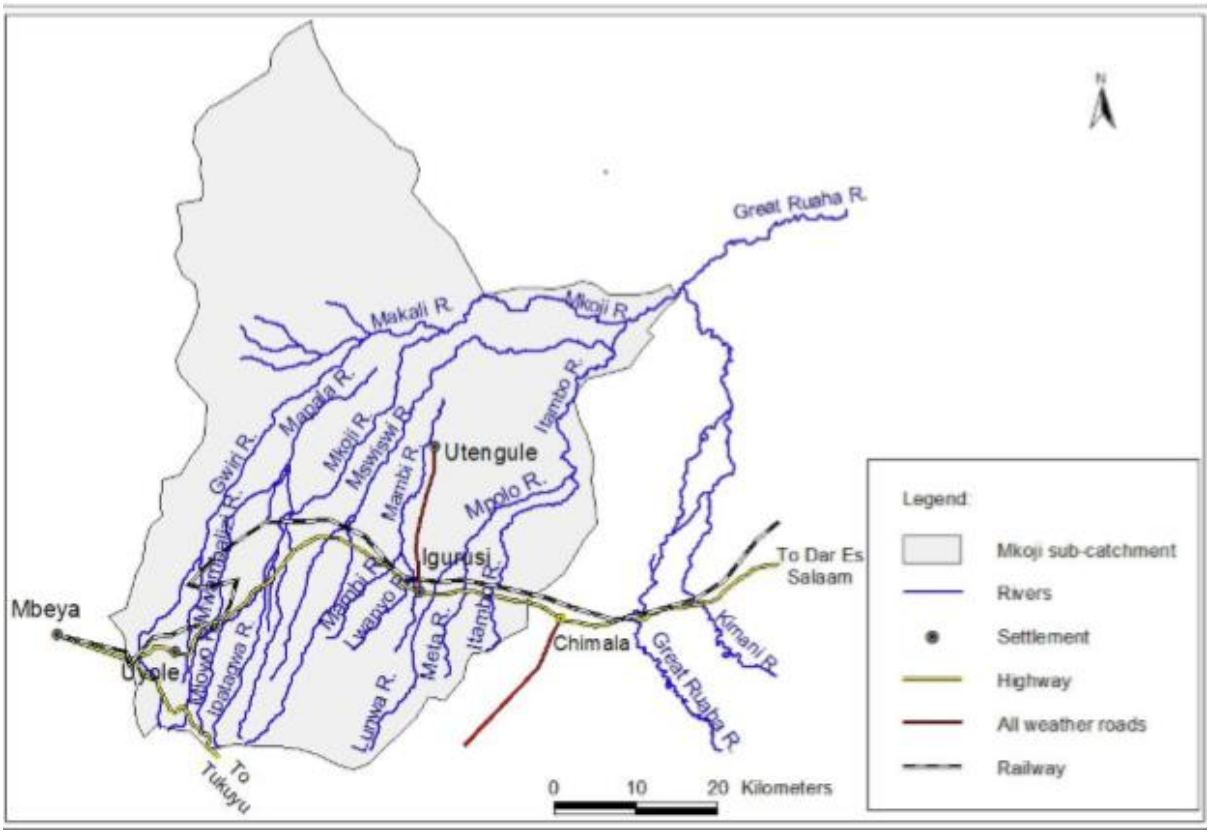


Figure 3. Map of Mkoji sub catchment showing rivers (RIPARWIN,2004).

# CHAPTER 2

# 2.0 LITERATURE REVIEW

## 2.1 Definition of Basic Concepts

### 2.1.1 Water user associations

Water User Associations (WUAs) are voluntary, non-governmental, and non-profitable but formal entities established and managed by a group of farmers located along one or several water source canals. Water users include farmers, peasants and other owners who pull together their financial, material and technical resources to improve the productivity of irrigated farming through equitable distribution of water and efficient use of irrigation and drainage systems (USAID, 1992). It is a kind of public water resources management as they are responsible in water allocation, financial support and resource management.

### 2.1.2 Water use

Water use means the amount of water used for a given task or for the production of a given quantity of some product or crop. In other words, it is the total amount of water withdrawn from its source to be used (Reig, 2013), both consumptive and non-consumptive uses. The term "water footprint" is often used to refer to the amount of water used by an individual, community, business, or nation (Chenoweth, 2008). Consumptive uses taking all the water uses without returning it into the water source after withdrawing while non-consumptive uses consider the use of water that returns water into the source. To understand water and manage water use efficiently, understanding of both water use, and water consumption should be addressed.

### 2.1.3 Environmental flow

Environmental flow describes the quantity, timing, and quality of water flows required to sustain freshwater ecosystems, the human livelihoods and well-being that depend on these ecosystems (Brisbane Declaration, 2007). It has three principles: 1) natural flow shapes the physical habitat (distribution of sediments and nutrients, channel geomorphology); 2) aquatic and riparian species have adapted to natural flow regimes (eg. variability and seasonality); and 3) maintenance of lateral and longitudinal hydrologic connectivity (including up and downstream).

Its basic idea is to maintain the quantity, quality and duration of the flow in order to keep the river and riparian ecosystem in a good state. Environmental flow methods are used to protect vulnerable fish species, riparian vegetation, water quality and groundwater (Sini and Maria, 2013). Environmental flow management imitates natural flow regimes and facilitates life cycle events like migration, pollination and spawning of aquatic organisms as well as rehabilitation and the improvements of ecosystem in general. It is only a component of river healthy and maximization of river healthy can be achieved through river restoration like fencing, erosion control, pest control and revegetation.

### 2.1.4 Management strategies

Management is a plan of actions designed to achieve a long term or overall aim in skillful or resourceful use manner of materials or resources. In the management, various strategies can be initiated to achieve a planned goal. Environmental flow management can be achieved through various strategies put into the environment components. Strategies can be based on either air, land or water component to manage the environment. It can also be through the sustainable utilization of the resources as the strategies or through the restoration strategies especially on the degraded or declined resources. Restoration and management of environmental flows can be attained through a conservation manner that puts into place by a conservation or a management group. Strategies can be used to help meeting the flow recommendation like in areas where sufficient unallocated water is not available water use efficiency strategies can be applied not only efficient use but also the treatment of waste water to meet environmental flow purposes (Texas living water,2015). They can incorporate various features of the component to make it successful as a whole but not as a single entity. For instance, managing a river flow can be strategized through watershed management to make sure all components are managed and to achieve the flow goal in quantity, quality and duration for both human needs and environment. Nile Basin Initiative(NBI), (2016) identified capacity building of their national technical staffs and the establishment of enabling national policy environments for E-flow management as some of its environmental flow management strategies among other strategies.

## 2.2 EMPIRICAL REVIEW

### 2.2.1 Methods/strategies used by WUAs for the restoration of the environmental flow and the degraded ecosystem

Management and restoration of the environmental flows and the degraded aquatic ecosystems by ensuring its increase in productivity and sustainability. NAP of 2013 in attaining of 2025 visions of National Strategy for Growth and Reduction of Poverty Development Strategy explained the use of sustainable irrigation for productivity and profitable agriculture as a mean for poverty reduction and food security through productivity increase but also emphasized the irrigation to be practiced in an efficient way to increase water productivity so that to reduce salinity in irrigation schemes (NAP of Tanzania,2013). IWRM integrating two systems: the natural system which is the fundamental for the water availability and quality, and the human system which determines the uses, wastes production and pollution of water resource (GWP,2000). In Africa agriculture is the main user of the freshwater with almost 70% of the total annual uses, which is different from Europe where industry ranking first (Boberg, 2005). Strategies as land management, water resource management, and ecosystems management should consider both plants and animals with their habitats management and restoration. Kadigi et al. (2005) reported on the water use rotation being one among the water management strategies for both restoration and management of this resource. This allows water users to use a small amount of water during dry seasons in rotation among themselves for their activities and allows some amount to be left for the environment. During the dry season the water is enough for all farms to sustain the agricultural products and hence lead to the associations to reduces the sizes of the cultivated areas so that the area to be cultivated can be sustained by the reduced flow in the rivers. (Rajabu,2007)

National Water Policy of 2002 identified WUAs as the lowest level in the management of water resources in the country. The formation of the water user association in Tanzania going through process and steps to be formalized. Before the formation of the water user association villagers should have agreed one another on the association and the purpose of their association in management of the resource and various stakeholders are consulted on the process. Regardless of being the water management tool these water user associations they don’t follow the basin boundaries instead they are formed following the villages borders and all the villagers are

considered to be members of the association. (Kasewa,2004) wrote that, the primary need for the formation of water user association is equity in water supply for all users and the secondary one is the water supplied to members leads to the adequate yields so that they can pay for their water fees. The formation process is time consuming and cost full which in leads to the left out of the marginalized and the livestock keepers (IWRA,2017), formation of these water user associations is to fulfill the objectives and pillars of IWRM which are equity, sustainability of the environment and the efficiency while the associations seemingly apolitical and technical organs (Derman and Prabhakaran, 2016 ) but gender mainstreaming in these association shows to lag behind by showing high number of men than women. Low representation of women in the associations show poor gender mainstreaming in many associations, (Lusuva,2009) identified the same problem in the Mkoji sub catchment of Rufiji basin when she reported on the unequal representation in all aspects of water resource management participation between men and women, which included the management as well as the uses of the resources while the women identified to walk a long distance for search of water while they are the ones who used small amount of water in their daily needs and activities. With this the sense of equality in integrated water resource management cannot be achieved easily, the barriers of should be removed in this aspect between men and women, also between losers and winners in the water resources as reported by (Kadigi et al., 2004), which explained the losers and winners of the Mkoji sub catchment.

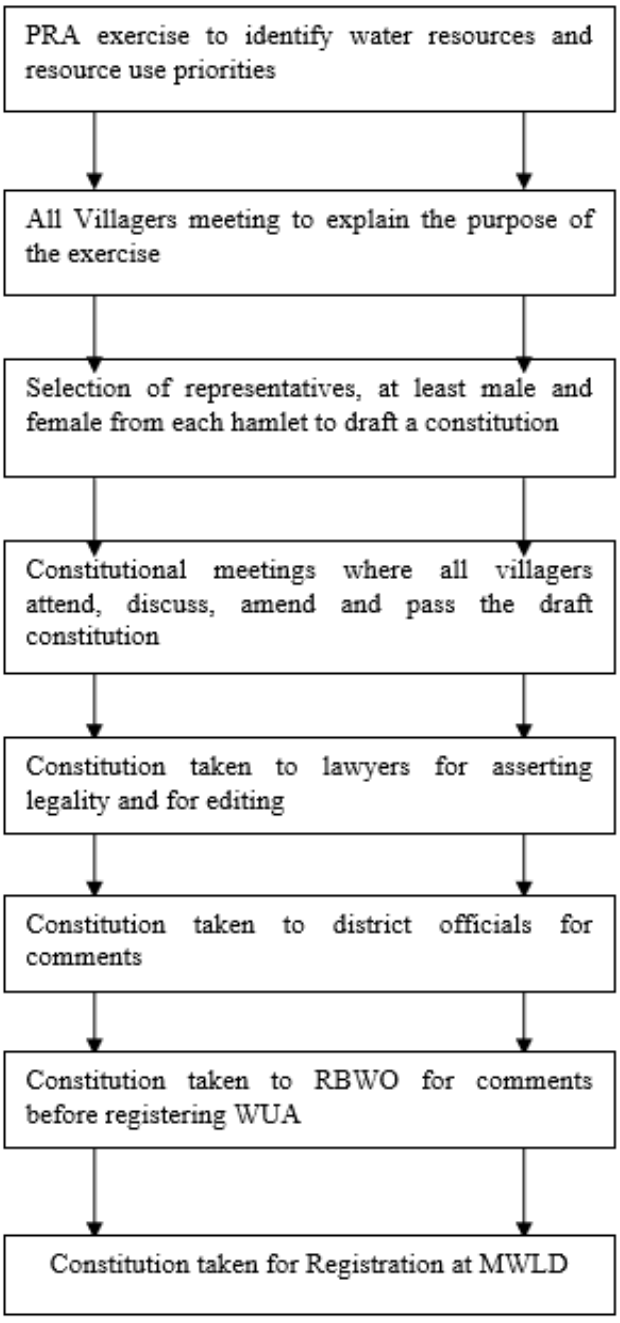


Figure4. Water User Association formation process (Kasele, 2004).

### 2.2.2 Influence of land uses in decreasing the environmental flow and degrading the ecosystem.

The increase of competition for water use creates a pressure on the resources in many developing countries. It can be due to the approaches required to know the available amount that can be shared between domestic, industrial, agricultural and environment, which is fundamental for the maintenance and management of the environmental goods and services (Kashaigili et al., 2006). Due to these competitions many of the agriculture activities are performed in the river valleys in most of the African countries, for instance part of the wetland flood plain converted into large-scale agriculture by multinational companies, Kenya is a good example that uses flood plains for the agricultural activities (Kinaro, 2008). In 2014, the global pesticide industry's projected worth is $52 billion and by 2020, the developing world will make up one-third of the world's chemical production and consumption (Watson, 2014). The use of pesticides and other chemicals in the agriculture for increasing the yields will lead to the unintended negative consequences for human health and the environment, especially in the developing world where regulations are lost or nonexistent. These pesticides when applied in the farms within the valley during the rainy period tend to be washed up and transferred with the runoff to the river, affect the aquatic ecosystems in the rivers and disrupt the food chain and food web of the rivers, and also persistence in soil cause the once-rich soil unusable for farming, bioaccumulation can wipe out living organisms in the soil which others acts as the agents of soil formation and nitrogen cycle in the soil, and sources of food, and runoff and groundwater infiltration can contaminate water, causing nutrient pollution (US EPA, 2005a ). There is a decrease in ecological metrics due to the various human activities alteration, which are reported due to the water abstraction and construction of dams in the river systems (Poff and Zimmerman, 2009). There is an interconnection between a river's natural flow regime and the trait composition of its riparian species including river flow duration, magnitude and timing shapes, ecosystem of the particular river and its life cycles which includes reproduction, maturity and redistribution (Merritt et al., 2009). As the value of ecosystem services reflects the interrelationship between ecosystems and human activities, the value is multidimensional (Busch, et al., 2012). Consequently, multiple and different stakeholders have different associations with the ecosystem service and may thus assign a different value for a different reason (More, et al., 1996; Tuvendal & Elmqvist, 2011 and van Rhijn, A.J., 2014). Indian sub continent has been affected by the intensive agriculture and irrigation which then affects most of the land. Green revolution development contributes into the over exploitation of land and water resources and use of fertilizers and pesticides have increased many folds with the direct impacts being soil erosion,

land salinization and nutrient loss (Nagdeve, 2004). Frequent ploughing for seedbed preparation without incorporating soil conservation measures, cultivation of steep slopes and hillsides, extending cultivation too close to watercourses and encroaching on wetlands, and turning of vital forests into farmland and settlements cause the erosion and contributes to biodiversity loss as habitats are reduced, and to climate change. (Kimaru and Jama, 2005). Maitima el al. (2004) explained that vegetation cover reduction causes the decrease in the soil holding capacity of water and hence reduced plant productivity which was found to be a direct link of how biodiversity loss leads to land degradation and vice versa. And degradation IUCN, 2004 land degradation the global assessment report stated that habitat destruction is the threat to the animals recorded with of 86%, 88% and 86% threatened species of birds, amphibians and mammals. Human activities have brought about certain modifications to the natural systems ecosystems that was self-regulating to suite human needs with little or no regards at all to the effects that these conversions bring to the quality of the natural resources and the environment (Maitima et al., 2004).

Bationo et al (2006) also pointed that in Africa natural resource conservation, food production, food security threatened by the degradation of the land, and it was estimated by (WMO and UNCCD, 2006) that crop productivity land loss in Sub Saharan Africa annually are in range of 0.5–1% and suggesting reaching at least 20% over the last 40 years. Intensified human activities results into the conversion of land cover e.g. forests, grasslands, shrub lands etc into an arable land and hence results into reduced soil biodiversity, crop yield and crop cover, and weakens the soil structure (Scherr, 1999). Diagana (2003) estimated the degradation at 65% of Sub Saharan Africa's agricultural land due to the water and soil erosion, chemical and physical degradation. Taking example of Niger delta, important fisheries have been lost due to the regulated river-flow and large-scale irrigation as it was in the irrigation project in the Senegal river-delta which uses a lot of water and destruct the river ecosystem (McCartney et al., 2010). Land use changes in East Africa and expansion of the cultivation in many parts of these counties has transformed land cover to more agroecosystems and less cover for natural vegetation, human settlements, and urban centres at the expense of natural vegetation. These changes are associated with deforestation that reduces the land cover, biodiversity loss, and land degradation (Maitima et al., 2009). These changes reduce the quality of the water in some of the African rivers due to the nutrients loads from the farms which in turns affects the ecosystems (Maitima et al., 2004). Wanyonyi (2010) stated, in the man modified ecosystems, that land quality degraded quickly over time causes the higher demands

for farm inputs to improve the productivity of the land, which later entered the water systems and affected the aquatic ecosystems and riparian vegetation.

In Tanzania, the cultivation of the rice during the dry season, farmers change direction of the water to flow in their farms which affects the river ecosystem by both siltation and decrease in the water level. Natural flows and sediments in the rivers have been altered by variety of human activities resulted in the sediment load which reduced the quality of the water also led to the negative impacts on the ecosystems like clogging the gills of the aquatic bottom filter feeders. Cutting down of the forests and clearing of vegetation for agriculture activities lead to the increase in the carbon in the atmosphere which is the primary GHGs and lead to the climate change and variability as a result causes the decrease in the flows due to the change in intensity and duration of rainfall. It is also a source to the soil erosion which degrades the quality of water for the use in turns increases the treatments costs as well as the increase in the turbidity in water reduces the penetration of the sunlight to the water which decreases the primary productivity of the river of both micro (phytoplankton) and macro aquatic plants. A loss of biodiversity has also been observed in East Africa due to a changing land use land cover pattern in this region of Africa. Environmental degradation has been the problem in Tanzania before and after the independence. Mongi (2008) while addressing the CTA seminar in Burkina Faso identified the main forms being deforestation, wild fire of grassland areas and slope cultivation which is common in widespread highland areas. Carbon in trees is accumulated as perennial biomass as both above ground and below ground growth also as soil organic matter deposition. When there are proper management grasslands can sequester soil carbon in great potentials, but drought and over grazing can lead to the degradation which results in soil erosion and exotic species composition (Franzluebbers et al., 2007). To attain desired production goals fertilization of the soil needed in order to achieve food security but these inputs excessively applied cause the environmental pollution. Agriculture activities partially produces some of the greenhouse gases. Example of the GHGs that are produced from agricultural activities are carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) (Franzluebbers et al., 2007). On a global scale, the relative contribution of Carbon dioxide accounts for almost 75% of the global warming potential of GHGs while its source being reported to be dominantly from fossil fuel combustion (EPA, 2006).

The agriculture activities taking place in the valley ended up causing the pollution of the water bodies and siltation of the rivers and streams as well as the swamps and the provision of incentives encourages the expansion of the farms and increase the encroachment of the valley (Mombo et al, 2007). Pollution from fertilizers, chemicals and pesticides has adversely impacted natural biota and inhibits the ecological character of many wetlands in the river valleys. The structure, composition and the abundance of the riparian vegetation are controlled by the river flow regime and the fluvial processes. Movements of the water and alluvial materials leads to the adaption of the particular riparian vegetation depends on the characteristics of the river flow regime, modification of the rivers by human activities alters the riparian vegetation (Merritt et al., 2010). (Mwakalila, 2011) stated that, since irrigation and land are related and has an interaction on one another dynamically, they are also seen to be the causative of dryness. Emphasized on the irrigation and farming activities in the sub catchment being unplanned as well as the grazing areas being in the similar manner and the land use planning on agriculture sector in general being ineffective in the sub catchment.

The mostof Tanzania's power generation 55% comes from hydropower. Of that total, over 80% of hydropower is generated in the Rufiji basin (the tributaries of the Great Ruaha River and the K ihansi River). Agenda 21 0f united nations suggested the inclusion of environment in all development agenda so that environment management and conservation can be achieved. It emphasized on its chapter 8 that, management of the water resources is achievable if it is done through the management of the environment which is the main controlling factor. It also emphasized on the integration of environmental consideration (Agenda 21, chapter8a) in all steps of development since planning up to the implementation of the project while the decision making of a certain activity or project should take into consideration environment health in terms of social, economic, cultural as well as fiscal in execution of the projects.

### 2.2.3 Climate change effects and variability on the environmental flow and the degraded ecosystems

Despite human influence, climate change and variability contribute to the degradation of the environmental flow and the ecosystem. Climate change and variability lead to extreme conditions that affect the flow regime of the river. Climate change is expected to have vital impacts on the global hydrological cycle, while affects both human uses of water resources and aquatic ecosystems (Thomson et al., 2014). Climate change associated with poor management of land and water resources catchment destruction has worsen the energy crisis and environmental degradation, especially in the central semi-arid areas and the dry sub-humid areas in the southern highlands (Muyungi,2007). Stagl and Hattermann (2016) stated, "Projection in climate change altering the river flows in Europe and the world. By 2050, ecological river flow characteristics will be affected by climate change. They go further and explain indicators which are commonly used for the climate impact assessment being the mean annual discharge, seasonal discharge (based on four seasons), monthly discharge and mean annual flooding. Climate change and its variability cause extremities like floods that affect the quality of the water in river (Dyer, 2013). The pollutants can attribute change in quality from known and unknown sources into river and degrade the quality of water, which eventually affects the ecosystem of the river. Stream flow shapes structure and function of the river system and its environmental related conditions like DO, water temperature, channel morphology, organic matter present in water, substrate concentration, particle sizes and sediments transfer. That means, habitat conditions of the river are controlled by hydrological variation within the river channel, floodplains, and stream-influenced ground water zones (Stagil and Hattermann, 2016). For example, drought reduces the flow and would not be enough to sustain human use and the ecosystem. Implications of temperature increase and change in the rainfall patterns can lead to the drought incidents (Devisscher, 2010), which can further decrease the flow and shrink the wetlands and the water resources while disrupting the connections and path of aquatic fauna within river systems. Changes in the extreme events frequencies have impacts on the process of land degradation, and those impacts are like floods and mass movements, soil erosion by both water and wind, and on soil salinization. Climate change may have impact on the ecosystem by the extinction of the present plant and animal species and emergence of new hostile species (Clarke and Randell, 2007). The Reduction of the rainfall and the shift in the seasons eventually affect the agricultural activities and make people encroaching the conserved

areas like wetlands, springs areas and rivers buffer zones and cause the destruction of the ecosystems and flow of the nutrients which supports the food web of the aquatic ecosystems (Kangalawe et al., 2011). Land management by farmers and livestock owners is among the causes of land degradation. Conservation and sustainable agriculture practices like, reduction or no tillage and zero grazing, are the sustainable arable land management as it considers the protection of the soil resources while increases the water use efficiency (Matari, 2007). Moreover, cultivating in the river valley decrease water quality and quantity for the downstream users. The change in the rainfall seasons also affects the spawning seasons of the fishes which reduces the fisheries production and lead to the over fishing or illegal fishing due to the fact that, the number of recruits is smaller than the demand of fish in the market. Illegal fishing normally causes destructions of the habitats and nursery grounds and over fishing disrupt the aquatic food webs. Drying up and reduction of water in the flood plains as a result of climate change reduces and destructs habitats for the plants and animals (especially low flowing species) that inhibits the particular area and make it hard for the specialized species of the area to survive. They are also spawning grounds for some species and hence affects the reproduction circle of those particular species. Decline in rainfall brings about dry up of the soil, decrease in vegetation cover and hence land degradation. land degradation also can be associated with the excessive rainfall that can wash loose and exposed soil away through floods. (Adosi,2007) reported that $CO_2$ exhibits a bimodal distribution, with a maximum in March and December being a maximum, while January and May observed as minimum and the annual cycle of vegetation cover pattern associated with the situation. When the land is bare it is when there is high maximum $CO_2$ season, and thus subjected to land degradation.

Climate change (in temperature and rainfall patterns) studies conducted in Tanzania showed the effects be the increase in rainfall in some parts of the country which would cause the floods and some parts decrease in rainfall and increase in temperature which would lead to the drought. Taking example of the study conducted by (Mwandosya as cited by Noel,2011) using rainfall and evapotranspiration impacts and the results showed that: the projected annual runoff of the three rivers, Ruvu basin: decrease of 10%, Pangani basin: decrease of 69% and Rufiji basin: increase of 5-11%.

### 2.2.4 Role of WUAs in influencing climate change mitigations strategies for the restoration and management of water and biodiversity.

Sustainable management and degradation both occur as a result of the activities of local people, though in some respects regardless of the activities natural cause of degradation take place. The more good management approaches are used in the production and development processes the more sustainable management is practiced while the more bad approaches are used the more degradation increased. Water users having knowledge on the cause of climate change by human influences and act upon that is the good approach in managing water resources as they consider sustainability of the resource due to the climatic condition of the area, availability and the status of the resource.

Due to the various water uses, water resources are under a high pressure from the competing users like irrigation, hydropower, industries, domestic uses as well as the ecosystems services. This competition has decreased the levels of the flow in rivers. Regardless the temporal and spatial distribution of these water resources, the excessive use and withdraw of water from the resources contributes have the large percent in the reduction. Water resources management is a difficult issue in an area that has so many water users because water allocation, prioritization and compromising between upstream and downstream create a challenge for both sides. Before 1990s, the environment was not considered as a rightful user of the water in Tanzania, so in this case environmental flow was not in place in the management of water resources. Not only Tanzania but also most of the countries failed to incorporate environmental goals in the productivity which in returns lead to the inequality between water security and environmental condition and ecosystem services (Overton et al., 2014). Sustainable Development goals (SDGs) 6, 13 and 15 of the United Nations highlighted the need for the protection and restoration of the water related ecosystems. More international cooperation is needed to foster water efficiency while supporting treatment technologies in developing countries. Particularly, it calls on nations "on the integration of the sustainable development into policies and programs while they ensure the rehabilitation of the lost environmental resources (Forslund et al., 2009).

Various social and economic projects were in place, Environmental Impact Assessments were conducted but they did not take into consideration downstream user environment. Some of the projects affected the environment directly like that of Kihansi power plant, which affected the endemic spray toad of downstream after construction of the dam for electricity production

(IUCN,2015). Nyumba ya Mungu dam in Pangani reduced flow, caused the salt water into Pangani estuary, and collapsed of the productive Kirua swamp fishery. Furthermore, water user competition between irrigators and livestock keepers of the Usangu plains, the upstream of Great Ruaha river which regulates reservoir Mtera dam decreased the flow downstream caused wildlife in Ruaha National Park to move away (Hirji and Davis, 2009).

Countries' water rights and the modern technologies encourage the abstraction of water from rivers. The increase in water abstraction from the tributaries of the Great Ruaha River (GRR) in Tanzania was due to water rights that gave legitimates in the abstraction of water and the development of the modern abstraction ways (Jambiya, 2005). Sokile and Koppen (2004) stated that water rights have many pitfalls to be used in the water management strategies as they allow users to draw as much water as they need and pay for it only if their permits and license allow them to do so. The problem is not only in the excessive abstraction without opposition from other users, but it is also the illegal transfer of the rights to some else without any notice to the managing authority, River Basin Water Board (RBWB). Other users tend to change their uses secretly and tend to abstract more than the allowed in their permits and licenses. Moreover, they said that the use of informal local groups in management show to be the better management strategy then using the formal water user associations. As many informal local groups have succeeded in water management, while the WUAs couldn't succeed (Sokile and Koppen, 2004)

At the meanwhile, most of the African local communities depends much on the ecosystem goods and services (Stacey et al., 2007). Before the adoption of IWRM the flow of rivers to the ocean seen as a wastage of water so, the rivers diverged to the dams and to the local irrigation schemes (Smakthtin and Anputhas, 2008). Water uses, and the infrastructures always change the quality and quantity of the flow in the river and may lead to the deterioration of the river. Environmental flows have various effects on the human life positively and negatively if they changed or deteriorate. IWRM stakeholders' participation emphasize transparency and accountability, ensuring the participation of all stakeholders in all activities and consultation process (INBO and GWP,2012). Sharing of information and accountability made possible the management of the resource through the use of the information in water use and its management, how much and when the resource can be used in which ways so that all the users can benefit from it while the conservation of the resource and environment is in line with its use. Consideration of the risks of damage to environment rather than water resource is another issue in IWRM because the

environment is the one determines the quantity and quality of the water rather than water itself (INBO and GWP,2012). Conservation of environment includes water and land as the part of it, and their living and non-living resources in general which influences the cycle from point to point.

Diseases due to the stagnant water and decline in the ecosystems goods and services for the livelihood. Modification of the river channels, infrastructure construction as well as the divergence of the river flows for the economic purposes have the consequences on socio-economic and cultural dimension on the human life. Taking example of Pangani river basin in Tanzania and Akasombo dam of River Volta in Ghana where the water user competition and deterioration lead to the salt water intrusion in the wetland and schistosomiasis flourished after the construction of the dam which reduced the flow of the waters respectively (Forslund, et al., 2009).

After the environmental degradation being vivid which lead to the decline in the production of food, energy production as well as ecosystems goods and services for both people and animals is when the determination of the environmental flow. Agenda 21 of the 1992 Rio Earth Summit to the Ramsar Convention, calls for the attention and implication on environmental flows on its International laws and agreements with the specified requirements for the flow (Forslund, et al., 2009).

In South Africa and Tanzania, after the basic human consumptions, the ecosystems water, the environmental flows, have the highest priority (Overton et al., 2014). However, due to the different consumptive and non-consumptive uses the implementation of IWRM to secure these flows is very hard especially in the areas of the multiple users, which normally affects the downstream users. But Tanzania goes even far after the adoption of the its National Water Policy of 2002, after the recognition of the importance water in the maintenance of the ecosystem goods and services, public participation in the environmental water allocation as well as intra and inter ministries and departments in the management of the water for the environmental purposes. (Hirji, and Davis, 2009). Annual and seasonal flows cycle especially low and high flows usually shape the ecological processes of rivers and streams. An adequate minimum flow is significance for maintenance of appropriate water conditions and habitats for aquatic life. High flows are of significance in the replenishment of floodplains and removal of accumulated sediments that can degrade the habitats while the low flows are significantly controlled so that development activities do not affect the rivers health (USGS,2013). Highly flows are the concerns of the wet climates where floods risk is their main problem while in arid climates their concern is the low flows due to the fear of ground

water withdrawals and excessive water use. Water flow alteration varies among the regions, this is a result of natural landscape features, land practices, degree of development, and water demand.

### 2.3 Theoretical Review

Theory on the environmental concerns started in the 1950s, but only the ideas and approaches are different from current years. Theory explained different actions on the environment management and governmental concerns on the environment on different decades. In 1970s and 1980s theories explained much about the environmental degradation than reforms, conventional political and civil society received attention, as there were no environment reform institutions during that periods. In 1990s, theories explained the emerging of the environmental concerned institutions and social practices under ecological modernization, economic processes of production and consumption blamed in this era as the source of degradation and lead to the formation of many companies' environmental management systems like Eco-tax and recycling. Environmental flow of sociology in the flow of environmental information, money, sustainable management concepts and green products.

Environmental flows concept is important in IWRM as it takes into consideration the development of coordination in management of water, land and other related resources for the sustainable economic and social development without compromising the availability and protection of the vital ecosystems. Environmental flow of IWRM in a river system requires negotiations and trade-offs among the water users in order to acquire the required environmental flow, and it is having three key strategic objectives and guiding principles;

Economic efficiency in water use of existing supplies, equity and environmental and ecological sustainability through use of sophisticated environmentally friendly technologies for development of new supplies and restoration of the degraded aquatic ecosystems, (Dan Tarlock, 2007). It can be achieved through various methods and approaches like application of the ecosystem services concept to watersheds. Climate change will change the magnitude, timing, frequency, duration, and variability of the different components of flow regimes in every populated river basin in the world, (Forslund, et al., 2009). There are many interrelationships between hydrological cycle and ecosystems, including terrestrial ecosystems. Management of the water resources link directly

with management of the ecosystem and vice versa through this approach. In addition, it may contribute essentially to the socially acceptable, cost-effective, as it is price side effects and follow-up costs of particular land use forms (Bastian et al, 2015). Leaving water to sustain various components of ecosystem is not something new; according to Tharme (2003), the practice of environmental flow has more than 200 different methods. Different land uses affect the quality and quantity of the flow of the rivers, contamination from agriculture activities and waste products from the industries are dumped in the receiving water bodies due to the urbanization, population growth and industrialization (Yesid Carvajal-Escobar 2008). Human development fragments river systems leading disconnection of the river and working independently of one another and modifies natural flows of water and sediments, which have direct effects on riverine ecosystems (Merritt et al., 2010). In recent decades, the availability of pesticides has increased in the developing countries, to the far-out reaches of the countryside where subsistence agriculture is still used (Watson, 2014). Damming of rivers, change of the river flow, withdrawal of river water and groundwater abstraction for agriculture have all resulted in the desiccation of many wetlands and increased the pollution from fertilizers and pesticides that have negative impacted on natural biota (including fish). Fish trade has been reduced by 18% (4,175 tonnes) as a consequence of these changes in Inner Niger delta of Mali due to the damming and irrigation schemes in the floodplain up streams and diversion of water (Zwarts et al., 2005; McCartney, 2010 )

Transfer of solutes in rivers and their deposition links between terrestrial and aquatic systems and upstream and downstream can be used as an indicator of pollution or disturbance due to the human activities or natural phenomenon on the stream (Stream Solute Workshop, 1990). Ecologically relevant elements of streamflow include the magnitude, frequency, duration, timing, rate of change in flow and inter annual variability and sequencing of flows. Katz (2008) identified theories of the environmental flows in relation to water markets in three theories of the no allocation of water for environment at all which have the externalities to the environment and this theory water for environment considered as the wastage of water. The second theory explained the minimum allocation of water for the environment. To ensure the availability of only certain crucial condition, only the minimum for the survival may be of the certain species, the last is consideration of the environment as the rightful user of the water, and there is allocation for it and realize the economic importance of it in market. With these theories, the last discussed approach shows the reduction in the environmental externalities that would be due to the water unavailability. Environmental flow

assessment can be done to solve various problems or as a means of water management and regulation. This can be done through the studies on maintaining hydrological characteristics of the river, to understand the hydrological status and disturbances. as well as biological indicators of the river which responds to any change of the river regime (it can be flora or fauna) and they show how the ecosystems responds to the water level and quality scenarios in different kind of situations (Yang et al 2012).

Participation theory of integrated water resource management led to the formation of the water user associations in many countries over the world. Roles played by these association members differ from one another due to the water availability and uses in each area. The participatory policy came into action due to inefficiency of management by the governmental organizations (Taqipour. et al., 2015). (Dick and Pradhan, 2001) local water user associations play an important role in water resource management, and their role became more practical recently through decentralization and devolution. Associations established for organizing water users for the control of construction, development, reconstruction, and maintenance of irrigation schemes within the legal framework (Ghalavand, 2006).

There are theories hypothesize the WUAs member's behavior in participation, one among them is the theory of planned behavior Theory explains the attitude of the member towards the implementation process. Member can perceive or with the influence from others, his/her capability or incapability of doing something before even attempt it. This means the tendency of each individual member of the association directly related by the behavior, positively or negatively to the concept of self-confidence (Taqipour et al, 2015). The villages where the farmers participation in the management is seemed to be low even the implementation of water management is low (Zhang, 2013) and a large group sized has a negative effect on the management rather the smaller sized group. There us other factors that contributes on the performance of these WUAs on of them is the group characteristic like heterogeneity of endowment, homogeneity of interests and the poverty level of the group. If the group members have the same interest the management is always good than that of the different interests. Moreover, the group of the low-income family tend to achieve high water productivity

According to Rahaman and Varis (2005), IWRM is the suitable approach to substitute privatization and water as the economic good in the management, as it comprises the transboundary river management, restoration and ecology, spiritual and cultural water value.

(a) Enabling Environment; for all stakeholders through awareness rising and education on the importance of environmental flow recognition (b) Management Instruments; through data and science consideration in the management of fresh water resources measuring of environmental flows and (c). Institutional roles, which looks on the equity and public participation in the planning and management with multidisciplinary approach and information transfer and sharing on (1) recognizing and identifying; (2) conceptualizing; (3) coordinating and detailed planning; and (4) implementing, monitoring and evaluating. Nevertheless, the component of institutional roles in participation and institutional faces challenges of bringing together diverse actors with different priorities involvement in political management from different sectors (Bielsa and Cazcarro, 2015). Compromising and negotiating which are the main factors to consider after the tradeoff in the multi sectoral diverse group is still a challenge in the implementation. Not only that but also developing just new institutions (local authorities) without clear cut of the roles to be done will still hinder the performance of the policy but if they can manage this while linking upstream and downstream issues the management can reach success (Joker, 2007).

Ecological modernization theory was developed in 1980s by a group of scholars., it explains the developments and the environmental harm (degradation of the ecosystem being among them). However, the theory suggested, as the development grow tends to slow the level of environmental destruction when the consumer of the development satisfied with the provision of development so is when the exploitation of the environment being reduced. The sociological ecological modernization theory argues that "feasible way out of the ecological crisis is by going further into the process of modernization" The theory looks on the way of reducing the ecological destruction is the modernization of the institutions which will lead to the decrease in its degradation. The use of modern tools and facilities as well as good structured institutions obviously results in the decrease of the ecological systems degradation as the laws and policies considers each and every factor to be put in place in order not to affect the ecosystems. WUAs formation is by the water users' agreements and then registered by the basin water board as indicated in the WRMA Act 11 of 2009 and NAWAPO 2002. Water user associations are formed by agreement of water users and registered by the BWB. The WRMA Act also makes provision for the offences related to: use of water more than a water use permit; failure to obtain ground water permit; water pollution; assault, threaten, resist, hinder, delay an authorized officer; and making false statement to procure permits.

Environment Management Act (EMA) No. 20 of 2004 also complies also with the management of the water resources through protection of environment, water being a component of environment. EMA section 6 states that ‘‘every person living in Tanzania shall have a stake and a duty to safeguard and enhance the environment and to inform the relevant authority of any activity and phenomenon that may affect the environment significantly’’. It’s the one that provides for the polluter pays principle and conducting any EIA for investments along; a river, riverbank, lake or lakeshore and shoreline may be declared to be protected areas and as such prohibit human activities within 60 metres – activities which are likely to compromise or adversely affect conservation or the protection of ocean, natural lake, shoreline, riverbank, water dam or reservoir. Water resources management also is done under the Section 4 of the Land Act, 1999 No. 4 of 1999 (Cap. 113) which states that “all land in Tanzania is a Public land and is vested in the President as trustee for and on behalf of all citizens of Tanzania”. And for the management purposes, Public land has been categorized into 3 categories which are: - General land, Village land and Reserved land while the reserved land defined as the “land parcel within a natural drainage system from which the water resource of the drainage basin originates”. The Forest Act No. 14 of 2002 deals with management of forests for ecosystem stability through conservation of forest biodiversity, water catchments and soil fertility. The land could be covered by forest reserved or used for the purposes of protection of water sheds, soil conservation and the protection of wild plants. Environmental Impact Assessment also should be done in this area of the land before any investment near or within the area. The EIA shall be done for any proposed development in a forest reserve, private forest or sensitive forest area including water sheds.

## 2.4 Conceptual framework

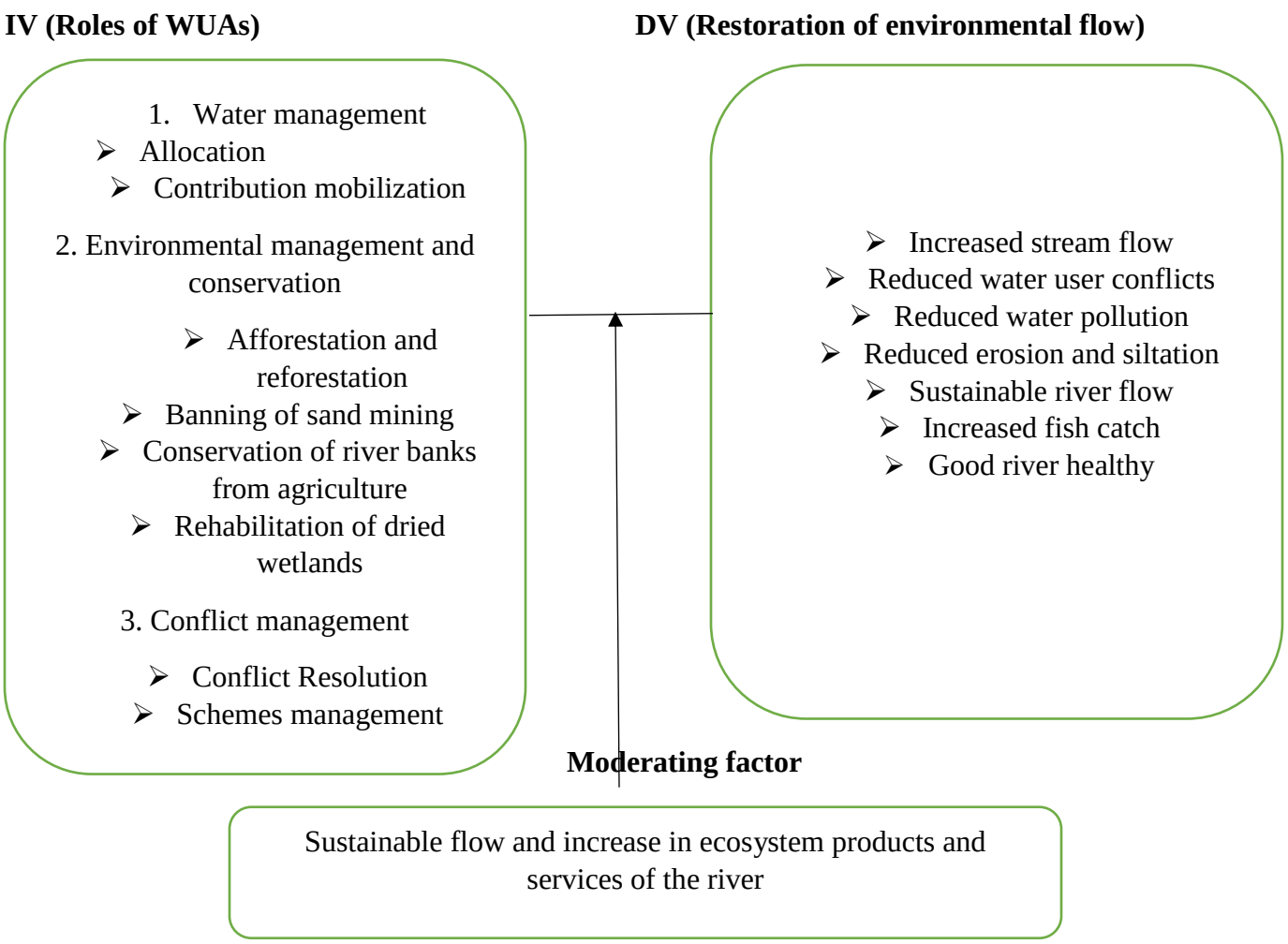


Figure5. Conceptual frame work

# CHAPTER 3

# 3.0 METHODOLOGY

## 3.1 Research design

Triangulation approach used in the research (use both qualitative and quantitative) in obtaining data

### Data collection

Qualitative and quantitative data were collected from April to July. During the data collection, the qualitative approach was used by the use of Focus Group Discussions, interviews and questionnaires. Qualitative data were collected in villages that covers the six water user associations namely Mkoji, Mambi, Mlowo, Gwili, Mpolo and Mswiswi that forms Mkoji water users' association board (Mkoji Apex).

The quantitative design showed the status and the trend of the increase and decrease of the flow and the ecosystem status before and after restoration. Also, the rainfall data from Mbeya, Kimani and Kapunga stations that represented upper, middle and lower zone of the sub catchment respectively collected from Tanzania Meteorological Agency (TMA) to show the trend of rainfall in sub catchments' zones as climate data. Reports reviews on temperature as climate data also was done to assess the increase and decrease of temperature in the study area, water use, water availability and water user association.

### Data collection instruments

The study used both primary and secondary data. Primary data obtained by focus group discussion, interviews and questionnaires. Focus group discussion used to collect data from water basin officers and other staffs as well as staff from the natural resources office on the active participation of different water user associations in the restoration and management plans from Mbarali district, villagers and water user associations. The groups of five to seven people were involved in the focus group discussion.

Interviews with water user association leaders, water basin managers and NGOs workers in the restoration departments and environmental flow research were carried out during the data collection as key informants.

Questionnaires were distributed to water user associations (Mkoji, Mambi, Mswiswi, Mpolo, Gwiri and Mlowo), villagers (farmers, fishermen, herdsmen, petty businessmen, businessmen) and other categories to obtain the needed data in the villages that forms all six WUAs within the study area. Secondary data were taken from reports and documents from basin offices, environment and natural resources department and NGOs that are working in the basin.

Reports from government offices (basin office) on the flow of the river were collected and used as the quantitative data of this research. Rainfall data from Tanzania Meteorological Agency also were collected and used for the study.

**Data analysis**

Collected data was analyzed in both qualitative and quantitative approaches. Qualitative data was analyzed in narrative form after being collected, were the data collected were classified, summarized and tabulated.

Quantitative data were collected analyzed by correlation method (Spearman's correlation) to assess the relationship between the environmental flow and the degradation of the ecosystems in the study site by Statistical Package for Social Science (SPSS) software. Ecosystem goods and services in the area quantify status of the degradation of ecosystem.

### 3. 2 Population and Target population

#### 3.2.1 Sample size and sample determination

The sampling size was determined by the Morgan and Krejcie (1970) as shown in the appendices attached, which consist of the 10 basin staffs, 10 natural resources staffs, 10 NGOs staffs, 10 WUAs leaders, 136 individuals from WUAs and 80 villagers. The category of natural resources staffs contained the people from land, environment, natural resource management and fisheries department. The category NGOs staffs contained people from land department, agriculture and climate change department and water resource management department. s

#### 3.2.2 Sample frame

Population size for the study was 350. And the sample size of 256 people was used in the research as identified by Morgan and Krejcie 1970 as presented in the Table 1 below.

Table 1. Sample frame table (Morgan Krejcie, 1970)

| CATEGORY | POPULATION SIZE | SAMPLE SIZE | SAMPLING TECHNIQUE |
|---|---|---|---|
| Basin staff | 10 | 10 | Purposive |
| Natural resource staffs | 10 | 10 | Purposive |
| NGOs staffs | 10 | 10 | Purposive |
| WUAs leaders | 10 | 10 | Purposive |
| WUAs | 210 | 136 | Simple random |
| Villagers | 100 | 80 | Simple random |
| **TOTAL** | **350** | **256** | |

The samples were taken from the upstream, middle and the downstream waters users. Random sampling method was done on the selection of the research population from each zone where water user association was chosen. Purposive method on the selection of the interviewees and groups for the focus group discussion. Sample population consisted of basin government officials, villagers, elders, other government officials and formal and informal water user associations in Mkoji sub-catchment basin.

**Characteristics of the Research Population**

Research population comprised of various stakeholders in the water resource management in a wholistic approach as presented in table 1 above. Villagers category comprised fishermen, farmers, pet businessmen, pastoralists and business men within the sub catchment. Water user associations are made up of five members from each village that the particular WUA covers.

**Mkoji Apex**

Mkoji apex is formed with six water user associations namely Upper Mkoji, Mlowo, Gwiri, Mswiswi, Mpolo and Mambi association, in all these association each association comprise the

members from all the villages in the area of associations. Leaders of the Mkoji apex are from each association leaders, (one leader from every association within the sub catchment).

**Research Assessment**

Qualitative Research Assessment method used in the assessment of this study.

Assessment of the study was done through the coverage of the study area, sample chosen for the research and the multiple data obtained from the research if they fill up research objectives and answer the research questions. Multiple data obtained for this research and multiple sampling techniques used in the research to reduce bias in data collection which also was the measure in assessing the research. Another measure of validity of this study was the frequency distribution of the data. How the results (frequencies) distributed in the plots. Reliability and validity of this study were measured through the relationship of the primary and the validation on the secondary data collected and reviewed to back up the primary data.

**Ethical consideration**

During the start to the end of the study all necessary ethical consideration was followed. That was include, the introduction letter from the director to the host institution during the research data collection and internship period, internship application letter to the host institute and introduction notice to the respondents attached to the questionnaires. Other ethical consideration of the study that was applied were the privacy of the respondents that responded on the research and their safety. Moreover, the confidential of the information given by different departments and their responses on interviews were considered throughout the research.

# CHAPTER 4

# 4.0 RESULT AND DISCUSSION

## 4.1. The evaluation of WUAs strategies

The primary tasks performed by WUAs are: (i) collection of water fees; (ii) maintenance of the infrastructure; (iii) scheduling and distribution of water, in particular during periods of water scarcity when water has to be rotated. These form the three basic water management tasks for water users' associations.

From the collected data, respondents showed that they were aware of the decrease in flow of the rivers in the sub-catchment. From the all zones within the sub-catchment, responds from villagers and WUAs showed that they were aware about the decrease of the flow from the upstream down the rivers and the tributaries. The data showed that 58% of the respondents, from both the WUAs and the villagers, were aware about the critical decrease of water flows within the sub-catchment; 31% of the respondents reported that the decrease though was not critical; 5% of the respondents were not aware about any decrease in the flows; while 6% of the respondents were strongly disagreed about the decrease of the flow in the rivers.

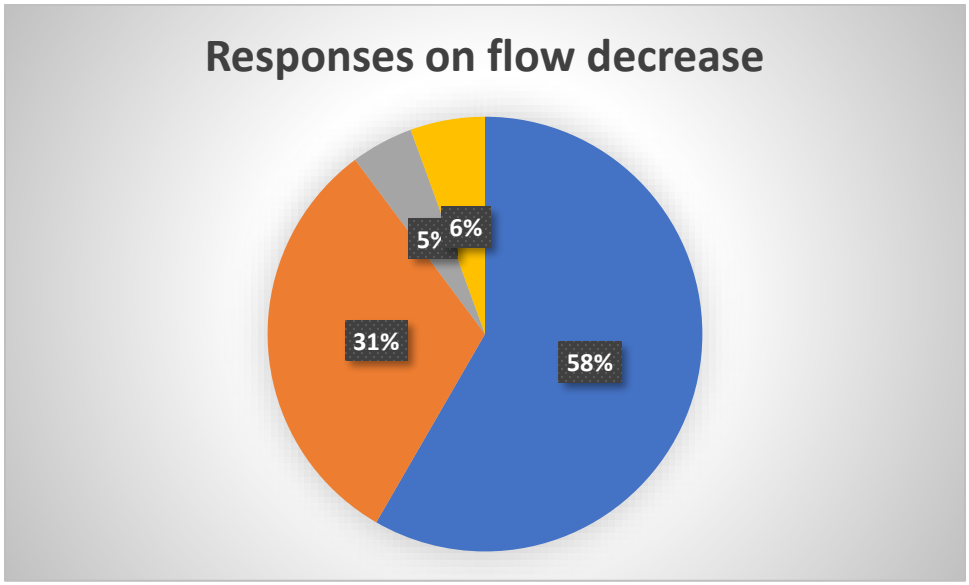


Figure 6. Percentage of respondent on the condition of the decrease in the flow of the rivers.

For the restoration of the environmental flow in the sub-catchment, most of the methods are the same for Gwili, Mswiswi, Mkoji, Mpolo, Mambi and Mlowo WUAs in the area. However, there are some differences between association to another because of their by-laws that were placed by themselves. WUAs have their own strategies that are based on the environmental management act and the water resource management act, which guide them in managing water resources and the environment in general. WUAs formulated their guidance by laws through these acts. Most of the methods reported to be done by the associations are done through. WUAs are responsible for irrigation administration, management and operation of all the schemes in the sub catchment. As the matter of efficient use of water WUAs are so attentive in the water distribution, fund collection from farmers who uses water from the schemes and financing the irrigation schemes (ASDP,2009).

### 4.1. 1 Land use management restoration strategies

During the interviews and the focus group discussion, respondents reported on the use of the climate resilient crops in some of the areas and cultivating of the short-term seeds of rice that take short time to cultivate without exhausting the land during the dry period and in arid areas within sub catchment. Most of the farmers from lower zone of the sub catchment reported on cultivating seeds that take short time to mature so they can harvest it before the dry season, which helps them not to exhaust the land and not to encroach the flood plains and water source areas for cultivation. All the respondents from WUAs in the lower zone of the sub-catchment reported that they played a good role in educating farmers about the seeds to be used based on its availability and irrigation time. 77.08% of the respondents who were not from the WUAs agreed that they have received information and education from WUAs regarding water availability and suitable seeds for cultivation, while 22.92% of the respondents disagreed and reported that they got the information from the government extension workers who are operating in their areas. But, WUAs are only collecting their money for the irrigation schemes operations.

In land management also, it was reported by the WUAs, agriculturalists and herdsmen that WUAs tended to remove people in the buffer zones of the rivers and near water sources from all economic activities to reduce river banks erosion and erosion around springs and other water sources. WUAs also plant trees in the water sources buffer zones according to the environmental Act of 2004. Planting of the trees in the deforested and degraded areas This is done through the application of

the Environmental Management Act of 2004, of abstaining all activities within 60m from the water sources to reduce soil erosion, water pollution and to make sure the activities of the upstream users do not compromise the environment and the use of the downstream users in anyway. Planting of trees also reported to be important during the interviews with governmental officials in the department of forest and environment by now the vegetation coverage increased especially in the riparian zones of the rivers, streams and water sources, through trees plantation near the river, stream banks and along the water sources within the sub catchment. Trees plantation also restores the degraded habitats for the riparian inhabits and corridor of the terrestrial aquatic organisms. In addition to trees plantation, abstaining the activities within the buffer zones of the water sources reduces the degradation of the habitats of aquatic organisms and restores the degraded habitats which in turns restores the degraded aquatic ecosystems. Riparian vegetation acts as the connector between the land and aquatic food life through food webs and nutrients recycling, they also help in the reduction of the river banks erosion and hence reduces the siltation of the rivers from erosion and deposition activities which in turns reduces the effects of siltation in rivers like smothering of the aquatic vegetation (both micro and macro flora) and the clogging of the gills of the filter feeders in Tanzania as a result of the poor agriculture activities on the slopes of the river banks, deforestation, livestock and settlement leads to sedimentation and water pollution which affected the aquatic flora and fauna and influences the migration of other species from place to place while reduced the fresh water fisheries (Payet and Obura 2004).

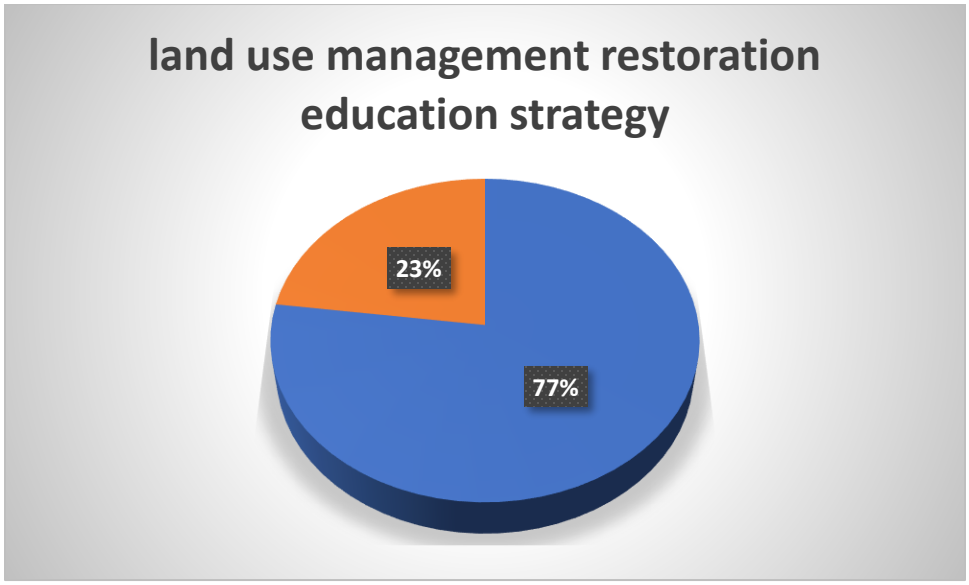


Figure7. Non WUAs responses on the climate resilience education on land management.

### 4.1.2 Water resource restoration strategies

Water resources permit holder in the sub catchment is Rufiji Basin Water Office and WUAs leaders have a mandate in supervising the used water in the schemes through collecting fees and making sure that water is returned to the rivers after using it for the environment and ecosystem use. The results showed that, WUAs have given mandate by the sub-catchment in the water allocation for the irrigation schemes by giving water users letters to be submitted to the sub-catchment office to get a water for irrigation permit. They are enforcing laws in their areas through sending people who are going against the water Act and the environmental Act of the year 2004 in the water management and land use management to the court. For water quality restoration in the rivers, WUAs are engaged in banning all washing activities that use river's water as car washing, cleaning of the containers that contain poisonous chemicals, dish washing even taking shower. Water quality restoration restricts the illegal fishing or using chemicals for fishing that reduces the quality of the water and kills fish. For the management and conservation of the water sources, WUAs use to fence all the restored and vulnerable water sources to protect it from human activities. Moreover, WUAs also dig of the buried springs and allow the flow of water from the sources is another way so that to increase the flow from various water sources which were buried and reduced the flow of water from upstream. Water use rotation in sub catchment is also used to allow water to flow in the rivers within the sub catchment and reach other users downstream. During the dry periods, WUAs are responsible for the preparation of the rotation schedules for the water users and especially the irrigators for their irrigation use so that all water users can have equity in the utilization of the resource considering the environmental flow within the sub-catchment and after the sub-catchment boundary for the Ihefu wetland downstream. WUAs use water information from the basin office and the researchers that have done various research in the sub catchment for the management of the water resources. This information is being shared to the farmers so that water can be used in the irrigation effectively in both seasons for all types of crops planted. Water information also are being used by the water user association in the water allocation for the irrigation schemes in the sub catchment especially during the dry season where water is not sufficient to all farmers and hence this information used for the arranging of the rotation of water in the schemes between upper and lower users.

All water irrigators in the sub catchment payed the same amount of money per annum for the water used regardless of the amount of water used or location of the farms along the canals

(Rajabu,2007). While the users blaming water user associations on collecting the fees for the water use when the water availability reported to be the problem and creates conflicts to user, associations blamed the water basin office on grating the permits to the users which in turns exceeds the capacity of the rivers and make it harder to them in management of the resource. During the focus group discussion held with water user associations they argued that, the availability of the permits that exceeds the capacity of the rivers is the source of the conflicts between users and they are not even responsible in taking away the permits of those that doesn't fulfil the requirements after grated the permits in spite they depends only on the associations to follow up on everything while they are not powerful enough to do so as their power are limited.

### 4.1.3 Ecosystem restoration strategies

WUAs are involved in the mission of banning the illegal fishing in all rivers within the sub-catchment. WUAs reported that illegal fishing was one of the major problems facing the flow and cause the decrease of the flow in many of the rivers in the sub-catchment as fishermen use the diversion of the rivers and close the rivers to catch fishes. Fishermen tend to make rectangles by ridges within the rivers to block water and remove all the waters from the rectangle by pumping it out to remain with the fish so that they can catch them. By this, they tend to block water that flows within the river and fauna ways as well as the riparian vegetation. WUAs are responsible in the management and restoration through removing those blocks, catching and sending those illegal fishermen to the court, replanting of the riparian flora along the river banks to allow the fishes refugia and nursery grounds for fishes. Therefore, WUAs remove the ridges to allow the flow, catch and send the fishermen to the court for other procedures to take place.

To make all these possible associations reported on working together with the village environmental committees, the local government are enforcing laws when people are against environmental act and water resource management act. They reported during the FGDs conducted during data collection that they have given mandate of catching and send them to the court. WUAs have also a rising awareness strategy for public through public meetings in villages to educate people about the importance of the environmental conservation and the restoration of the degraded environment. Water User Associations leaders reported also that they are aware on the role of the trees on the climate change mitigation when they emphasized that they distribute trees seedlings to the villagers and on the world environmental day while encouraging afforestation and reforestation for the combating and as the mitigation measure of climate change in Carbon

sequestration. WUAs have already planted about 166500 trees since 2007 to 2017 with the average of 27750 trees per association with the average of 2775 trees per year.

It is also reported during the FGDs with Mkoji juu association that, they have the control committee which is responsible in water rotation in various schemes and zones collaboration with village environmental committees. Rotation of the water use is for the purpose of making sure that water should be remained in the rivers to sustain the environment and aquatic ecosystem while it was reported also during the same focus group discussion that over abstraction of the water and diversions due to the increase in the number of farmers and lead to the decrease in the flow and even dry flows during the dry season.

All the WUAs surveyed reported about their contribution in the rising awareness meetings at villages about the environmental conservation and the importance of water resource management to people and the environment in general.

### 4.2 Analysis on the influence of land uses in decreasing the environmental flow and degrading the ecosystem.

On the analysis of the land use and the decreased environmental flow, 83.3% of the respondents agreed on the decrease in the flow of water in the sub-catchment explaining it to be critical in dry season while 16.7% of the respondents said there is an increase in the flow within the sub catchment. Respondents who responded in the increase of the flow in the sub-catchment were 87.5% from Mkoji juu association area and its villages and the rest are from Mambi association and its villages. The increase in the flow was reported to be the result of WUAs activities in the area after the restoration of some of the water sources which were already dried up before the engagement of WUAs in water resource management. Data collected from the focus group discussion conducted in Mkoji juu association identified the role of WUA in the restoration of Shamwengo water source that the flow to Ipatagwa river as an example of the increase in the flow due to the Water User Associations activities in the sub-catchment. Table 2 presents dates of dry and flow resumptions for some rivers in Mkoji sub-catchment.

Table 2. Flow resumption in Mkoji sub-catchment.

| NO | River name | Start of zero flow | Resumption of flow | Zero flow days | Remarks |
|---|---|---|---|---|---|
| 1 | Lwanyo | Nov.2003 | Dec.2003 | 41 | The river never dried in 2004 |
| | | | | | |
| 2 | Mswiswi | 2003 | | 3 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 2004 | | 2 | The river -never dried continuously due to rotational water abstraction schedules |
| 3 | Mkoji | Sept. 2003 | Dec.2003 | 102 | |
| | | Aug.2004 | Dec.2004 | 121 | |
| 4 | Mlowo | June.2003 | Jan.2004 | 198 | |
| | | July.2004 | Dec.2004 | 136 | |

### 4.2.1 Agriculture

It was reported also on the expected positive environmental impact because of irrigation water use implementation. These impacts include: improved skills for farmers; improved soil fertility and better land management; higher degree of environmental awareness; increased productivity; increased land, soil and water conservation; value added due to water use. But these positive impacts brought with some negative impacts like land degradation, contamination of stored water, water and land use conflicts, loss of natural habitats and loss of fauna and flora.

At the same time, 100% of the respondents from the middle and the lower zones of the sub-catchment reported that they noticed a zero flow in their areas during the dry season. During the focus group discussion conducted in lower and middle zones of the sub-catchment the participants agreed on the decrease after the extension of the agriculture activities. Participants also agreed that the growth of agriculture activities has contributed in the degradation of the ecosystem as many farmers did not perform smart technologies of agriculture. Most of the farmers tended to cut down forests to establish farms. Moreover, the extension of farms made farmers cultivate even in the flood plains and along the river banks which degraded the riparian ecosystems and blocked the way of the aquatic fauna like fishes to move up and down the stream. The increase in water abstraction for irrigation led to a decrease in flow and hence reduced both habitats and refugia for the aquatic animals and this extensive abstraction reduced the amount of water which was conducive for the vegetation and cut off the connection between land and aquatic environment which in general degraded the ecosystem as a holistic system between land and aquatic environment. The increase in the industries and businesses activities in the area also led to an increase in the abstraction, which reduced the flow of the rivers and hence led to the zero flow during the dry period in many of the rivers. The zero flow in the Mkoji river itself cut the connections between the downstream and upstream ecosystems of the aquatic ecosystem. Figure 7 describe the percentages of the respondents on the influences of the agricultural activities on the

decrease of the river flow and ecosystem degradation. 83% of the respondents accepted on the change of the river being associated with the agriculture activities while the rest denied on the contribution in the decline of the river flows and degradation of the aquatic ecosystem.

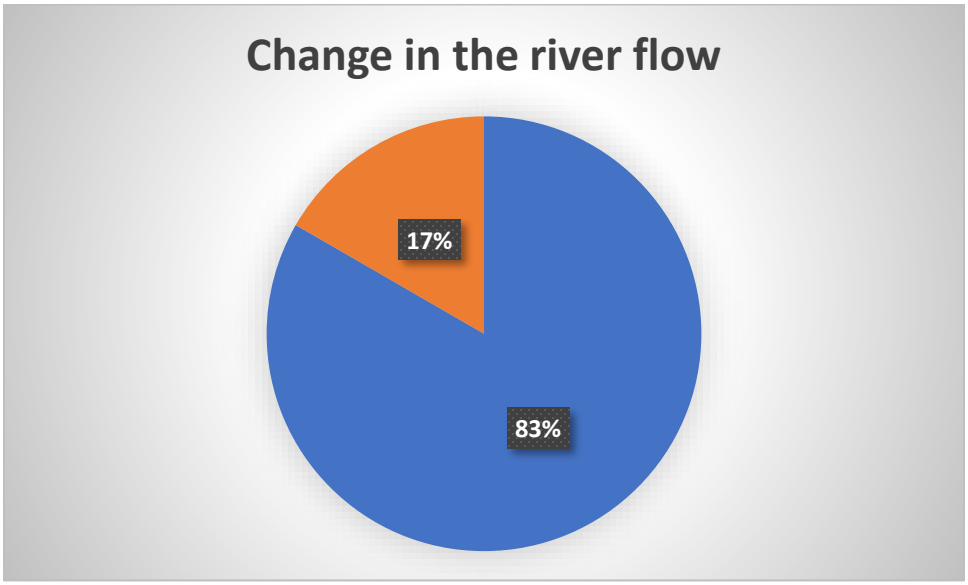


Figure8. Change of the river flow in Mkoji sub catchment.

From the conducted interviews, responses showed that the expansion of agriculture activities influenced the decrease in the flow of the rivers in the sub-catchment as well as the degradation of the ecosystem. Responses from departments of agriculture and irrigation responded on the presence of both traditional and developed irrigation schemes in the area and increase in the number of irrigation schemes in the sub-catchment. During the interviews also, it was identified that most of the developed irrigation schemes were done by donors or government support projects. Most of the developed projects were owned by communal or private while traditional schemes were owned by either a group of farmers or by the communal ownership. The increase in the irrigation increased in the uptake from the rivers which led to a decrease in the flows. Results were supported from the secondary data presented in the research report (Rajabu et al, 2005) that there were 108 abstraction points in the sub catchment with only 20 points with improved headworks. Large number of schemes showed that they lose water through seepage in the ground as it was identified that about 0.024l/s/m length in abstraction point at Luanda Majenje irrigation scheme

during the conducted seepage test is lost every day but also through taking of the more water from the rivers than the needed amount for the irrigation as elaborated in Table 3.

Table 3. Ratios of the amount of water abstracted to the water rights

| NO | Scheme name | Mean daily abstractions(m3/s) | Mean daily water right (m3/s) | Average ratio of abstraction to the water rights(m3/s) |
|---|---|---|---|---|
| 1 | Ipatagwa | 0.268 | 0.609 | 44 |
| 2 | Luanda Majenje | 0.097 | 0.107 | 90.24 |
| 3 | Kongolo Mswiswi | 0.100 | 0.213 | 47.01 |
| 4 | Mkoji | 0.051 | 0.175 | 29.05 |
| 5 | Inyala B | 0.043 | 0.103 | 41.46 |
| 6 | Moto Mbaya | 0.160 | 0.730 | 21.90 |

Source: (Rajabu, 2005).

The department of natural resources under the forests office and the environmental office reported on environmental destructions in various areas through various human activities, which caused a reduction in water quality. They spotted that Matajiwazi area was the most destructive due to the human activities with 82% being very destructed and 86% being destructed from department of forest and environment, respectively. From the department of agriculture and water basin it was reported on the increase in the number of irrigation schemes from 18 schemes in 2009 in all 6 associations in the sub-catchment to 37 in only 5 association out of 6 within the area (Lusuva,2009). Moreover, the use of the agrochemicals has reduced water quality in the area.

It was also reported that the local irrigation schemes were in place but, farmers tended to take water directly from the rivers when they didn't get the needed amounts. It was hard to know how much water they took from the rivers for irrigation and it was hard to control water loss at the intake of the schemes. The increase in the intakes for irrigation caused decreased the flow in other rivers. It was also reported that Mromboji River used to drying up during dry seasons. Water from farms after its use tended to be returned into the river. However, it was polluted and reduced the quality of water in the rivers as it is shows in the table below that are above the allowable limits of Tanzania Bureau of Standards (TBS).

Table 4. Water quality data that shows the parameters and their allowable limits in Tanzania

| Parameter | Mkoji | Umrobo | Nsalaga | Ipatagwa | Mlowo | Inyala | Hayuya | Uta | Mwambalizi | Allowable limits in Tanzania |
|---|---|---|---|---|---|---|---|---|---|---|
| DO (mg/l) | 6.9 | 7.43 | 7.6 | 6.4 | 8.08 | 9.54 | 0.85 | 9 | 8.7 | 5 to 9.5 |
| Sediment (mg/l) | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0 |
| Colour (Pt/Co) | 783 | 753 | 41 | 475 | 789 | 14 | 328 | 867 | 296 | 50 |
| Turbidity (NTU | 386 | 278 | 9.3 | 251 | 414 | 4.45 | 103 | 452 | 91.3 | 25 |
| Total coliform (nu/100ml) | 110 | 144 | 152 | 20 | 120 | 82 | 30 | 88 | 130 | 0 |
| Faecal coliform (nu/100ml) | 235 | 295 | 320 | 56 | 280 | 180 | 67 | 190 | 290 | 0 |
| pH (mg/l) | 7.59 | 6.63 | 5.72 | 6.82 | 6.63 | 5.21 | 6.59 | 6.25 | 6.38 | 6.5 to 9 |

Source: (Rufiji Basin Water Board, 2014).

The data in the table above from WBO showed that the levels of some parameters are higher than the allowable limits. Looking into all water sources the levels of coliforms are higher than the normal allowable ranges of the country. Presence of total coliform in water indicates the presence of poor sanitation in the areas and it might be due to the grazing of animals around the water sources as the total coliforms found in both human and warm-blooded animals faeces, so grazing of the animals along the water sources as it was reported can be one of the reason in the presence of these coliforms in water. Turbidity also showed to be very high and agriculture activities around the water sources might be of blame because these data were collected on June were the influence of the surface run off to the rivers is not considered, because the rainy season was over.

Moreover, cultivation in the buffer zones has also decreased the quality of water in the rivers. Results from the water basin office on the water quality showed that there was an increase in water colour with the values of 783 Pt.co, 753 Pt.co, 41, 475, 789, 14, 328, 867 Pt.co and 296 Pt.co while the Tanzania allowable limit is only 50 Pt.co. The increase in the colour might be due to the activities that are taking place along the water sources. As the data was collected in June so there were no influences of the surface run off from land and river banks floods erosion. Turbidity was also higher in all tested water sources due to the agriculture activities performed on the river buffer zones and the returned water from the farms (agricultural wastewater) polluted the river. Turbidity

decreases sun light penetration in the water surface, reduces the activities of the primary producers in the water which produce the food web of the aquatic ecosystem and can inhibit the energy and nutrients flow in the ecosystem.

During the officials interviews it was reported that the number of the local irrigation channels (furrows) was reduced compared to previous years but still there were furrows that contributed to the water loss as there were no actual counts in the intake and the furrows. Secondary data reviewed (Rajabu et al,2005) supported the information provided that showed the Kongolo Mswiswi scheme abstracted more water for paddy irrigation (2.7 Iitres/sec/hacter) instead of 0.976 I/s/ha, that was the normal requirements for the paddy in the area. It was elaborated that the reason could be the nature of the intake which was a traditional one made of tree branches, soil and wooden logs which makes it difficult to control the abstraction amount from the river.

Answers from respondents were supported by the secondary data that showed the abstraction of water for agriculture as a cause of the decreased flow of the rivers in the sub-catchment. The Mkoji sub-catchment alone had 70 intakes with a capacity of abstracting 12 cubic metres of water per second with 100% abstraction efficiency (SMUWC, 2001).

In places where there were improved irrigation schemes like in the Ipatagwa, Motombaya, Luanda Majenje and Majengo the irrigation committees were more active and responsible for allocation and management of irrigation water use. The area under rainfed agriculture was identified to be larger in Lower Mkoji followed by the middle Mkoji while the upper Mkoji zone having the smallest area under rainfed agriculture compared to all zones of the sub catchment, this can be due to the fact that a large amount of water is being used in upper Mkoji and being finished mostly in the middle part of the sub-catchment. So the lower part depends much on rainfall rather than the irrigation due to the decreased flows in most of the rivers and streams in the sub-catchment, while the dry season irrigation is more practiced in Upper Mkoji than the rests of the zones (middle and lower zones) due to the reason being reported by the lower zone users as the rivers flows didn't reach the lower zone as most of the rivers dried in the dry season while the upper zone of the sub catchment tended to have flows in its rivers during this period because they are up stream users . Results from FNPP (2003) showed that water use for the crop were 14.55 $Mm^3$ and 20.52 $Mm^3$ in middle and lower part of the sub-catchment, respectively, while the total estimation for the whole sub-catchment was estimated to be 35.52$Mm^3$ (FNPP, 2003; Kasele, 2004).

### 4.2.2 Livestock keeping

After chasing out the livestock keepers from the land near Ihefu wetland and making the land as a reserved area, Mkoji now is populated with animal keepers too. The increase in the number of livestock reduced the carrying capacity of the land to produce enough pasture for the cattle. According to (Moirana and Nahonyo,1996) excess number of livestock cause the removal of the grass cover and hence leads to the increase in the water loss from the soil through evapotranspiration. During the focus group discussion, it was also discussed that cattle were the source of the ecosystem degradation as most of the cattle were being grazed near the rivers and the water resources, which destructed the aquatic ecosystem and the riparian ecosystem. Grazing near the water source led the cattle to bury the water source and contributed in the decrease of the water flow downstream and hence caused the degradation of the rivers ecosystem.

Other land use activities like brick making and settlement establishment were also reported during the Focus Group Discussion that were conducted in all associations and with all villagers who participated in the FGDs. Most of the elders reported that human development activities were the other cause for the decrease of the land destruction of the ecosystems. People who make bricks within the buffer zones of the water sources caused a disconnection of the riparian zones between the terrestrial and the aquatic environment which disrupted the aquatic ecosystems and the flow of the nutrients and refugia for both riparian flora and aquatic organisms. Making bricks within the buffer zones has also increased water turbidity and smothering the aquatic flora that depend on the photosynthesis for their survival. The turbidity increased has also led to a decline in the phytoplankton and fish production. Hence a reduction in fisheries within the basin was a result. 75% of the questionnaires reported on the decrease in the fisheries in their rivers as indicated in the Figure 8 below. While arguing that illegal fishing has contributed in the decrease of the fish catch as it killed fishes and polluted the water. Washing in the rivers also decreases water quality and brings problems to the freshwater organisms that are living in the waters.

72% of questionnaire respondents reported on the loss of riparian vegetation on most of their rivers. Out of those respondents, 55.8 % reported on the critical decrease while the rest reported on the normal decrease. WUAs reported both agricultural activities and animal keeping along the rivers being the reason for the disappearance of these vegetation. During the FGDs conducted in the area it was argued by herdsmen that agriculture expansion and cultivating along the rivers is the cause of the disappearance while the agriculturalists blamed the herdsmen on the disappearance of the

riparian vegetation. Officials as the key interview informants urged that these are among the reasons of EMA of 2004 and the NAWAPO 2002 to give mandate to WUAs in the follow up of these regulations applications by citizens. Un planned land use and enforcement of the laws in the sub catchment is the source of these all, there is no planned area for the herdsmen for their livestock requirements on the pasture and water. The absence of pasture land was reported to be the reason for the herdsmen to feed their livestock in the farms and protected areas. Feeding of the cattle along the rivers reported to be one of the reasons on the disappearance of some of the riparian vegetation in some of the areas, for example a vegetation like matangalulu (a native name in the area) is now hard to find along the areas of the Mlowo river which were almost everywhere in previous years along the river, as it was reported by Mlowo water user association in focus group discussion.

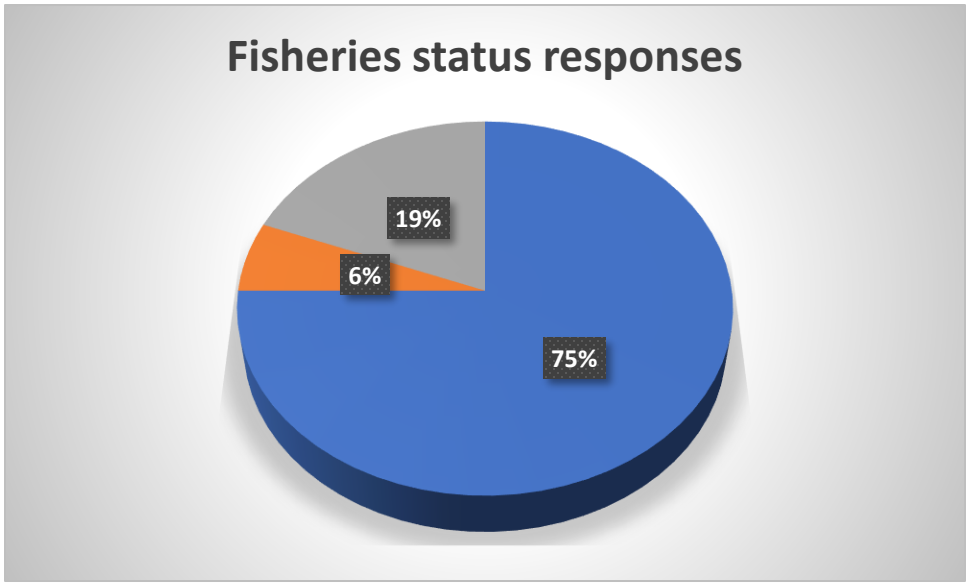


Figure9. Fisheries status responses in Mkoji sub-catchment.

Figure 8 above shows the percentages of respondents on the status of the fish catch in the sub catchment. 75% of respondents reported on the decrease of fish catch in the sub catchment river while 19% of the respondents responded on not being sure of the current situation on the fish catch and giving out the reasons for their uncertain answer and 6% of the respondents reported that there is no decrease in fish catch.

### 4.2.3 Settlement

The increase in human population caused expanding settlement over the green areas. This change on land cover caused a change in the flow regime and the ecosystem of the area. Reducing the green areas for settlement led to a bare land that was subjected to soil erosion due to the lack of the compactness of the soil particles as it lacks vegetation cover. During the FGDs conducted respondents were aware of the soil erosion taking place in the area and its effects on the flow as they were reported by some people who use to build their houses in the seasonal rivers during the dry period and hence caused the change of the water flow during the rainy season. It was also reported that, there were rivers that left their normal ways and change the flow, like Mlowo river which was shifted from where it was before. They also reported on Gwiri valley at Lwiwa area that there was no specific water way, waters were just flowing over especially during rainy season because people built on the water channel. The change in the water flow direction and flowing of the water outside the streams have decreased the fisheries in many areas in the sub-catchment also reported being the cause, for the decrease in the fisheries catch, areas like Luhanga area reported in the loss of the river channel and hence contributed in the decrease of the flow in the Mambi River and Ilongo area which was flowing towards Mlowo river which all of them drains into Mkoji River. Building in the river course has destructed the habitats which in turns degraded the fishing activities. This was also due to the clearing of the riparian vegetation which were the bridge between land and aquatic ecosystems. Settlements in the river ways decreased water quality due to the poor sanitation in the settlements. Data about water quality from WB office in the sub-catchment showed that the levels of total coliforms in the rivers were 110 nu/100mls, 144, 152, 20, 120, 82, 30, 88 and 130 nu/100mls while the allowable limits are 0 numbers of coliform per 100mls of water sample. And the faecal coliform levels were 235, 295, 320, 56, 280, 180, 67, 190 and 290 nu/100mls while the allowable limits are just o numbers per 100mls of water sample. The sources of these faecal were from both human and animals as it was reported that poor sanitation

was also the problem in the unplanned settlements and poor land use planning caused the herdsmen to feed the herds along the rivers and in the rivers which in turns polluted the water.

### 4.2.4 Infrastructure development

The infrastructure development has altered the river flow regime, degraded the riparian vegetations and destructed the aquatic ecosystems. Building dams at the rivers to increase irrigation schemes led to a degradation of the environmental flow as it reduced water quality of the rivers and affected the ecosystems. Modifications of these rivers reported to be among the reasons on the flow and aquatic ecosystem in general. During the FGDs conducted in the lower zone of the-sub catchment it was reported that the construction of the developed irrigation schemes in the upper zones were the reasons for the over abstraction of the water and that caused the decrease in the flow down stream reached even zero flow in some rivers during the dry season. From the questionnaires at the lower zone of the sub-catchment, 82% of respondents reported a decrease of the flow being associated with the modification of the river and regulation of the flow through developed irrigation schemes built in upper zone which are efficient and take a lot of water from the rivers and leave nothing for the downstream users. Development of infrastructures changes the soil structure and texture and its permeability which affected the infiltration capacity of the soil that increased the surface flow of the water during the rainy season without or with a little percolation which in turns reduced groundwater recharging. The data showed that during years 2003 and 2004 Lwanyo and Mlowo rivers had coefficients of abstractions of almost 100% and over 95% respectively. This over abstraction from these rivers decreased the flow to the downstream rivers, and hence caused conflicts between water users. From agriculture activities it was reported that two types of conflicts emerged in the sub catchment, conflict between irrigators and livestock keepers and conflict between upstream users and downstream users. Data from Lower Mkoji showed that irrigators were the main player in the conflict in the sub-catchment due to the over extraction of water from the rivers which affected the livestock downstream due to the shortage of water and pasture land. On the other hand, the data from middle and upper Mkoji showed that livestock keepers were the main players of these conflicts as they tended to feed their herds in the farms. All users from downstream blamed the users of the upper zones as they deteriorated the quantity and quality of the water and make it unsuitable for the downstream user and reducing the water to zero flow during the dry season for the downstream users.

### 4.2.5 Other uses

In the sub-catchment there were other land uses that reported to have an influence on decreasing the environmental flow and degrading the aquatic ecosystem. During the interviews it was identified that charcoal making and firewood collection for household use and for business accelerated the deforestation in the sub-catchment. Interviews conducted in the environment and natural resources department and NGO staffs emphasized that deforestation for the purpose of charcoal burning and firewood collection was another problem for the degradation of the terrestrial ecosystem which has connection to the aquatic ecosystem through flow of nutrients and connectivity through riparian vegetation and ground water storage. From the questionnaires, the results showed that deforestation for the charcoal making and firewood uses were the second after expansion of agriculture activities with 32% from all respondent when responding on the question asked "Is the size of the natural forest and wetland increased or decreased? Why?". Excess cutting down of the forest changes the land cover and hence lead to the deterioration of the water quality in the catchment due to the soil as a result of the erosion from bare land during the rainy season. Deposition of these silt from erosion caused also the deposition in the river systems which changes the nature of the river and hence its flow regime. Deposition can cause a change of the fast-flowing rivers to be slow flowing rivers and hence changes the ecosystem status of the particular rivers due to the change of the habitats type and food web. Figure 7 below shows the causes of deforestation in the sub catchment as it was reported. The figure showed 54% of the respondents from the questionnaires reported on the agriculture being the source of deforestation while 32% reported on the cutting down of the trees for fuel (charcoal making and fire wood) being the source of the deforestation and then 14% of the respondent reported on other sources like grazing, brick making, poles for housing and the cutting down the trees for the establishment of the settlements.

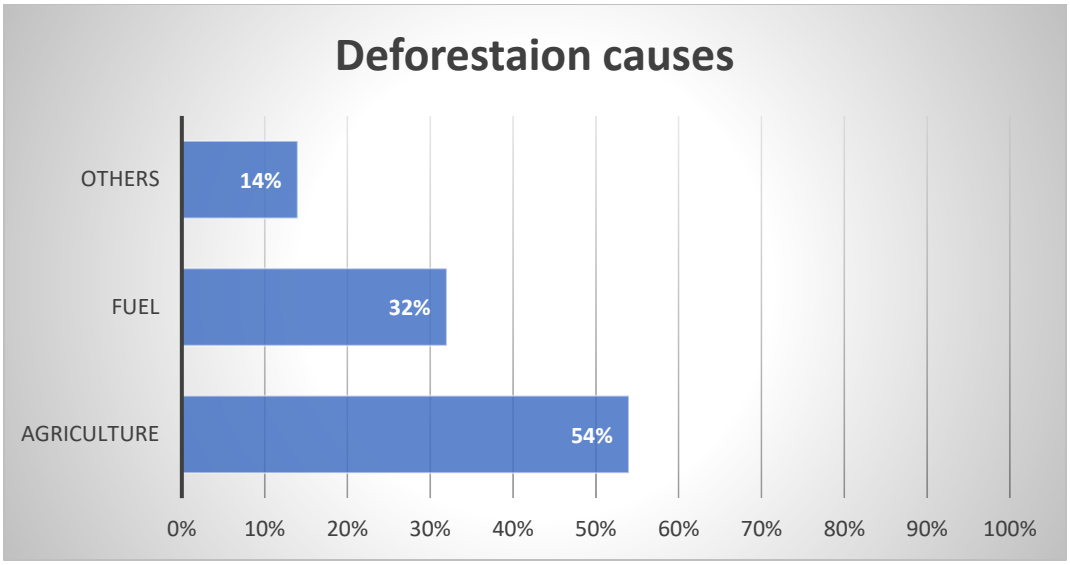

Figure10. Responses on the causes of the deforestation in the sub catchment.

From the fisheries office it was reported that, before the Ihefu wetland gazetted as the reserved area rivers fisheries production were higher than recently but after gazetted of the Ihefu wetland as the reserved area and banning of the fishing activities in the area production from the rivers went down. Before the fisheries production from the rivers were higher than 700 tonnes per year while recently production dropped to the lower than 500 tonnes and it was worse last year when it was only 216 tonnes for the whole year. During the focus group discussion in Mlowo it was reported on the change of the river flow lead to the decrease in the fisheries catch as the amount of water tend to be decrease in the flows as it affected the riparian vegetation in the sub catchment. Figure 10 below showed the trend of catch in rivers within the sub catchment since 2009. There is no much difference in the catch since 2009 to 2016, all the fisheries catch lies between 250 tonnes and 300 tonnes per year with the highest catch in 2016 and then dropped in 2017 with the lowest fisheries catch compared to all years with the tonnes lied between 200 to 250 tonnes.

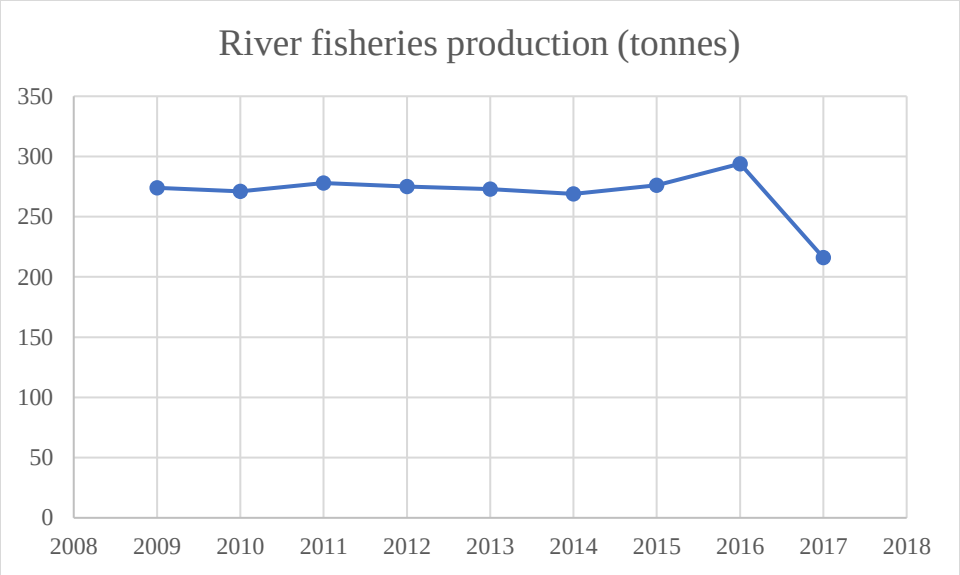


Figure11. Fisheries data from the Ministry of livestock and fisheries.

8 people out of 10 government officials interviewed (80% of all respondents) reported on the irrigation and other environmental degradation activities like deforestation and cultivating near rivers to contribute in the fishing reduction in the rivers. Livestock also had been reported to be of blame in the reduction of the catch as many herdsmen tended to graze their animals within the water sources and rivers which then caused habitats destruction and the destruction of the habitats caused the reduction in the number and types of the habitats and refugia for the fishes and food for the fishes hence reduced in the catches of the rivers.

Statistical data showed, there is significant correlation between the flow and the aquatic ecosystem with the significance level of 0.01 as presented in Table 4 below. This statistical relationship shows that as the rainfall increased the aquatic ecosystem gets better, and as the rainfall decrease the aquatic ecosystem got worse. This it can be due to the reason that, as the rainfall increased the flow of water increased in the river which allows the connections throughout the river and increases the number of refugia and habitats for fish. Also increase in the flow facilitates the nutrients loads and fish food, it is also facilitating the growth of riparian vegetation which is used as the breeding sites and habitats for fishes. The relationship above in table 4 is related to the correlation represented in table 6 below. This statistical relationship is in line with the primary data collected from various sources and explained above with 89% agreed on the decreased flow with 75% respondents agreed

on the decrease in the fish catch in the sub catchment with various reasons one being the change of the flow, drying up of rivers and change of the rivers and land use change.

Table 5. Correlation between aquatic ecosystem and the flows

**Correlations**

| Control Variables | | | RAIN FALL PERIOD 1 | RAINFALL PERIOD 2 | RAIN FALL PERIOD 1 | RAINFALL PERIOD 2 | RAIN FALL PERIOD 1 |
|---|---|---|---|---|---|---|---|
| | | Correlation | 1.000 | . | . | . | . |
| | RAIN FALL PERIOD 1 | Significance (2-tailed) | . | . | . | . | . |
| | | df | 0 | 0 | 0 | 0 | 0 |
| | | Correlation | . | 1.000 | . | . | . |
| | RAINFALL PERIOD 2 | Significance (2-tailed) | . | . | . | . | . |
| | | df | 0 | 0 | 0 | 0 | 0 |
| FISH CATCH | | Correlation | . | . | 1.000 | . | . |
| PERIOD 1 & FISH | RAIN FALL PERIOD 1 | Significance (2-tailed) | . | . | . | . | . |
| CATCH PERIOD 2 | | df | 0 | 0 | 0 | 0 | 0 |
| | | Correlation | . | . | . | 1.000 | . |
| | RAINFALL PERIOD 2 | Significance (2-tailed) | . | . | . | . | . |
| | | df | 0 | 0 | 0 | 0 | 0 |
| | | Correlation | . | . | . | . | 1.000 |
| | RAIN FLOW PERIOD 1 | Significance (2-tailed) | . | . | . | . | . |
| | | df | 0 | 0 | 0 | 0 | 0 |

### 4.3 Climate change effects and variability on the environmental flow and the degraded ecosystems

All the respondents were asked if they are aware of the climate change and variability. 91% responded that they are aware while 9% said they were not aware, so with the percentage it seemed the respondent were aware of the climate change and variability. Respondents explained it in different ways on their natures of the categories, most of the interviewers explained training as their source of information while other categories they had mixed answers on how they were aware of the climate change and variability. As to what extent respondents are aware on the climate change and variability the answers were 56% medium, 32% being high while 12% have low awareness on the climate change. On how the respondents got information about climate change, 54% of the respondents got the information from the formal studies and trainings, 27% from media and through informal studies while 19% got it through using local perceptions on the climate change and variability identification.

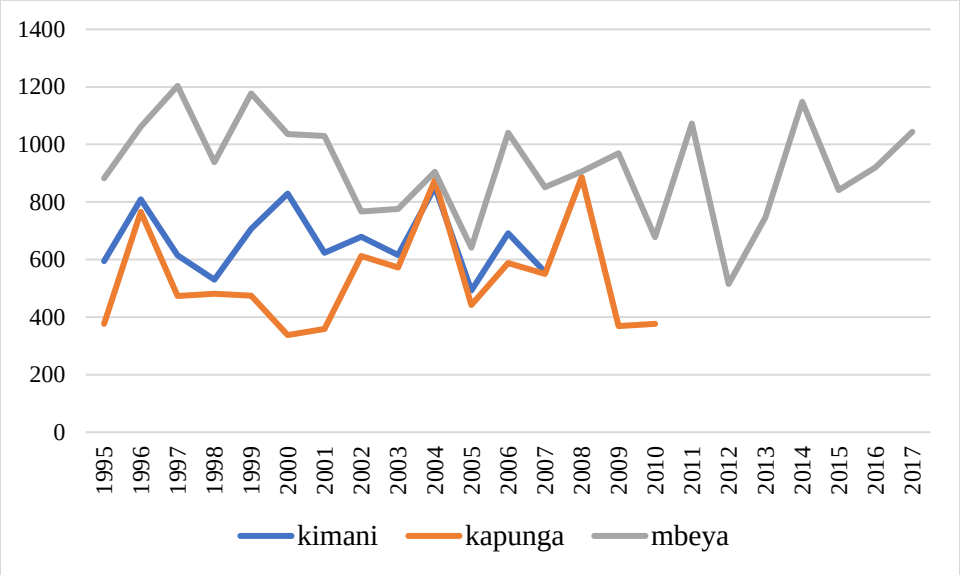


Figure12. Rainfall trends in the sub-catchment (1995-2017)

Table 6. Rainfall statistics in the sub-catchment

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | | Std. Deviation |
|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| kimani station | 13 | 492.50 | 852.30 | 661.2769 | 31.69747 | 114.28687 |
| kapunga station | 16 | 337.60 | 886.40 | 533.8750 | 44.23310 | 176.93238 |
| mbeya station | 23 | 515.10 | 1203.30 | 919.6217 | 36.85169 | 176.73449 |
| Valid N (listwise) | 13 | | | | | |

The data showed there is no much difference in the rainfall amount from 1995 to 2017,2010 and 2017 in upper, lower and middle Mkoji respectively (Fig.11 and Table 6). The data showed also the decrease in the rainfall in 2005 with rainfall amount of below 500mm in both middle and lower zones of sub catchment. But it was discussed and reported during the interviews and FGD that there are seasonal and spatial rainfall change with early starting of the rains compared to previous years and early stops of the rains compared to previous years. It was also reported that there is change in the duration of the rainfall, it rained in high intensity but in short period but in some other years it can take a long time to rain but with low intensity. Change of these rainfall patterns

reported to be also among the reason for some of the birds to leave the area and migrate to other areas. During the FGDs and interviews conducted the respondents reported that there were shifting of the birds from the area during the dry periods especially those which ate the fishes from the sub catchment to other areas. This is due to the decline in some of the streams and drying up of the some of the rivers during the dry season. This change also reported to be the reason in the disappearance of some of the riparian vegetation in dry years that required storm water for them to survive rather than the normal flow of the river.

Reviewed data on climate and hydrological data included the evaporation data in the area. Evaporation rate varied considerably within the sub-catchment, the higher the altitude the lower the rate of evaporation, which means that the rate of evaporation is higher at Lower Mkoji which is situated at plains compared to the upper Mkoji which is subjected to higher altitudes. Results from reviews showed that evaporation rate using the evaporation pan method were the pan evaporation is 2430 mm/year at Igurusi which represented the middle zone and decreased to 1890 mm/year in Mbeya, which represented the upper zone of sub-catchment. The yearly variation was small and steady (variation coefficient of 7% at Igurusi). The lowest evaporation was experienced in February (during the wet season) and increased during the dry season (from August to December), reaching the maximum in October/November.

Climate change effects on water resources was reported to be the main reason for the increase in water demand for the irrigation activities, Farmers said that recent years they need large amount of water to irrigate their crops compared to the previous years.

The data also showed there is significant correlation between the flow of the water in the rivers and the rainfall in the area with the correlation of one as illustrated in table 7 below. Though the climatic data showed no much difference in the change of the rainfall (decrease) but as it was reported in various focus group discussions conducted and reported above that there is shifts in the patterns which is likely to say the rains starts early and finished early different from previous years.

This relationship shows the higher the rainfall the higher the flow in the rivers and the low the rainfall the lower the flow, but it can also be the longer the rainy season the shorter the season of lower flows in the rivers and the shorter the rainy season the longer the lower flows period. Rain influences the storm flow and increases the flow in the rivers, even abstractions and diversions have no effects on the flows during this season of the year.

Table 7. Statistical Relationship between the flow and the rainfall in the area.

**Correlations**

| Control Variables | | | FLOW BETWEEN 1960 2014 | FLOW BETWEEN 2015 2017 |
|---|---|---|---|---|
| RAIN FALL PERIOD 1 & RAINFALL PERIOD 2 & RAIN FALL PERIOD 1 & RAINFALL PERIOD 2 & RAIN FALL PERIOD 1 | FLOW BETWEEN 1960 2014 | Correlation | 1.000 | . |
| | | Significance (1-tailed) | . | . |
| | | df | 0 | 0 |
| | FLOW BETWEEN 2015 2017 | Correlation | . | 1.000 |
| | | Significance (1-tailed) | . | . |
| | | df | 0 | 0 |

### 4.4 The role of WUAs in influencing climate change mitigations strategies for the restoration and management of water and biodiversity

In climate change and WUAs different answers were reported. Some of the WUAs acknowledged that training opportunities regarding climate change and variability issues were given in their areas while others had not. Water user associations agreed on climate change mitigating in their areas by the knowledge provided or by their own knowledge from school or from the media. For climate change mitigation, water user associations engaged themselves in planting trees near the water resources and along the river banks and deforested areas in collaboration with Tanzania Forest Service Agency (TFS), afforestation and reforestation were their strategy in mitigating climate change. Through afforestation and reforestation, they tended to reduce the rate of evaporation from water resource to reduce the drying up of the water source by creating shades from the planted trees to the springs and the water sources and to increase water holding capacity of the land to ensure the availability of the groundwater which is also part of the environmental flow and ecosystem. They reported that, trees leaves created the shades and prevented the direct sunlight toward the water surface then reduced evaporation rates on those water sources and springs. Trees also are good carbon absorbers and reduced the amount of carbon present in the atmosphere which accelerated climate change and variability. Moreover, all the WUAs during their FGD reported that the trees that are planted are water friendly trees so that they did not affect the water sources. Officials from environmental and forest department also reported that there were actions by the ministry of agriculture and livestock under agriculture section to take into consideration the trees which are both climate resilient and of commercial importance by the WUAs in their activities. This is to make sure there were efficient use of the water resources to all water users in the sub

catchment. WUA reported on the awareness they have on the contributions of trees leaves in increasing humus content in soil and reducing the problem of infertile and unsuitable soil for cultivation which had been affected by soil erosion that influenced people to cultivate in the river valleys, which in turns degraded the environment and ecosystem as the whole. WUAs also reported to be engaged in the climate change and variability awareness rising to the community through village meetings held by village governments to make communities more aware on the change of the weather and their economic activities.

Crop rotation and changes were reported as among the strategies that WUA suggested to the farmers about climate change and variability in the area. They reported that, suggesting the crops that use little amount of water and those which take a short time to mature are their ways to use water efficiently in Mkoji area, which is considered dry in the dry season (water is not enough at all to sustain all the farmers). Farmers also agreed on receiving the service from WUAs, 77.08% of the respondents who were not from the WUAs agreed that they have received information and education from WUAs regarding water availability and suitable seeds for cultivation. Water rationing with the crop change and change make it possible for farmers to harvest even during the dry season despite of the shortage of water which cause the decline in the production. Farmers indicated that planting drought-resistant such as millet and sorghum and early maturing varieties such as beans were important strategies during drought years as a measure of reducing risks while maximising returns while intercropping used by maize and beans. Farmers said also change of the crops and crop rotation increase in the humus into the soil which increase in the production of the farms. WUA reported during the FGD that they gained all these through trainings and workshops that were given by the basin through extension workers to give them knowledge as water management stakeholders so that they can manage water efficiently to the irrigators. Not only the basin but also NGOs reported to be involved in awareness rising activities to the WUAs. During the Focus Group Discussions with Upper Mkoji association it was reported that they had the project with AWF and they were responsible in rising awareness of WUA and afforestation and reforestation program in the springs to restore the water flow in the sub catchment as it is located in the upstream where most of the water sources are originates from Poroto mountains.

WUAs reported that the use of climate information from the basin climate data and hydrological data in water rotation and water allocation for the irrigation made it possible for them to manage

the allocation of water to the irrigation schemes while managing the environmental flow within the rivers and without harming the water sources. They also reported that the data are useful for forecasting the agricultural season so that they can advise farmers on the situation and how water can be allocated in all schemes in the area and how they can be rationed within the season so that it will not affect the production due to the variability of either duration or amount of the rainfall to reduce the effects through the use of sustainable practices to subsidize the climate influences on land degradation. The data also helped the associations on the management of resources through advising the farmers on the reduction of the land size to cultivate depending on the water available so that water can at least to cope with the resource available on the particular time. Reducing the cultivating land size reduced the amount of water to be used for irrigation and hence associations and irrigation committee they had been helped out with this method to make sure atleast there is equity in water resource utilization.

Incorporating of the local knowledge on the rain information through the use of vegetation and animals and the climate, hydrological data are also used by the WUAs as reported by the farmers and other categories. This local information they were reported to be useful in knowing or forecasting the seasons climatic conditions through them. It was reported that the use of blooming of some trees at certain time indicate something while shifting of certain species of the birds from one area to another is another indication of the climate and reported to be used in the climate change and variability mitigations to reduce the effects on the biodiversity and environmental flow whilst ensuring food security to the people.

# CHAPTER 5

# 5.0 CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

This study aimed at finding the role of the water user association on the restoration of the decreased environmental flow and degraded aquatic ecosystems in Mkoji sub catchment of Rufiji basin of Tanzania using qualitative and quantitative approach method. Results showed that, water user association are useful resource in the restoration of the decreased flow and management of the water resources in general also they are responsible for restoration and management of the environment around the water sources and environment in general. They are using various of strategies in the restoration and management of water resource depending on the water resources management act and environmental management act rather their work showed not that much product as there is still water shortage, competition among the users which contributed in the various conflicts within sub catchment and the drying up of some of the rivers being the persistent problem while exhaustion of the aquatic ecosystem is still there and cut off the connection between still troubling them. Other challenges like shortage of the funds and un capabilities of relocation of the lost river directions from where they were flowing originally. And the statistical data showed correlation between the flow and the fish catch but there is no correlation between the flow and the rainfall. Non-correlational can be due to the direct cause of the climate to the flow of the rivers in the sub catchment.

Water user associations is one among the IWRM principle in Tanzania in the management of the water resources. They encourage the public to participate in the management of the water resources and water projects in general. They help in the aliveness of the projects as it gives the ownership of the projects to the community but sometimes they are not panacea for the all problems in the water resource management and its projects. Water user associations are doing their work as a volunteer work for the sake of their own needs, uses and the environment in general for the sustainable utilization of the resource. Working as volunteers sometimes makes it hard to work properly due to the lack of resource to accomplish some of the works on management. Taking examples on Mkoji water user associations since its Mkoji apex establishment of 2008 a lot took place in the apex and its associations, but the achievements are still low. Most of the WUAs depend very much on the projects by the NGOs like that of AWF in the Upper Mkoji association on the

restoration of the water springs and planting of the trees which is actually blamed by the associations downstream to have no effect on them. As some of the factors piling up and make it hard for the association to achieve the restoration completely in the all sub-catchment. Reasons like population growth and expansion of agriculture which are uncontrolled and facilitated by unplanned land use are pulling back the water user associations regardless of their work. WUAs are operating based on the water resources management act number 11 of 2009 but each of the WUA has their own by laws to do their work. By laws differ from one association to another due to the allocation of the association villages and the water use of the association.

In many rivers of Tanzania there is no permanent volume of water to be left in the rivers for the environmental uses regardless of the environment being the second water user in the country and given the priority. The increase in the water abstractions and rivers diversions for human use increase the tension on the water resources. In Mkoji sub-catchment daily water use permits guaranteed by the basin office for the water use especially for the agriculture activities intensifies the rivers and decreases the flow to zero during the dry periods in many rivers in the sub-catchment. Many of the agricultural channels in the sub-catchment are local canals with local intakes that allow water to enter in the farms without any measurement to quantify the allowable amount according to the permit. Managing of these local canals is not easy because it is hard to measure how much water has been taken from the rivers and if they are complied with the permits. Over extraction of the allowable amounts from rivers contributes in the degradation of the aquatic ecosystems.

Water resources management in Tanzania is intersectoral considering all the stake holders from the national to the community level. All projects concerning water resources involve stakeholders from the planning phase. Tanzania is trying to achieve Sustainable Development Goals especially goal number one, no hunger to all, through increasing the agricultural production for both big scale and small holders within the country and reduce the gap while pushing development agenda. In its various policy agenda Tanzania like that of National Agricultural Policy of 2003, National Water Policy of 2002, Agriculture Strategy Development Project of 2009 and National Irrigation Strategy. All these policy documents support the efficiency use for the production and the environmental management with instructions from Environmental Management Act of 2004. The

environmental management act guides the sustainable use of all resources for the present and future generation in the country including land and water which are the primary sources for production

There is lack of infrastructures for water storage in the sub catchment which could be used during the rainy season to store water that would be used during the dry period for irrigation. Shortage of infrastructures in management of water is challenging in many developing countries. Most of the people in Mkoji sub catchment are using pots in water storage which are not enough to store water for the long-term use during the dry period for the even domestic use. (Rajabu,2007)

Cultivating in the river banks valleys is associated with the shortage of water storage structures for the use during the crisis periods which then leads the farmers looked on the wet areas to cultivate and end up cultivating in the river bank valleys so that they can plant their crops. Cultivating in the river banks and valleys contributed in the degradation of the ecosystems and reduces the quality of water in many of the rivers. It cuts the connections between the components of the environment.

## 5.2 Recommendation

***Water user associations***

Water user associations are still doing good regardless not being able to solve all the problems in water resource management. The government can still support these associations and try to solve some of the problem because there are some of the areas that succeeded in the water resource management through WUAs as the Pangani basin in Tanzania.

The government of Tanzania should consider the capacity building of the new WUAs. But also, the government should allocate some of the budget for WUAs activities for the capacity building from the ministry instead of leaving it all in the basin management. Learning from experience is a good way and the government should consider this while putting in place measures to achieve this strategy of using water user association in the management. However, that depends on the active NGOs in these basins because the associations activities depend much on these NGOs budgets and schedule while the government budget would make things clear and easier for the associations. The government, in each sub-catchment, should have a schedule for the capacity building, and the trainings should include climate change issues to ensure the sustainable utilization of water resources for both production and other activities.

WUAs claimed to be aware of the climate change and working on the issues but more knowledge and information should be given in order to cope and being resilient with the situation. Trainings would be beneficial for the efficiency water use in the sub-catchment for both downstream and upstream users.

It is advisable to involve animal keepers in the WUAs rather than marginalizing them while they are the rightful water user in the basins. Moreover, women should be encouraged to join the WUAs as they are the primary victims in the water shortage and they are the teachers of their families. Participation of all stakeholders in the management will lead to a successful approach due to the full representation in the decision-making process that considers the equity, efficiency and all needs.

***Management of water sources and reserved land from human activities***

In management of the water resource through the land strategy and management of water sources as indicated in Environment Management Act of 2004 by leaving 60m from water sources free of any human activities. This should reach all land owners in order to protect water. All the lands within 60m around the water source should be vacated according to the environmental act but this should be considered in the act and policies to achieve management of water and land in general. Erosion continues to take place and going towards the settlements, which then leads to the vacation of the land by human, but this will continue up to no end and might cause conflicts between the government and land owners. Negotiations between the government and land owners near water sources on how to use a particular land should be considered with the helps from water user associations, if its land as farms the land owners should leave at least the first 30m from the water source with absolutely no use except for the conservation and the following 30m can be used for the human activities while applying the conservation measures. This can be taken example from Pangani basin where the agricultural activities after the 30m from the water sources are used for conservation agriculture under the supervision of agriculturalist association called UWAMAKIZI to make sure the activities in the areas are conservative and they are not against the environmental management, same to the settlement areas rather than chasing them out of the areas within 60m from the water sources. This can help reduce conflicts between the government and the land owners, but also the government policy and this act should specifically give out the specification of the size of these water sources instead of collective word water source. The act should be more specific on the size of the water source if it's from the channels, streams to big rivers and ponds, wells to

The use of pay for ecosystem services can be a useful mean to these associations in implementing the management and especially the restoration actions in the degraded areas to motivate them on what they are doing rather than letting them be a toothless organ. Increasing water permits while the resources are still the same with the same degraded condition will deteriorate the situation. Therefore, more care should be taken when granting the permits to the water users and WUAs should have the power to make sure that only the allowable amounts are extracted from the rivers. Granting of water permits that exceeds the renewable water resources will exhaust the environment and make the aquatic flora and fauna vulnerable to the environmental factor changes especially in the dry season.

***Land use planning***

The sub-catchment lacks good land use planning, which it is a crucial matter in the management. Land use planning like grazing areas and agricultural activities will eliminate the conflicts between farmers and animal keepers. Failure in the land use planning will increase water user conflicts especially in the areas where there are farmers and animal keepers. Land use planning also reduces the conflicts between upstream and downstream users in the sub catchment as the water would be planned according to the uses and the needs of each user. Proper land use planning would reduce the building of the houses on the river channels and blocking of the water ways which will reduce the flow downstream and cause conflicts and water shortage for the downstream users.

Aquaculture can be used as means to increase the source of protein from fish instead of using illegal fishing in the sub catchment. There is still opportunity to use aquaculture especially for the species which are tolerant to the low amounts of water so that community will have a source of protein without extensive degradation of the ecosystem. Taking the example of the Mbarali district where five associations were found, the whole district up to last year had only 348 fish ponds and this shows opportunity to use fish culture to supply population needs rather than the natural rivers.

***Environmental flows***

The government should consider measure and put the environmental flows for all the rivers in each basin and sub-catchment starting with the most congested basins and that needs environmental attention so that environmental degradation can be reduces in the sub catchments of Tanzania and the already degraded areas can be restored easily. Knowing the Environmental flows can accelerate the management of the water resources and the ecosystem in general, especially during this era of climate change when most of the rivers faces the problem of decline in the flows due to climate change and variability while other sub catchments undergo the problem of floods. Being sure of how much is needed for the use and ecosystem for both wet and dry season to make sure the flow is enough for human needs and environment with the needed quality at a needed time for both intensified and non-intensified basins. Research and other engineering activities would be performed in the Mkoji sub catchment to research on the potentiality of the rivers to be dredge so that to allow the flow of water in the channel, also research on the channelling of the rivers so that the lost rivers would flow again in their respective channels after being lost for years.

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APPENDECIES FOR MY THESIS

QUESTIONNAIRE

This questionnaire is for master thesis research on the restoration of the decreased environmental flow in Mkoji sub catchment. The information shared will be back to the community and office but the privacy of the people who answer this questionnaire is confidential;

SECTION A: PERSONAL PARTICULARS

2. Age:……

3. Sex:……

4.Education:……..(primary/secondary/advanced/higher education)

5. District:……..

6.Occupation:……

SECTION B: Put the tick in the respective number of choice

| Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| View | Strongly agree | Agree | Not sure | Disagree | Strongly disagree |

1. Water user associations are performing good in your area

2. There is a decrease in the river flow from up stream

3. Farmers are using artificial fertilizers and discharge water from farms to the river

4. P reparation of farms for cultivation cause deforestation

5. Cattles are the source of decreasing the flow.

6. Some of the vegetation nowadays are not found near the river

7.There is a decrease in the fishing

8.There are some areas experiencing soil erosion

9. Associations are aware of the climate change

10. Associations have the mitigations and adaptations plans concerning climate change on the restoration and management of the river water

11. Associations participate in conflict management

SECTION C: Open ended question; fill in the blanks

1. Is there any change in the river flow now from that of the previous years? Comment
   ……
   ……
   ……
2. What are the change? Increased or decreased?
   ……
   ……
   ……
   .
3. Does the introduction of SAGCOT (Southern Agriculture Corridor of Tanzania) resulted in any effects on the natural vegetation? What are they?
   ……
   ……
   ……
4. Are there any management measures taking place in the valley? How?
   ……
   ……
   ……
5. Is the community involved in the management? YES/NO Explain……
   ……
   ……
   ……
6. Which groups are involved in management?
   ……
   ……
   ……
7. What are the roles of water user association in the management?
   ……
   ……
   ……
8. Are the agricultural activities associated with the change in the river flow? Why do you think so?

……
……
……

9. Is there any reduction in water quality of the river (turbidity)?
……
……
……

10. Are there any tributaries that were contributing to the river which are dried now?
……
…….
……
……

11. Is the size of the natural forest and wetland increased or decreased? Why?
……
……
……

12. What was the roles played by the water user associations on the situation?
……
……
……

13. Is there any water user conflict during water shortage?
……
…….
……
…….

14. Is there erosion in the river banks and loss of the aquatic vegetation?
……
……
……..

15. Are the endemic species of the birds still present? How about the distribution and abundance?
……
……
……..

16. Are the fish species caught years back still in the catch nowadays? How about their abundance
……
……
……

APPENDEX 2

FOCUS GROUP DISCUSSION

AGENDA

1. How the management of the watershed practiced earlier

2. How it is practiced now (water user association approaches in management)

3. Is there any change in the management system?

4. Management participation by the water user association has any positive impact in the management

5. Community knowledge in the management on water resources for the ecosystems purposes has any implication on environmental flow restoration

6. Differences in the approaches in the management

7. Challenges of the management through water user associations

APPENDEX 3

INTERVIEW GUIDE

1. What is your current position?

……..……..

2. How many years in the running office?

……

3. What does the agriculture policy say regarding the agricultural activities in the basin?

……..…

4. What does the policy of environmental management and natural resources say about the activities

……

5. What are the management strategies?

……

6. Is the community part of the management?

……..

7. How are they involved in the management?

……

8. Are there any signs of climate change or variability effects on the flows?

……..

9.What about river water flow before the water user associations activities?

…….

b. And what about the flow now? Any dried tributaries and small channels?

……..……..

10. What about water quality before the expansion of the activities?

……

b. And what about water quality now?

……

11. Are there any plans for restoring the degraded ecosystem?

……

12. Is there any knowledge given about climate change to the community?

.....……..

Explain

……

13. Are here any resiliency strategies given to the association?

……

16. Are there any resiliency measures taken by the basin board that are practiced by the communities?

……
……..……

17.What about the fishing during decreased environmental flow?

……..……
……..

b. And what about that now?

……
……. ……..

APPENDEX 4

TIME PLAN TASKS TO BE PERFORMED DATES TO

| **STARTING DATES** | **ENDING DATES** | **ACTIVITIES** | **PERSON IN CHARGE** |
|---|---|---|---|
| November /2017 | December/2017 | Proposal writing | Researcher |
| December/2017 | January/2018 | Proposal submission | Researcher |
| January/2018 | February/2018 | Proposal evaluation | PAUWES |
| March/2018 | April/2018 | Data collection | Researcher/Assistant |
| May/2018 | May/2018 | Data analysis | Researcher |
| June/2018 | July/2018 | Thesis writing | Researcher |
| July/2018 | 31/July/2018 | Thesis submission | Researcher |
| September/2018 | September/2018 | Thesis defence | Researcher |

Template

**MBEYA MONTHLY TOTAL RAINFALL (mm)**

| **YEAR** | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1995** | 247.3 | 223.4 | 224.3 | 59.6 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 20.3 | 106.6 |
| **1996** | 254.4 | 200.0 | 147.3 | 156.9 | 9.4 | 0.0 | 0.0 | 0.0 | 0.1 | 22.4 | 35.6 | 235.9 |
| **1997** | 137.2 | 190.4 | 41.0 | 192.1 | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 22.7 | 246.1 | 372.4 |
| **1998** | 190.7 | 351.8 | 124.3 | 160.7 | 8.8 | 0.0 | 0.0 | 0.0 | 0.0 | 16.5 | 8.6 | 76.6 |
| **1999** | 331.2 | 124.6 | 329.7 | 169.7 | 52.6 | 2.5 | 0.0 | 4.9 | 2.1 | 3.1 | 12.2 | 144.7 |
| **2000** | 150.9 | 179.6 | 215.5 | 66.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.9 | 154.4 | 252.6 |
| **2001** | 451.3 | 106.5 | 103.0 | 95.6 | 24.1 | 0.0 | 0.0 | 0.0 | 8.6 | 32.6 | 33.3 | 174.5 |
| **2002** | 191.5 | 182.7 | 152.0 | 61.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 3.2 | 21.4 | 153.9 |
| **2003** | 247.7 | 111.2 | 167.0 | 43.5 | 0.0 | 0.0 | 3.4 | 0.0 | 0.0 | 16.6 | 24.2 | 162.3 |
| **2004** | 175.5 | 144.0 | 110.0 | 134.3 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 7.4 | 38.5 | 286.9 |
| **2005** | 163.9 | 127.8 | 132.6 | 54.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 47.1 | 112.9 |
| **2006** | 199.4 | 94.6 | 114.0 | 160.7 | 60.5 | 0.0 | 0.0 | 0.0 | 0.0 | 17.8 | 74.1 | 319.6 |
| **2007** | 240.2 | 140.5 | 141.6 | 70.1 | 12.2 | 8.0 | 0.0 | 0.8 | 0.0 | 17.7 | 11.0 | 209.1 |
| **2008** | 197.7 | 187.0 | 169.0 | 76.7 | 25.2 | 0.0 | 0.0 | 0.0 | 0.0 | 8.2 | 74.3 | 167.4 |
| **2009** | 242.2 | 187.7 | 229.9 | 25.8 | 10.7 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 105.4 | 160.7 |
| **2010** | 151.1 | 123.9 | 239.1 | 37.8 | 14.7 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.6 | 93.1 |
| **2011** | 134.6 | 167.4 | 167.4 | 118.3 | 9.0 | 0.0 | 0.0 | 0.0 | 14.5 | 43.1 | 62.3 | 356.3 |
| **2012** | 149.9 | 153.0 | 105.7 | 24.4 | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 | 24.4 | 38.2 | m |
| **2013** | 124.5 | 159.2 | 144.1 | 53.2 | 72.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.0 | 159.6 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2014** | 258.3 | 363.9 | 135.8 | 127.1 | 5.3 | 0.0 | 0.0 | 0.0 | 0.0 | 26.0 | 51.6 | 180.3 |
| **2015** | 215.8 | 127.3 | 97.8 | 94.2 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 32.2 | 126.1 | 145.6 |
| **2016** | 355.4 | 146.0 | 138.8 | 160.7 | 20.5 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 43.3 | 52.6 |
| **2017** | 200.9 | 217.3 | 130.8 | 106.2 | 13.1 | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 132.5 | 236.6 |

**MBEYA MONTHLY MEAN MAXIMUM TEMPERATURE (°C)**

| **YEAR** | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1995** | 23.7 | 23.1 | 24.0 | 23.3 | 23.7 | 22.5 | 22.3 | 23.9 | 25.7 | 27.6 | 27.7 | 24.9 |
| **1996** | 23.6 | m | M | m | m | m | 22.3 | 24.4 | m | 27.5 | 27.3 | 24.4 |
| **1997** | 24.5 | 23.2 | 24.3 | 23.3 | 23.1 | m | m | m | m | m | m | m |
| **1998** | m | m | M | m | m | 22.4 | 22.5 | 23.0 | 25.8 | 27.0 | 27.0 | 26.9 |
| **1999** | m | 24.9 | 22.9 | 22.4 | 22.2 | 21.2 | 20.6 | 22.5 | 24.8 | 25.8 | 25.9 | 25.2 |
| **2000** | 24.0 | 23.9 | 23.3 | 23.6 | 23.1 | 21.8 | 21.4 | 22.8 | 25.5 | 27.1 | 24.7 | 23.5 |
| **2001** | 22.2 | 23.6 | 24.2 | 23.5 | 22.3 | 21.6 | 21.8 | 23.9 | 26.2 | m | 27.1 | 25.3 |
| **2002** | 22.8 | 24.0 | 23.9 | 23.4 | 23.2 | 21.7 | 23.6 | 23.1 | 25.4 | 27.3 | 26.3 | 24.9 |
| **2003** | 23.9 | 25.1 | 25.1 | 23.6 | 23.6 | 21.8 | 21.7 | 24.0 | 25.3 | 27.4 | 27.5 | 25.3 |
| **2004** | 24.6 | 23.9 | 24.1 | 22.8 | 22.6 | 21.5 | 22.4 | 24.4 | 25.2 | 26.7 | 27.1 | 23.9 |
| **2005** | 23.9 | 25.6 | 24.4 | 23.7 | 23.5 | 23.0 | 22.2 | 24.1 | 25.5 | 27.1 | 27.2 | 26.7 |
| **2006** | 24.8 | 24.6 | 23.7 | 23.0 | 22.6 | 21.5 | 21.7 | 24.5 | 25.0 | 27.7 | 25.9 | 23.1 |
| **2007** | 23.6 | 24.1 | 24.5 | 24.1 | 22.9 | 22.3 | 22.3 | 23.7 | 26.2 | 27.0 | 27.3 | 24.4 |
| **2008** | 23.3 | 23.3 | 23.5 | 22.4 | 22.6 | 21.2 | 21.8 | 23.8 | 26.4 | 27.3 | 26.6 | 23.9 |
| **2009** | 24.4 | 23.5 | 24.2 | 23.3 | 23.8 | 23.6 | 21.9 | 23.8 | 26.8 | 27.8 | 25.8 | 25.0 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2010** | 24.6 | 24.2 | 24.7 | 24.5 | 23.8 | 22.3 | 22.0 | 23.4 | 25.6 | 28.1 | 27.9 | 25.2 |
| **2011** | 24.5 | 24.2 | 24.2 | 23.6 | 23.4 | 23.7 | 23.1 | 24.4 | 25.8 | 27.3 | 26.9 | 24.7 |
| **2012** | 24.4 | 25.4 | 24.7 | 23.6 | 23.6 | 23.2 | 23.2 | 25.3 | 27.0 | 28.2 | 26.7 | 26.1 |
| **2013** | 25.0 | 25.4 | 24.9 | 24.1 | 23.0 | 22.4 | 22.7 | 23.9 | 27.1 | 27.7 | m | 25.3 |
| **2014** | 23.8 | 23.8 | 24.6 | 23.6 | 23.2 | 27.0 | 23.1 | m | 25.4 | m | 27.5 | 25.4 |
| **2015** | 24.7 | m | M | 23.5 | 23.2 | 23.4 | 23.7 | 25.0 | 26.5 | 27.5 | 26.5 | 25.1 |
| **2016** | 24.4 | 25.6 | 26.0 | 23.6 | 22.5 | 22.1 | 22.1 | 23.8 | 26.0 | 28.1 | 28.0 | 26.1 |
| **2017** | 24.6 | 25.3 | 24.2 | 23.9 | 22.8 | 22.6 | 22.9 | 24.1 | 26.5 | 29.0 | 26.7 | m |

**MBEYA MONTHLY MEAN MINIMUM TEMPERATURE (°C)**

| **YEAR** | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1995** | 15.0 | 14.6 | 14.5 | 12.5 | m | 5.3 | 5.8 | 7.8 | 9.7 | 12.5 | 13.9 | 15.0 |
| **1996** | 14.7 | 14.8 | 13.9 | 12.7 | 10.2 | 6.1 | 4.5 | 4.7 | 9.3 | 12.7 | 14.6 | 14.7 |
| **1997** | 14.4 | 14.6 | 13.5 | 12.6 | 9.0 | m | m | m | m | m | m | m |
| **1998** | m | 16.2 | 14.9 | 14.0 | 9.0 | 5.1 | 5.7 | 8.2 | 11.1 | 11.1 | 14.3 | 14.3 |
| **1999** | m | 14.0 | 14.3 | 12.3 | 9.3 | 7.1 | 6.8 | 9.6 | 11.6 | 11.2 | 14.3 | 13.6 |
| **2000** | 14.3 | 14.2 | 14.5 | 12.2 | 9.0 | 7.3 | 6.8 | 8.4 | 10.1 | 13.8 | 15.2 | 15.1 |
| **2001** | 14.9 | 15.0 | 14.0 | 12.2 | 10.9 | 7.2 | 7.5 | 8.0 | 10.1 | m | 14.1 | 14.9 |
| **2002** | 14.9 | 15.1 | 14.7 | 13.6 | 9.1 | 7.2 | 6.9 | 8.8 | 11.6 | 13.4 | 14.1 | 14.8 |
| **2003** | 15.0 | 14.1 | 14.5 | 12.5 | 10.0 | 7.7 | 7.1 | 6.4 | 11.7 | 13.3 | 14.9 | 14.8 |
| **2004** | 14.9 | 14.7 | 14.5 | 13.1 | 8.1 | 6.3 | 5.6 | 7.0 | 11.3 | 14.0 | 14.8 | 15.0 |
| **2005** | 14.6 | 14.6 | 14.8 | 12.9 | 9.0 | 7.5 | 5.8 | 6.9 | 10.8 | 13.4 | 14.9 | 14.5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2006** | 14.9 | 14.4 | 14.1 | 12.8 | 11.2 | 6.9 | 5.9 | 7.5 | 10.4 | 13.4 | 14.6 | 14.6 |
| **2007** | 14.9 | 15.0 | 13.4 | 12.0 | 11.1 | 7.5 | 7.5 | 7.1 | 10.6 | 12.9 | 13.5 | 14.3 |
| **2008** | 14.5 | 13.5 | 13.6 | 11.7 | 9.5 | 6.6 | 6.2 | 8.5 | 9.7 | 12.7 | 15.2 | 14.7 |
| **2009** | 14.0 | 14.2 | 13.6 | 12.3 | 9.4 | 7.0 | 6.7 | 8.2 | 9.7 | 13.5 | 14.7 | 14.8 |
| **2010** | 15.1 | 15.6 | 15.2 | 13.0 | 11.1 | 8.1 | 7.8 | 6.5 | 9.4 | 12.2 | 14.2 | 13.9 |
| **2011** | 13.7 | 14.3 | 13.7 | 12.9 | 11.0 | 7.2 | 5.6 | 7.0 | 10.0 | 13.5 | 13.9 | 14.1 |
| **2012** | 14.7 | 13.4 | 15.1 | 12.6 | 9.6 | 7.1 | 5.0 | 7.8 | 11.2 | 14.3 | 14.9 | 15.1 |
| **2013** | 15.9 | 15.0 | 14.3 | 13.0 | 10.1 | 4.2 | 4.8 | 7.6 | 10.5 | 13.5 | m | 14.1 |
| **2014** | 14.0 | 13.9 | 13.3 | 13.3 | 9.5 | 15.1 | 6.7 | m | 10.4 | m | 14.6 | 14.8 |
| **2015** | 14.8 | 14.5 | 14.4 | 13.4 | 10.6 | 7.3 | 6.3 | 7.2 | 11.6 | 14.6 | 14.6 | 15.0 |
| **2016** | 15.6 | 15.1 | 15.5 | 13.9 | 9.2 | 7.3 | 6.6 | 8.4 | 9.0 | 12.9 | 14.7 | 15.3 |
| **2017** | 15.4 | 15.3 | 14.0 | 13.2 | 10.7 | 8.1 | 6.7 | 9.9 | 8.3 | 13.8 | 14.1 | m |

**KAPUNGA MONTHLY TOTAL RAINFALL (mm)**

| **YEAR** | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1995** | 91.6 | 69.7 | 136.1 | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 75.2 |
| **1996** | 127.0 | 292.9 | 235.4 | 53.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 57.6 |
| **1997** | 84.6 | 76.3 | 38.9 | 26.1 | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 40.1 | 202.3 |
| **1998** | 168.8 | 152.7 | 99.7 | 47.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.5 |
| **1999** | 169.5 | 81.0 | 139.1 | 69.7 | 5.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 | 4.8 |
| **2000** | 61.6 | 49.4 | 54.0 | 11.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.0 | 148.2 |
| **2001** | 100.7 | 23.6 | 67.6 | 12.3 | 5.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 148.3 |
| **2002** | 191.6 | 168.5 | 110.0 | 23.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 116.8 |
| **2003** | 168.9 | 64.1 | 104.0 | 54.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 62.1 | 118.3 |
| **2004** | 139.1 | 167.2 | 153.6 | 80.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.5 | 319.1 |
| **2005** | 134.7 | 56.7 | 180.5 | 36.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.6 | 18.2 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2006** | 119.2 | m | 152.6 | 15.6 | 16.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 85.6 | 198.0 |
| **2007** | 127.9 | 80.6 | 108.2 | 22.6 | 8.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 202.5 |
| **2008** | 185.0 | 279.4 | 165.4 | 10.0 | 11.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 63.1 | 170.2 |
| **2009** | 62.0 | m | 87.5 | 74.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | m | 145.0 |
| **2010** | 117.8 | 188.7 | 42.3 | 7.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.0 | m |

**KIMANI MONTHLY TOTAL RAINFALL (mm)**

| **YEAR** | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1995** | 90.8 | 185.6 | 154.5 | 19.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 143.9 |
| **1996** | 261.1 | 68.8 | 167.1 | 187.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 125.2 |
| **1997** | m | 102.1 | 46.4 | 59.9 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 13.1 | 95.9 | 296.3 |
| **1998** | m | 214.4 | 164.4 | 87.1 | 14.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 31.8 | 17.8 |
| **1999** | 98.0 | 114.0 | 295.9 | 90.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 7.8 | 100.5 |
| **2000** | 96.8 | 56.7 | 112.6 | 41.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 116.3 | 404.8 |
| **2001** | 243.2 | 112.0 | 88.0 | 39.3 | 1.2 | 0.0 | 0.0 | 0.0 | 2.3 | 0.0 | 7.0 | 130.6 |
| **2002** | 172.6 | 190.3 | 78.9 | 26.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.9 | 196.6 |
| **2003** | 144.4 | 78.8 | 185.4 | 33.3 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 11.2 | 25.1 | 135.9 |
| **2004** | 141.2 | 123.2 | 122.6 | 62.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | m | 31.0 | 371.5 |
| **2005** | 150.0 | 77.9 | 159.1 | 14.1 | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 37.8 | 48.0 |
| **2006** | 107.0 | 96.9 | 126.1 | 34.3 | 6.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.2 | 296.7 |
| **2007** | 198.2 | 190.8 | 115.8 | 13.0 | 27.5 | 0.0 | 0.0 | 0.0 | 1.7 | 3.4 | 6.6 | m |

**Note:- m = Missing data**

Template 2

Fisheries catch data

| | | | | | | |
|---|---|---|---|---|---|---|
| **Na** | year | number of ponds | ponds catch | rivers catch | total | |
| | | | | | (T) | |
| **1** | 2009 | 263 | 135 | 274 | 409 | |
| **2** | 2010 | 269 | 142 | 271 | 433 | |
| **3** | 2011 | 271 | 1 53 | 278 | 431 | |
| **4** | 2012 | 301 | 166 | 275 | 431 | |
| **5** | 2013 | 312 | 187 | 273 | 450 | |
| **6** | 2014 | 320 | 192 | 269 | 451 | |
| **7** | 2015 | 334 | 101 | 276 | 377 | |
| **8** | 2016 | 340 | 125 | 294 | 419 | |
| **9** | 2017 | 348 | 144 | 216 | 360 | |
| | | | | | | |

Template 3

Water quality data

| LOCATION | RUFIJI BASIN WATER QUALITY MONITORING | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | Unit | Sampling points , Lab ID and Coordinates | | | | | |
| | | Mlowo river at the bridge Dist.Mbarali | Umrobo river at G st. Dist.Mbarali | Nsalaga str at Mby urb t/plant Dist.Mbeya(ur) | Mkoji river at Ilongo Dist.Mbarali | Ipatagwa at G st.1KA45C Dist.Mbeya(r | Allowable Tanzania Standard |
| Lab ID | | 65/14 | 66/14 | 67/14 | 68/14 | 69/14 | |
| Coordinates | | S08° 46´ 0.6´´ E033° 42´ 00.9´´ | S08° 49´ 11.5´´ E033° 40´ 50.7´´ | S08° 54´ 04.4´´ E033° 33´ 21.8´´ | S08° 47´ 06.5´´ E033° 42´ 34.5´´ | S08° 48´ 59.1´´ E033° 41´ 06.4´´ | |
| pH | | 6.63 | 6.63 | 5.72 | 7.59 | 6.82 | 6.5-9.2 |
| Temperature | °C | 21.3 | 21.4 | 20.9 | 20.7 | 21.1 | N.M |
| Dissolved Oxygen | | 8.08 | 7.43 | 7.506 | 6.9 | 6.4 | 5-9.5 |
| Sediments | ml/l | 0.2 | 0.1 | < 0.1 | 0.2 | 0.1 | 0 |
| Conductivity | µs/cm | 93.9 | 98.3 | 255 | 67.3 | 72.8 | < 2000 |
| TDS | mg/l | 46.9 | 49.2 | 127.7 | 33.7 | 36.4 | 1000 |
| Colour | Pt.Co | 789 | 753 | 41 | 783 | 475 | 50 |
| Turbidity | NTU | 414 | 278 | 9.30 | 386 | 251 | 25 |
| Alkalinity | mg/l | 42 | 28 | 98 | 15 | 12 | N.M |
| Hardness | mg/l | 12 | 20 | 37 | 10 | 15 | 600 |
| Sodium | mg/l | 14.02 | 8.89 | 27.2 | 9.68 | 8.35 | 200 |
| Potassium | mg/l | 2.0 | 5.6 | 18.5 | 2.5 | 3.5 | 50 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Calcium** | **mg/l** | `3.6 | 2.4 | 3.2 | 2.4 | 4.8 | **300** |
| **Manganese** | **mg/l** | 0.329 | 0.983 | 0.106 | 0.114 | 0.884 | **0.5** |
| **Total Iron** | **mg/l** | 2.41 | 2.42 | 0.02 | 2.44 | 1.31 | **0.3** |
| **Iron(II)** | **mg/l** | 0.08 | 0.07 | 0.00 | 1.20 | 0.80 | **N.M** |
| **Magnesium** | **mg/l** | 0.72 | 3.40 | 7.04 | 0.97 | 0.72 | **N.M** |
| **Ammonia** | **mg/l** | 1.10 | 1.03 | 0.04 | 0.11 | 0.69 | **1.0** |
| **Nitrate** | **mg/l** | 4.3 | 19.47 | 10.18 | 0.442 | 9.73 | **100** |
| **Nitrite** | **mg/l** | 0.088 | 0.088 | 0.014 | 0.095 | 0.056 | **3.0** |
| **Orthophosphate** | **mg/l** | 2.04 | 2.08 | 1.45 | 2.12 | 1.48 | **6.0** |
| **Sulphate** | **mg/l** | 4 | 16 | 0 | 16 | 8 | **600** |
| **Chloride** | **mg/l** | 2.12 | 3.54 | 10.6 | 9.92 | 3.54 | **800** |
| **Fluoride** | **mg/l** | 0.0 | 0.01 | 0.43 | 0.00 | 0.0 | **8.0** |
| **Copper** | **mg/l** | 0.0 | 0.0 | 0.00 | 0.01 | 0.01 | **3.0** |
| **Chromium** | **mg/l** | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | **0.05** |
| **Aluminum** | **mg/l** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.2** |
| **Total Coliforms** | **No/100ml** | 120 | 144 | 152 | 110 | 20 | **0** |
| **Feacal Coliforms** | **No/100ml** | 280 | 295 | 320 | 235 | 56 | **0** |

| LOCATION | RUFIJI BASIN WATER QUALITY MONITORING | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | Unit | Sampling points , Lab ID and Coordinates | | | | | |
| | | Hayuya spring near TAZARA qtr<br><br>Dist.Mbeya(r) | Inyala spring at Inyala<br><br>Dist.Mbeya(r) | Uta stream at Iyawaya bridge<br><br>Dist.Mbeya(r | Mwambalizi stream at darajani Imezu<br><br>Dist.Mbeya(r) | | Allowable Tanzania Standard |
| | | 70/14 | 71/14 | 72/14 | 73/14 | | |
| Coordinates | | S08°49´36.1´´<br>E033°40´04.7´´ | S08°51´59.5´´<br>E033°38´12.8´´ | S08°51´59.5´´<br>E033°38´12.8´´ | S08°51´39.8´´<br>E033°37´35.6´´ | | |
| pH | | 6.59 | 5.21 | 6.25 | 6.38 | | 6.5-9.2 |
| Temperature | °C | 22.2 | 22.1 | 22.2 | 22.3 | | N.M |
| Dissolved Oxygen | | 8.05 | 9.54 | 9.0 | 8.7 | | 5-9.5 |
| Sediments | ml/l | < 0.1 | < 0.1 | 0.2 | < 0.1 | | 0 |
| Conductivity | µs/cm | 123.8 | 222 | 114.6 | 105.0 | | < 2000 |
| TDS | mg/l | 61.9 | 110.8 | 57.3 | 52.5 | | 1000 |
| Colour | Pt.Co | 328 | 14 | 867 | 296 | | 50 |
| Turbidity | NTU | 103 | 4.45 | 452 | 91.3 | | 25 |
| Alkalinity | mg/l | 34 | 44 | 22 | 42 | | N.M |
| Hardness | mg/l | 17 | 22 | 21 | 22 | | 600 |
| Sodium | mg/l | 20.98 | 38.26 | 13.21 | 13.67 | | 200 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Hardness** | **mg/l** | 17 | 22 | 21 | 22 | | **600** |
| **Sodium** | **mg/l** | 20.98 | 38.26 | 13.21 | 13.67 | | **200** |
| **Potassium** | **mg/l** | 0.5 | 3.0 | 4.1 | 0.4 | | **N.M** |
| **Calcium** | **mg/l** | 2.4 | 6.8 | 4.0 | 4.0 | | **N.M** |
| **Manganese** | **mg/l** | 0.644 | 0.994 | 0.884 | 0.272 | | **0.5** |
| **Total Iron** | **mg/l** | 0.99 | 0.01 | 2.86 | 0.93 | | **0.3** |
| **Iron(II)** | **mg/l** | 0.02 | 0.00 | 0.59 | 0.03 | | **N.M** |
| **Magnesium** | **mg/l** | 2.67 | 1.21 | 2.67 | 2.91 | | **N.M** |
| **Ammonia** | **mg/l** | 0.65 | 0.03 | 0.25 | 0.37 | | **1.0** |
| **Nitrate** | **mg/l** | 16.82 | 5.0 | 17.26 | 7.9 | | **100** |
| **Nitrite** | **mg/l** | 0.040 | 0.008 | 0.101 | 0.035 | | **3.0** |
| **Orthophosphate** | **mg/l** | 1.46 | 0.88 | 1.97 | 1.37 | | **6.0** |
| **Sulphate** | **mg/l** | 3 | 0 | 2 | 3 | | **600** |
| **Chloride** | **mg/l** | 10.63 | 15.59 | 9.92 | 3.57 | | **800** |
| **Fluoride** | **mg/l** | 0.01 | 0.29 | 0.02 | 0.00 | | **8.0** |
| **Copper** | **mg/l** | 0.01 | 0.02 | 0.0 | 0.0 | | **3.0** |
| **Chromium** | **mg/l** | 0.00 | 0.00 | 0.00 | 0.00 | | **0.05** |
| **Aluminum** | **mg/l** | 0.0 | 0.0 | 0.0 | 0.0 | | **0.2** |
| **Total Coliforms** | **No/100ml** | 30 | 82 | 88 | 130 | | **0** |
| **Feacal Coliforms** | **No/100ml** | 67 | 180 | 190 | 290 | | **0** |