CLIMATE VARIABILITY AND CLIMATE INFORMATION USE FOR WATER RESOURCES CONSERVATION DECISIONS: A CASE OF KILOMBERO RIVER CATCHMENT, TANZANIA

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

2018

ABSTRACT

This study assessed climate variability and the use of weather and climate information for water resources conservation decisions in the Kilombero River catchment. In addition, it assessed the extent of climate change adaptation strategies in the National Water Policy of 2002. Data were collected from 120 household respondents, three focus group and seven key informants in the three study villages. Historical rainfall and temperature data were also obtained from the Tanzania Meteorological Agency to discern climate variability in the area. The rainfall and temperature data were analysed for trends using Mann-Kendall test. Quantitative data were analysed using Statistical Package for Social Sciences while qualitative information was analysed using content analysis. Tobit regression model was used to established factors which influence use of weather and climate information. Results show inter-annual and seasonal rainfalls do not show consistence increasing or decreasing trends in Mahenge, Kilombero and Ifakara stations for the period 1986 - 2016. However, annual and intermediate (January and February) rainfalls in Mahenge showed decreasing trends significant at 0.05 α level of significance. Temperatures were increasing at Mahenge station for all seasons, but significant trends were observed in annual minimum and minimum temperatures during short rains (October, November and December) at 0.05 and 0.01 α levels of significance respectively. Weather and climate information are locally available in the area with medium use. Extension visits (β=0.079; $p<0.01$), scientific types (β=0.182; $p<0.05$), traditional methods (β=0.114; $p<0.05$) and household income (β=0.072; $p<0.05$) were the only factors which had significant and positive correlations with decisions on water resources conservation. It is concluded that climate is highly variable and there is medium use of weather and climate information. The study recommends improvements of communities' adaptive capacity emphasize factors which had significant positive correlations with decisions on water resources conservation.

DECLARATION

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

Emanuel Lorivi Moirana	15/11/2018
(MSc. Candidate)	**Date**

The above declaration is confirmed

Prof. J.J. Kashaigili	15/11/2018
(Supervisor)	**Date**

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ACKNOWLEDGEMENTS

Above all, I give glory to the Almighty God for giving me strength and endurance throughout the study period.

Several institutions and individuals have directly and indirectly contributed towards successful completion of this study. I wish to express special thanks to my employer Tanzania National Parks (TANAPA) for granting me permission to pursue higher studies at Sokoine University of Agriculture (SUA). My profound gratitude goes to Uncertainty Reduction in Models for Understanding Development Applications (UMFULA) project under Future Climate for Africa (FCFA) programme for financial support to undertake my research work.

I am very grateful to my supervisor, Prof. J.J. Kashaigili from the Department of Forest Resources Assessment and Management, SUA for his professional guidance, encouragement and constructive criticism during the course of the study. I am also grateful to my fellow MSc students and all staff at the Department of Wildlife Management, SUA for their support and encouragement during the course of the study.

Fieldwork could not have been successful without the help of Mr. Patrick Njiwa for his valuable contribution during household surveys and to farmers and village leaders who spared their precious time to respond to my questions. To them, I remain very grateful. I am indebted to the support by Rufiji Basin Water Board (RBWB), Lumemo, Nakafulu and Biro village governments.

Last but not least, since it is difficult to specifically mention each and every one who participated in this study, I hereby pay tribute to everyone who in one way or another, took part in the accomplishment of this study.

DEDICATION

This dissertation is dedicated to my parents; Lorivi Moses Moirana and Frida Moirana and my family; my wife Judith Mokil and our children David, Ethel and Ephraim. They motivated me to do well in my studies while missing my presence at home. To them, I express my heartfelt gratitude.

TABLE OF CONTENTS

ABSTRACT ii

DECLARATION iii

COPYRIGHT iv

ACKNOWLEDGEMENTS v

DEDICATION vi

TABLE OF CONTENTS vii

LIST OF TABLES x

LIST OF FIGURES xi

PLATE xii

LIST OF APPENDICES xiii

LIST OF ABBREVIATIONS AND ACRONYMS xiv

CHAPTER ONE 1

1.0 INTRODUCTION 1

1.1 Background Information 1

1.2 Problem Statement 2

1.3 Justification for the Study 3

1.4 Objectives of the Study 3

1.4.1 Overall objective 3

1.4.2 Specific objectives 3

1.5 Research Questions 4

1.6 Conceptual Framework 4

CHAPTER TWO 6

2.0 LITERATURE REVIEW 6

2.1 Overview on Climate Variability and Change.. 6

2.2 Climate Information Availability.. 7

2.3 Climate Information and Use for Water Resources Conservation.............................. 7

CHAPTER THREE 9

3.0 MATERIALS AND METHODS 9

3.1 Description of the Study Area 9

3.1.1 Location 9

3.1.2 Climate and topography... 9

3.1.3 Socio-economic activities..10

3.2 Research Design 11

3.3 Sampling Procedure and Sample Size...11

3.4 Data Collection 12

3.5 Data Analysis...13

3.5.1 Rainfall and temperature variability and trends...13

3.5.2 Availability of weather and climate information 16

3.5.3 Extent of use of weather and climate information 16

3.5.4 Qualitative data 18

3.5.5 Extent of climate change adaptation strategies...18

CHAPTER FOUR..19

4.0 RESULTS AND DISCUSSION 19

4.1 Socio-Demographic Characteristics of Respondents...19

4.2 Rainfall and Temperature Variations and Trends...20

4.2.1 Rainfall variations 20

4.2.2 Inter-annual and seasonal rainfalls trends...22

4.2.3 Temperature variations..24

4.2.4 Inter-annual and seasonal temperatures trends 25

4.2.5 Impacts of rainfall and temperature variations on water resources..........27

4.3 Weather and Climate Information in Kilombero River Catchment..........28

4.3.1 Availability of weather and climate information 28

4.3.2 Sources of weather and climate information 31

4.4 Weather and Climate Information Use for Water Conservation Decisions..........35

4.4.1 Status on use of weather and climate information in Kilombero river catchment..........35

4.4.2 Extent of use of weather and climate information in decisions to conserve water resources..........38

4.4.3 Factors affecting decisions to use weather and climate information in decisions to conserve water resources..........39

4.4.4 Measures for improving use of weather and climate information in Kilombero river catchment..........43

4.5 Climate Change Adaptation Strategies in the National Water Policy of 2002..........44

4.5.1 Policy environment for climate change adaptation and mitigation..........44

4.5.2 The analysis of climate change adaptation strategies in NAWAPO of 2002..........45

CHAPTER FIVE..........47

5.0 CONCLUSION AND RECOMMENDATIONS..........47

5.1 Conclusion..........47

5.2 Recommendations..........48

5.3 Areas for Further Research..........49

REFERENCES..........50

APPENDICES..........56

LIST OF TABLES

Table 1: The sample size for the study 12

Table 2: Details of monthly rainfall and temperatures data for Kilombero River Catchment considered for the study 12

Table 3: The respondents socio-demographic characteristics 20

Table 4: Mann-Kendall test statistic and Sen's slope estimate for inter-annual and seasonal rainfalls for the three stations 24

Table 5: Mann-Kendall Test statistic and Sen's slope estimate for inter-annual and seasonal Temperatures in Mahenge 26

Table 6: Type of weather and climate information available in study villages 30

Table 7: Relationships between sources and attributes of weather and climate information 34

Table 8: The water resources conservation decisions implemented in Kilombero River catchment 37

Table 9: Distribution of respondents based on three categories of use of weather and 39

Table 10: Tobit model estimates of intensity and factors influencing use of weather and climate information 40

Table 11: Proposed measures for greater use of weather and climate information 44

LIST OF FIGURES

Figure 1: Conceptual framework for the study 5

Figure 2: Location of Kilombero River catchment in Tanzania and study villages 10

Figure 3: Mean monthly rainfall at the three study stations in the Kilombero River catchment 21

Figure 4: Total annual rainfall at the three study stations for the period 1986-2016 in Kilombero River catchment 22

Figure 5: Annual and seasonal maximum and minimum temperatures for period 1993-2017 and 1994-2017 respectively in Mahenge 25

Figure 6: Indicators of climate variability as perceived by respondents in Kilombero River Catchment 27

Figure 7: Perceptions on impacts of climate variability on water resources 28

Figure 8: Perceptions on weather and climate information availability villagewise in Kilombero River catchment 29

Figure 9: Sources of weather and climate information in Kilombero River catchment 32

Figure 10: The extent of use of weather and climate information by respondents 38

PLATE

Plate 1: A FGD meeting conducted in Nakafulu village in Ulanga District 13

LIST OF APPENDICES

Appendix 1: Description of independent variables included in the two-limit Tobit model 56

Appendix 2: Household Survey Questionnaire 57

Appendix 3: Interview Guide for Focus Group Discussions 59

Appendix 4: Checklist for Interviews with Key Informants 60

LIST OF ABBREVIATIONS AND ACRONYMS

CARIAA	Collaborative Adaptation Research Initiative in Africa and Asia
DoE	Division of Environment
EDA	Exploratory Data Analysis
EMA	Environmental Management Act
FCFA	Future Climate for Africa
FGDs	Focus Group Discussions
GHGs	Greenhouse Gases
IPCC	International Panel on Climate Change
JF	January and February
JJAS	June, July, August and September
KGCA	Kilombero Game Controlled Area
KIIs	Key Informant Interviews
KOCD	Kilombero Organization for Community Development
m.a.s.l.	Metres above sea level
MAFC	Ministry of Agriculture, Food Security and Co-operatives
MAM	March, April and May
MLFD	Ministry of Livestock and Fisheries Development
MoW	Ministry of Water
NAWAPO	National Water Policy
NCCCS	National Climate Change Communication Strategy
NCCS	National Climate Change Strategy
NEP	National Environmental Policy
NWBs	National Water Boards

NWP	National Wildlife Policy
OND	October, November and December
RBAs	River Basin Authorities
RBWB	Rufiji Basin Water Board
SPSS	Statistics Package for Social Sciences
SUA	Sokoine University of Agriculture
TANAPA	Tanzania National Parks
TBC	Tanzania Broadcasting Corporation
TMA	Tanzania Meteorological Agency
UMFULA	Uncertainty Reduction in Models for Understanding Development Applications
UNDP	United Nations Development Project
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
VPO	Vice President Office
WCA	Wildlife Conservation Act

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Most developing countries including Tanzania have been using climate information in addressing the risks of climate variability whose impacts are manifested in many sectors including agriculture, water, energy and the environment. The rise in temperatures, rainfall changes and the rise in sea level are the main indicators of climate variability and change whose associated impacts include deterioration of water quality, a decline of agricultural productivity and the loss of biodiversity (IPCC, 2013; Kangalawe, 2017).

Climate change and variability in Tanzania is expected to lead to a rise in temperatures by 2-4°C by 2075, a decrease in rainfall of between 0-20% in the inner parts of the country, increase of rainfall by 25-50% in the North-east, South-east and Lake Victoria Basin and rise of sea level at a rate ranging from 0.1 to 0.9 meters (Paavola, 2008). According to Mvungi (2007), impacts of climate variability and change currently experienced in Tanzania include severe and recurrent droughts that often trigger power crisis; the drop of water levels in Lakes Tanganyika, Victoria, Manyara and Jipe and dramatic recession of seven kilometres of Lake Rukwa in about 50 years. The loss of 80% of the glacier on Mount Kilimanjaro since 1912 which is projected to be gone by 2025, the intrusion of sea water into fresh water in wells along the coast of Bagamoyo and the inundation of Maziwe islands in Pangani have also been reported by Mvungi (2007).

The local climate is reported to have varied and or changed in Kilombero River catchment within the Rufiji Basin. The River catchment is the largest seasonally freshwater lowland floodplain in East Africa that joins the Great Ruaha, Rufiji and Luwegu Rivers, as evidenced by an increase in temperature, unpredictable rainfall and frequent occurrence of floods and deterioration of water sources (Balama *et al.,* 2016). Since water resources are inextricably linked with climate, it is unequivocal that climate variability and change are affecting the resources massively in the area as is the case in any other areas (UNDP, 2013). The impacts of climate variability and change and the ongoing adaptations efforts in the area are of global, national and local significance. This is because the area provides water for a number of functions including domestic use, agriculture and industrial activities and it support the ecology of seasonally migrating animals in Selous-Mikumi ecosystem which host almost 75% of the world's population of wetland-dependent puku antelopes (*Kobus vardonii*) (Lyon *et al.*, 2015).

1.2 Problem Statement

The manifestation of climate variability and change in Kilombero River catchment is reported to have severe impacts on the water sector (UNDP, 2013). These climate phenomena are likely to continue to negatively impact water resources which are vital for the country's socio-economic development. URT (2012) accounted the impact of climate variability and change on water resources as decrease in water flow in rivers, change of perennial rivers to seasonal, drying up of some wetlands and environmental degradation due to pollution, over abstraction of water up stream and encroachment of water catchments. These changes have cumulatively led to, among others, water scarcity and an increase in water demand for use by households, farming purposes, pastoralism and wildlife in the area (Kangalawe, 2017).

Climate information which is useful for end users to understand the impacts of climate variability and change, social and biophysical vulnerabilities and to assist them to adapt to these changes through legislation and individual actions is professed in the area. However, despite the importance of climate information, little is known about its contribution to planning and decision making for water resources conservation. Previous studies in the same area (Balama *et al.*, 2016; Sophia and Emanuel, 2017) revealed the need for actual implementation of climate variability and change strategies at grass root level to enhance adaptive capacity at household level. However, the extent of climate changes in policies especially those relevant to the water sector which is responsible for the management of water resources has not yet been explored. The study is likely to contribute significantly to improving awareness on climate variability and improve use of weather and climate information on decisions to conserve water resources in Kilombero River catchment.

1.3 Justification for the Study

The results of this study are expected to broaden the understandings of rainfall and temperature variability and features of climate information used in decisions to conserve water resources in Kilombero River catchment. The results are also expected to be instrumental in guiding future mainstreaming of climate change issues all documents within the water sector.

1.4 Objectives of the Study

1.4.1 Overall objective

The main objective of the study was to assess climate variability and availability and use of weather and climate information in decisions on the conservation of water resources in Kilombero River catchment.

1.4.2 Specific objectives

The specific objectives of the study were:

1. To assess rainfall and temperature variability and trends in the study area.
2. To assess the availability of weather and climate information.

iii. To assess the extent of use of climate information in decisions on the conservation of water resources.

iv. To determine the extent to which climate change adaptation strategies are integrated into NAWAPO of 2002.

1.5 Research Questions

The study was guided by the following research questions:

i. How has rainfall (1986-2016) and temperature (1993-2017) been varying in the study area?

ii. What are the available weather and climate information in the study area?

iii. What decisions are made using weather and climate information in water resources conservation?

iv. How has climate change strategies been integrated into NAWAPO of 2002?

1.6 Conceptual Framework

A conceptual framework illustrated in Figure 1 was developed to serve as a guide in addressing the objectives of this study. This conceptual framework is based on the roles of climate information from various sources in the climate system which include; detecting climate variability and change, identifying social and biophysical impacts and vulnerability, and planning and making adaptation decision relevant for the conservation of biophysical resources such as water resources. The independent variables in this study were socio-demographic characteristics of the respondents and other additional variables (e.g. education level, wealth status, climate information and sources of climate information). These variables have been affecting various adaptations measures implemented by different water users in the study area. The dependent variable was the use (adoption) quotient formulated by numerous water conservation decisions implemented in the area. The two limit Tobit regression model was used to select variables which significantly distinguish users of climate information from a set of variables which were hypothesized to influence adoption behaviour (Sileshi *et al.*, 2012).

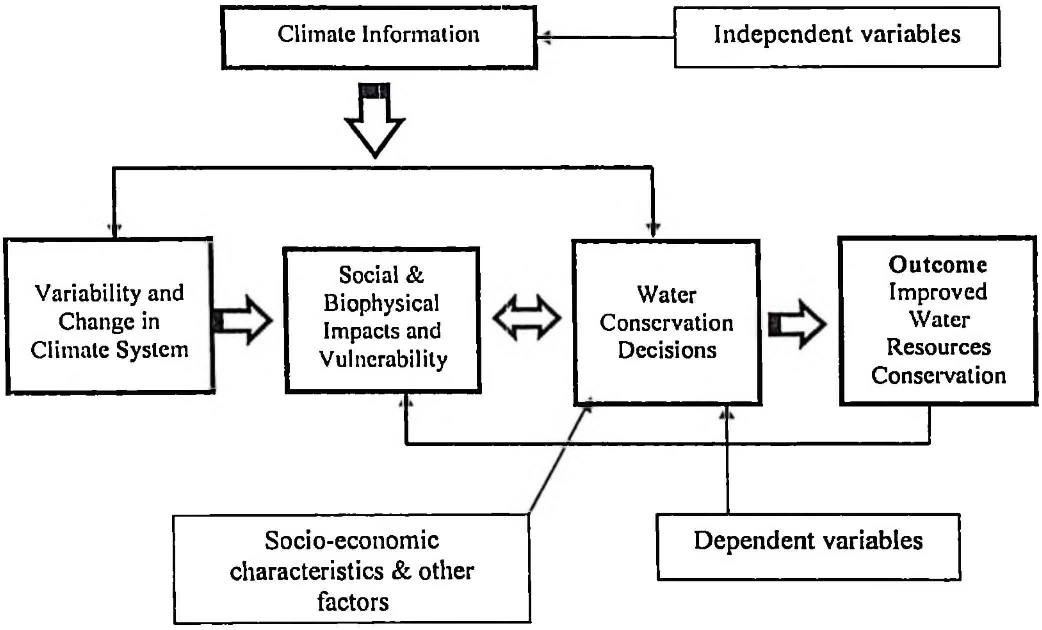

Figure 1: Conceptual framework for the study

1.7 Dissertation Structure

This dissertation is organized into five chapters. Chapter one presents the background, the problem statement, justification, objectives and conceptual framework of the study. Chapter two presents a literature review and discusses issues associated with climate variability and change, climate information availability and climate information use for water resources conservation. Chapter three describes the materials and methods of the study. Chapter four presents results and discussion. Conclusions and recommendations emanating from the results of the study are presented in Chapter five.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview on Climate Variability and Change

Climate variability and change is critical to natural and human systems because their effects span from global to local scales and from individual to society levels (Brath *et al.,* 2015). Climate variability is the variation of the normal state and other statistics of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or anthropogenic external forces (external variability) (IPCC, 2013).

The International Panel on Climate Change (IPCC) defines climate change as: "change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability over comparable time periods". Since the industrial revolution (the 1750s), humans have contributed to climate change through emissions of greenhouse gases (GHGs) such as carbon dioxide, methane, and nitrous oxide. Humans have also contributed to land use changes (Brath *et al.,* 2015). The concentration of carbon dioxide which is the main gas responsible for climate change increased from 278 parts per million in 1960 to 401 parts per million in 2015; and this has led to changes in chemical and physical properties of the atmosphere, the rise in radiation and subsequently surface temperatures (Brath *et al.,* 2015). Furthermore, the global average surface temperature has risen by 0.85°C for the period from 1880-2012, more than half of which is attributed to the anthropogenic origin (IPCC, 2013). There is a projected increase in global temperature by an additional 1.4 to 5.8°C by 2100 and an increase in rainfall which would vary by region with some showing decreasing and others increasing trends (IPCC, 2013).

2.2 Climate Information Availability

Climate information encompasses statistical analysis of historical trends, as well as forecasts and predictions about future weather and climate from local and scientific sources and the resultant implications on development, people's livelihoods and the environment (Ambani and Fiona, 2014; Daly *et al.*, 2016). Climate information also encompasses climate scenarios, climate projections, traditional and modern seasonal outlooks and its impacts, risks and consequences, climate advisory services, and modern and traditional climate adaptation practices (Lumosi, 2014). The need for this information is heightened by social and ecological impacts of climate change and the need for fostering human capacities of adapting to changing climate condition (CARIAA, 2010). This information increases our understanding of droughts, floods and other climate hazards, as well as the opportunities and options that inform our decisions on adaptation.

At the national level, the main source of weather and climate information is the Tanzania Meteorological Agency (TMA). However, there are other national and sub-national institutions that are also involved in the generation of climate and meteorological information including various ministries such as the Ministry of Agriculture, Food Security and Cooperatives (MAFC), the Ministry of Livestock and Fisheries Development (MLFD), the Ministry of Water (MoW) and the River Basin Authorities (RBAs) (Daly *et al.,* 2016). Making climate information accessible, timely and relevant can help countries cope with climate variability and limit economic and social damages caused by climate-related disasters (Lumosi, 2014).

2.3 Climate Information and Use for Water Resources Conservation

Climate and weather conditions affect almost every sector and industry in nearly every country (Gunasekera, 2010). Water plays a major role in supporting the performance of other sectors such as agriculture, transport and health and therefore it (the water) needs to be conserved for long-term support on the country's economy (URT, 2002; UNDP, 2013). Climate information as a tool can provide the impetus for the need for conserving water resources through planning and decisions making on water resources management. Some of these decisions are made by choosing and implementing autonomous adaptation which is defined as; those that do not constitute a conscious response to climate stimuli, but result from changes to meet altered demands, objectives and expectations which, whilst not deliberately designed to cope with climate change, may lessen the consequences of that change (Bates *et al.,* 2008). According to Bates *et al.* (2008) and Kashaigili (2009) autonomous adaptations are widespread in the water sector.

The climate information use concept is derived from "Adoption" and "diffusion" concepts. These are two interrelated concepts which depict the decision to use or not to use and the spread of a given technology among economic units over a period of time (Mignouna, 2011). Therefore in this study, climate information use is used interchangeably with climate information adoption. The use of climate information can be influenced by household-specific characteristics and other extraneous factors.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

This study was conducted in Kilombero River catchment within the Rufiji River Basin. The main part is in Kilombero, Malinyi and Ulanga Districts of Morogoro Region. The area is located between longitudes 34.563° and 37.797° East and latitudes 7.654° and 10.023° South (Smith, 2016) (Figure 2). The area is surrounded by steep slopes rising up to 2576 meters above sea level (m.a.s.l.) in the northwestern side while the land rises more gradually along the southeastern side reaching a maximum altitude of 1516 m.a.s.l. (Minas, 2014). The Kilombero River catchment also shares borders with the Udzungwa Mountains to the North and West and with Mahenge highlands to the East. The area harbours myriad of rivers and swamps which collectively form the Kilombero floodplain.

3.1.2 Climate and topography

The Kilombero River catchment is situated in the tropical humid zone and generally has a semi-arid climate which is highly variable and controlled by topography (Smith, 2016). The mountainous areas are cooler and wetter with a mean daily temperature of 17°C and annual precipitation totals ranging from 1500 to 2100 mm. The lowlands are hot and humid with a mean daily temperature of 24°C and an annual precipitation totals ranging from 1200 to 1400 mm (Minas, 2014). The area experiences a bimodal rainfall regime (Smith, 2016).

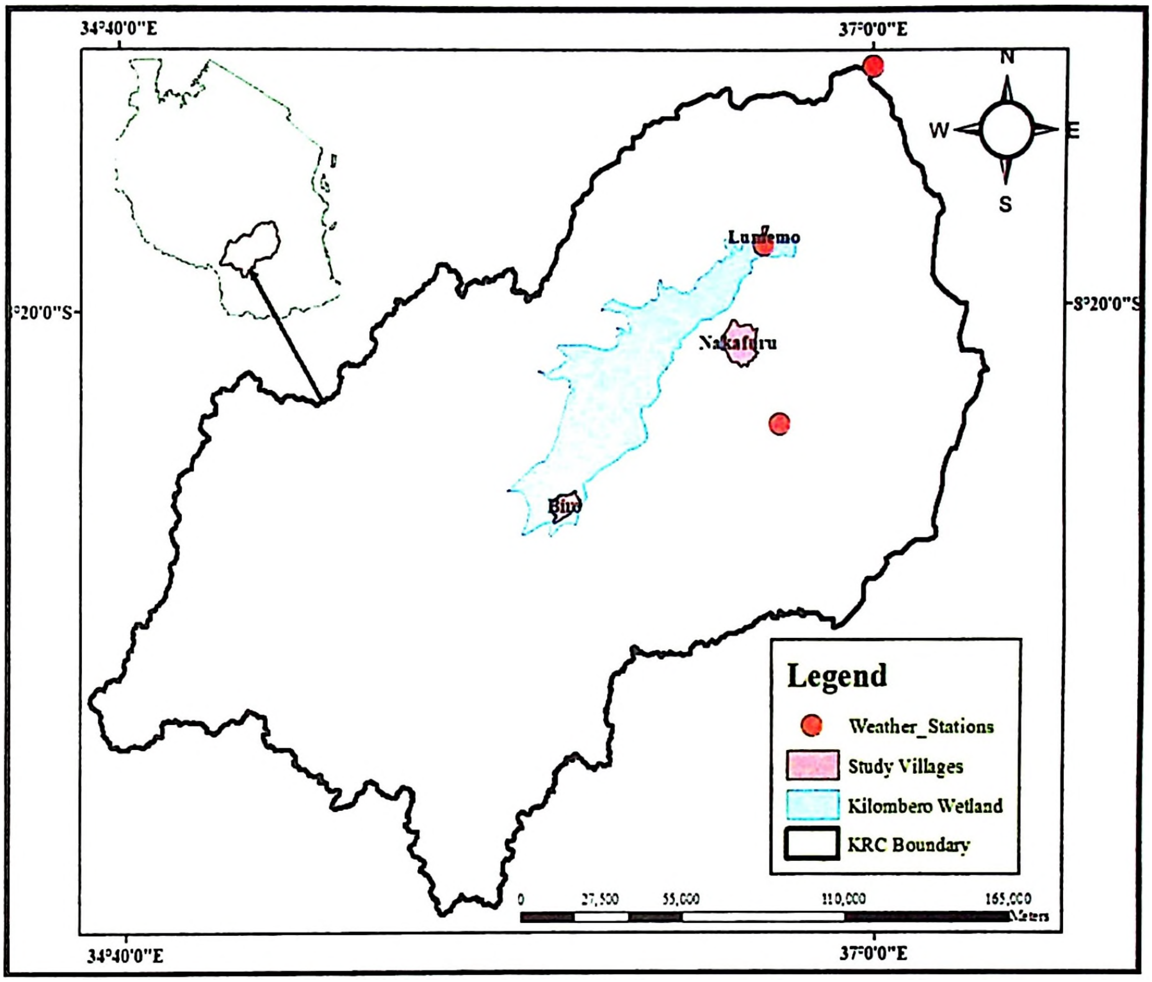

Figure 2: Location of Kilombero River catchment in Tanzania and study villages

3.1.3 Socio-economic activities

The main socio-economic activity is agriculture with over 80% of the population predominantly engaged in subsistence farming using about 329 600 ha of irrigated land to grow rice, maize, bananas and sugarcane which are the main crops in the area (Minas, 2014). The remaining 20% is shared by livestock keeping and fisherman. However, on the one hand, most of the livestock keeper are recent immigrants from other parts of the country and on the other fishing is not yet utilized to its full potential (Minas, 2014).

3.2 Research Design

A cross-sectional research design was employed in this study. The design was used because it allows the collection of data from different groups of respondents at one point in time (Kothari, 2004). Using this design, the study was able to obtain the respondent's insights on perceptions pertaining to climate variability and change, climate change impacts on water resources and availability and use of climate information in decisions on conservation of water resources.

3.3 Sampling Procedure and Sample Size

Purposive sampling technique was used to select study districts and villages while simple random sampling was used to obtain the respondents. Three districts namely Kilombero, Malinyi and Ulanga were selected purposively because they occupy a larger portion of the river catchment while three villages of Lumemo in Kilombero, Nakafulu in Ulanga and Biro in Malinyi due to the presence of many water resources and accessibility.

Simple random sampling was used to select the respondents using village register as a sampling frame. According to Barley (1994 cited in Mignouna, 2011), a sample of 30 cases is the minimum allowed sample size which is valid for statistical data analysis in a research. However, the sample size for this study was 40 respondents in each of the three villages making a total of 120 respondents (Table 1). The respondents for focus group discussions (FGDs) were purposively selected from people who had stayed in the area for long periods hence understands local climate changes and how climate information is used in making water conservation decisions in the area. Members of key informants interviews (KIIs) were village executives, Game officers from Kilombero Game Controlled Area (KGCA) and a Hydrologist and Water Engineer from Rufiji Basin Water Board (RBWB).

Table 1: The sample size for the study

District	Ward	Village	Household Number	Sampled household
Kilombero	Lumemo	Lumemo	2 198	40
Ulanga	Lupilo	Nakafuru	567	40
Malinyi	Biro	Biro	1 432	40
Total			**4 197**	**120**

3.4 Data Collection

Multiple data collection tools were employed in collecting primary data. The tools were direct observation, household questionnaires and checklists for KIIs and FGDs. The quantitative phase involved the collection of household data using questionnaires where a total of 120 households were interviewed, 40 from each village. The qualitative phase of data collection involved FGDs and KIIs where three FGDs in the three villages and seven KIIs were conducted to village executives and officers from KGCA and RBWB. Historical data on monthly rainfall and maximum and minimum temperature were obtained from the Tanzania Meteorological Agency (TMA) in Dar es Salaam. The obtained rainfall data were for three stations while temperature data were for one station within Kilombero River catchment (Table 2).

Table 2: Details of monthly rainfall and temperatures data for Kilombero River Catchment considered for the study

Station	TMA Code	Coordinates		Elevation	Period Examined	
		Latitude (degree)	Longitude (degree)	m.a.s.l.	Rainfall (mm)	Temperature (°C)
Mahenge	9836027	08°40'	036°43'	1500	1994-2017	1993-2017Min 1994-2017Max
Ifakara	9836013	08°10'	036°40'	251	1989-2016	Nil
Kilombero	9737029	07°40'	037°00'	304	1986-2016	Nil

Plate 1: A FGD meeting conducted in Nakafulu village in Ulanga District

3.5 Data Analysis

3.5.1 Rainfall and temperature variability and trends

The annual, monthly and seasonal rainfall and temperature datasets were analysed using exploratory data analysis (EDA) to summarize their main characteristics. This was followed by trends analysis using the Mann-Kendall test and Sen's methods.

3.5.1.1 Mann-Kendall test

The Mann-Kendall test was used to detect the presence of monotonic increasing or decreasing trends in annual and seasonal rainfall and temperatures (Salmi, 2002; Mosase and Ahiablame, 2018). The seasons in this study were classified as; short rains

(October, November and December (OND)), intermediate rains (January and February (JF)), long rains (March, April and May (MAM)) and dry season (June, July, August and September (JJAS)) according to Smith (2016). Since the data values for rainfall and temperature series were more than 10, the normal approximation (Z Statistics) was computed using S and σ^2_S as given in equation (4). The Mann-Kendall test is applicable where the data values xi's of time series are assumed to obey the model;

$$X = f(t) + \varepsilon_i \quad \text{.......(1)}$$

Where f (t) is a continuous monotonic increasing or decreasing function of time, ε_i is residuals assumed from same distribution with zero mean and constant variance.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) \quad \text{.......(2)}$$

Where x_j are sequential data values, n is the length of the data set, and

$$sgn\left(x_j - x_i\right) - \begin{cases} 1, for\ t > 0 \\ 0, for\ t = 0 \\ -1, for t < 0 \end{cases} \quad \text{.......(3)}$$

The variance of S (σ^2_S) is computed as:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+) - \sum_{p=1}^{q} t_p\left(t_p - 1\right)\left(2t_p + 5\right)\right] \quad \text{.......(4)}$$

Where n is the number of data points, q is the number of tied groups in the dataset and t_j is the number of data points in the j^{th} tied group. The S and σ^2_S were used to compute test statistics Z as;

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ s < 0 \end{cases} \quad \text{.......(5)}$$

The presence of a significant trend was evaluated using the Z statistic value. A positive Z value indicates an upward trend while a negative Z value indicates a downward trend. A two-tailed test at 0.05 and 0.1 α levels of significance was done to test whether the existing trend is monotone upward or downward. The H_0 was rejected if the absolute value of Z statistic is greater than Z_{1}-α/2, where Z_{1}-α/2 is obtained from the standard normal cumulative distribution tables (Salmi, 2002).

3.5.1.2 Sen's slope estimator

The Sen's method was used to estimate the true slope of the existing trend. It was expressed as a change per year in the annual and seasonal rainfall and in the annual and seasonal maximum and minimum temperatures. This method assumed the trend to be linear if f (t) in Equation (1) is equal;

$f(t) = Qt + B$ .... (6)

Where Q is the slope and B is a constant.

To get the slope estimate Q in equation (6), the slopes of all data value pairs were calculated first

$Q_i = \frac{x_j - x_k}{j-k}$ .... (7)

Where j>k.

If there are n values xj in the time series we get as many as $N = \frac{n(n-1)}{2}$ slope estimates Qi.

The Sen's estimator of slope is the median of these N values of Qi. The N values of Qi are ranked from the smallest to the largest and the Sen's estimator is;

$= Q_{[((N+1)/2)]}, If\ N\ is\ Odd$ .... (8)

Or

$Q = \frac{1}{2}(Q_{[N/2]} + Q_{[(N+2)/2]}), If\ N\ is\ even$ ....(9)

Where N is the number of calculated slopes.

3.5.2 Availability of weather and climate information

Exploratory analyses were performed in Statistical Package for Social Sciences (SPSS) on main variables such as frequencies of demographic features of households surveyed. The multiple response analyses were also done to determine the types of weather and climate information that farmers, fisherman and pastoral currently receive from different sources.

3.5.3 Extent of use of weather and climate information

Descriptive statistics such as frequency and percentage as well as cross-tabulations and Chi-square analyses were performed in SPSS to determine decisions on the conservation of water resources. The use of weather and climate information was determined by the use (adoption) quotient (Farid *et al.*, 2015). The use/adoption quotient for an individual respondent was calculated based on the use scores gained by respondents for the use of weather and climate information (Equation 10).

$$\text{Use Quotient} = \frac{\text{Total Score Gained by Respondents}}{\text{Maximum Use Score}} \times 100 \qquad \text{.......................................(10)}$$

On the basis of the use/adoption quotient, farmers were classified into three categories for Chi-square analysis such as low use = < (Mean – 1 Standard Deviation), medium use = (Mean ± 1 Standard Deviation) and high use = > (Mean + 1Standard Deviation). For two-limit Tobit regression analysis in STATA, use (adoption) quotient formed a dependent variable and was used as a continuous variable while the independent variables were; types of climate information (local and scientific forecasts), sources of climate information (radio, television, extension visits, neighbors or relatives, traditional methods and village meetings), wealth status, economic activity, position in community, size of land owned, age, gender and education level (Appendix 1). The model was used in this study because it can measure both probability and extent of use of climate information in each decision while minimizing inadequacies such as heteroscedastic disturbance term (μi) produced inherently by other linear probability models leading to biases of standard deviations of estimates (Sileshi *et al.*, 2012).

The Tobit model used was

$$Y^* = \beta x_i + \epsilon_i, \; \epsilon \sim N[0, \delta^2] \quad \text{......(11)}$$

$$Y_i = \beta 0 + \beta_1 X_1 \ldots \beta_n X_n \ldots i = 1 \ldots n \quad \text{......(12)}$$

Denoting Y_i as the observed dependent (censored) variable;

$$Y_i = Y_i^* = \begin{cases} 0 \text{ if } Y_i^* \leq 0 \\ X\beta + \mu i \text{ if } 0 < Y^* < 1 \\ 1 \text{ if } Y_i^* \geq 1 \end{cases} \quad \text{......(13)}$$

Where;

Yi = observed dependent variable,

Yi* = latent variable (unobserved for values less than 0 and greater than 1),

Xi = vector of independent variables (factors affecting climate information use),

$\beta 1$ = vector of unknown parameters, and

μi = normally distributed residuals.

Although the regression parameters do not directly correspond to the changes in the expected level of usage, their signs indicate the direction of change in the probability of use and marginal intensity of use as the respective explanatory variable change (Sileshi *et al.*, 2012).

3.5.4 Qualitative data

Qualitative data were analysed using content analysis whereby pieces of information were organized into different themes; indicators of climate change, impacts on water resources, availability and use of climate information for water resources conservation and climate change adaptations strategies implemented in the study villages.

3.5.5 Extent of climate change adaptation strategies

The NAWAPO of 2002 was analysed using document analysis methods according to Bowen (2009). This involved systematic examination of the policy document with regards to research objective. It involved a search of keywords 'climate change' to identify areas where these words have been addressed in the policy and their frequency of appearance. The entire document was then examined in details to see how climate change adaptations strategies have been addressed according to prioritized adaptation themes outlined in the National Climate Change Strategy (NCCS) of 2012 (URT, 2012).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-Demographic Characteristics of Respondents

Results on characteristics of respondents are presented in Table 3. The results show that the majority (53.3%) of the respondents were aged between 40 and 59 years. This age was considered to have enough experience on changes in the local climate and adaptation mechanism used. These results are similar to those obtained by Harrison (2006) in a socio-economic baseline survey conducted in 19 villages within Kilombero River catchment. They show that most of the villages in the river catchment have ageing populations. FGDs conducted in the three villages revealed that a higher percentage of the ageing population in the area is a result of youth moving to towns to seek economic opportunities. Results further show that (65.8%) of the respondents were males whilst (34.4%) were females. Further, the majority (91.7%) of the respondents were married. This indicates that most of the households in the area are male-headed. About (91%) of the respondents were farmers, (5.0%) were fishermen and the remaining (4.2%) were pastoralists. This indicates weather and climate information types related to rainfall are the most prominent in the area.

As for land ownership, 19.1% owned less than 3 hectares (ha) 26.7% owned between 3and 5 ha and more than half (54.2%) owned more than 5ha. The large size of land owned by the majority is allocated to them by the village government or inherited from parents (Harrison, 2006). Results on wealth status indicate that most 77.5% of the respondents belonged to the low-income category, 20% belonged to medium income and only 2.5% had high incomes. As regards to education level, most of the respondents 85.0% had completed primary school education. This has a serious implication on issues of awareness about climate change because education plays an important role in raising awareness. Idrissa *et al.* (2012) observed that literate people are better equipped with the knowledge and skills of sourcing, synthesis and use information than illiterate.

Table 3: The respondents socio-demographic characteristics (n=120)

Characteristics	Category	Name of Village			Total
		Lumemo	Nakafuru	Biro	(Average)
Age of respondent	20-39	12.5	27.5	15.0	18.3
	40-59	42.5	50.0	67.5	53.3
	>=60	45.0	22.5	17.5	28.3
Land size (ha)	Less than 3	32.5	10.0	15.0	19.2
	3-5	27.5	25.0	27.5	26.7
	More than 6	40.0	65.0	57.5	54.2
Sex	Male	77.5	42.5	77.5	65.8
	Female	22.5	57.5	22.5	34.2
Marital status	Married	97.5	82.5	95.0	91.7
	Single	2.5	17.5	5.0	8.3
Education in level	Illiterate	10.0	2.5	5.0	5.8
	Primary	67.5	95.0	92.5	85.0
	Secondary & High school	15.0	2.5	2.5	6.7
	Graduate and above	7.5	0.0	0.0	2.5
Household income	Low	62.5	82.5	87.5	77.5
	Medium	37.5	10.0	12.5	20.0
	High	0.0	7.5	0.0	2.5
Economic activity	Farmer	82.5	95.0	95.0	90.8
	Pastoralist	7.5	2.5	2.5	4.2
	Fisherman	10.0	2.5	2.5	5.0

4.2 Rainfall and Temperature Variations and Trends

4.2.1 Rainfall variations

The visual observations of rainfall data indicated the study area has a bimodal rainfall regime with slightly lower amounts in February making two distinctive peaks in January and April (Figure 3). Smith (2015) observed similar results when analyzing the mean monthly rainfall data in Kilombero River catchment. The highest rainfall amounts in all stations were experienced in April, 426 mm in Mahenge, 408 mm in Ifakara and 332 mm in Kilombero. This is because April is the peak of long rains (MAM) in the area. Lowest rainfall amounts were recorded during the dry season (JJAS) when less than 29 mm was received in all the stations.

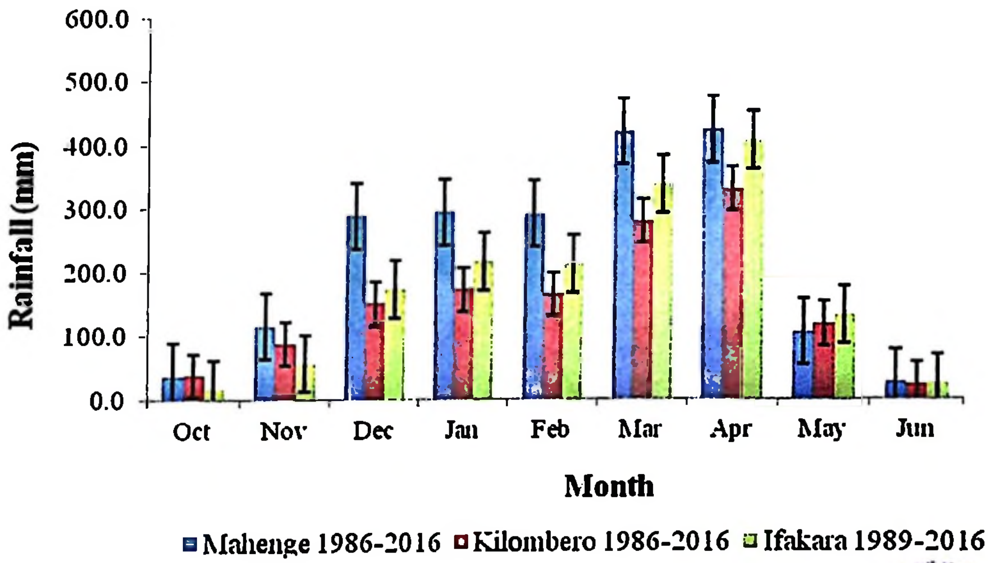

Figure 3: Mean monthly rainfall at the three study stations in the Kilombero River catchment

On temporal scales, results have shown rainfall differed considerably between the years 1986-1996, 1995-2005 and 2011-2016 while on spatial terms there was clear variation between places, with Mahenge receiving more rainfall than Ifakara and Kilombero (Figure 4). These results are supported by Mason *et al.* (2015) who reported that the largest part of climate variability that needs to be managed by practitioners occurs at timescales of approximately 1 to 10 years when considering rainfall. The long-term trends show a clear decline of rainfall in all stations for the period of 1986-2016 (Figure 4).

The results were against Mason *et al.* (2015) who reported long-term trends are much more evident in temperatures than rainfall. URT (2010) argued that the inter-annual and seasonal variations in rainfall in the Rufiji Basin are due to the recurrence of dry conditions in September and October which characterize short rains (OND) or "Vuli" and long rains (MAM) or "Masika".

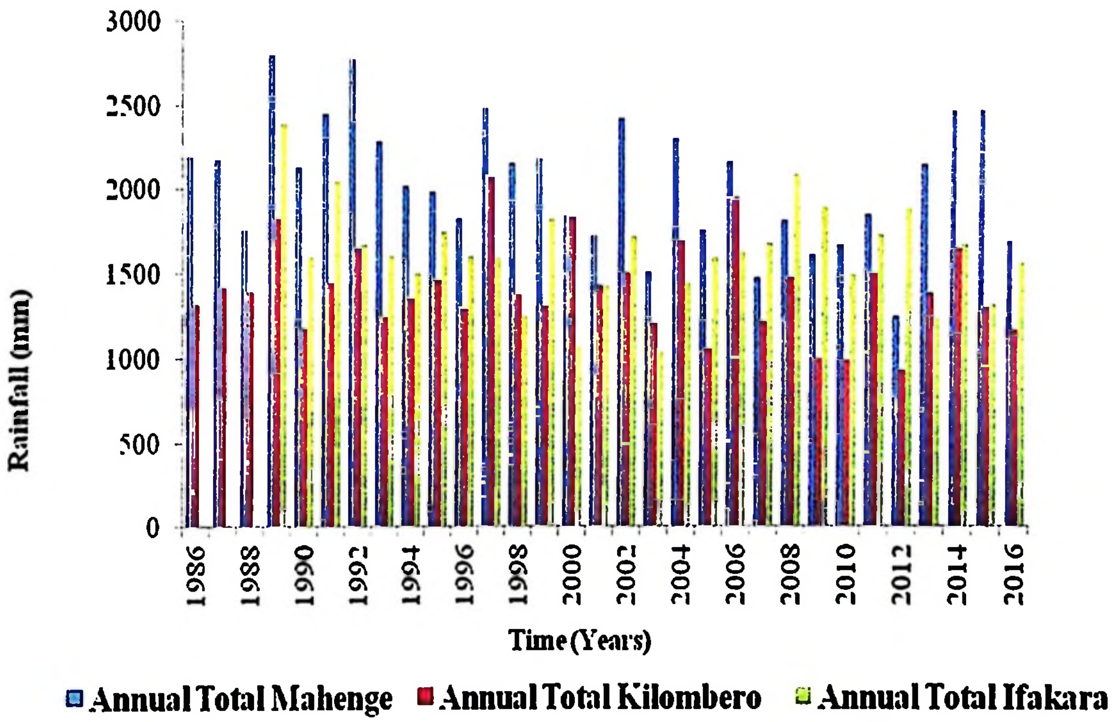

Figure 4: Total annual rainfall at the three study stations for the period 1986-2016 in Kilombero River catchment

4.2.2 Inter-annual and seasonal rainfalls trends

Results on trends analysis for inter-annual and seasonal rainfall are presented in Table 4. The results show annual and intermediate (JF) rainfalls in Mahenge (Z = -2.057 and -1.989) were decreasing significantly at 0.05 level of significance.

The rest of inter-annual and seasonal rain results showed decreasing trends except the intermediate (JF) rains in Kilombero (Z = 0.986), short rains (OND) in Ifakara (Z = 1.167) and rains during dry season (JJAS) in Ifakara (Z = 0.667) which showed increasing trends that were not statistically significant. The magnitude of change as revealed by the Sen's slope estimate (Q) varied from a maximum decline of 4.107 mm/year recorded in the intermediate (JF) rains in Mahenge to a maximum increase of 1.367 mm/year recorded in the short rains (OND) in Ifakara station (Table 4). This decline was attributed to a decline in seasonal rainfall amounts with the highest decline observed in the intermediate rains (JF) followed by long rains (MAM). This increase was contributed by an increase of short rains (OND) (URT, 2010).

These findings on the declines were supported by the respondent observations who reported that there have been delays in the onset of rains, the shortening of the rainy season and a decrease in rainfall quantity (Figure 6). Respondents revealed during FGDs that rainfalls had been decreasing in the study villages during the past leading to changes in the farming dates. In Biro village, a shift in short rains "Ndita lupi in Ndamba language" from September to November has caused changes in farming dates and subsequent decrease in farming size due to uncertainties linked.

Table 4: Mann-Kendall test statistic and Sen's slope estimate for inter-annual and seasonal rainfalls for the three stations

Time Series	First Year	Last Year	n	Test Statistic (Z)	Sen's Slope Estimate (Q)
Annual Mahenge	1986	2016	31	-2.057*	-1.412
Short rains(OND) Mahenge	1986	2016	31	-0.799	-1.207
Intermediate (JF) Mahenge	1986	2016	31	-1.989*	-4.107
Long rains(MAM) Mahenge	1986	2016	31	-0.476	-0.961
Dry season (JJAS) Mahenge	1986	2016	31	-0.799	-0.145
Annual Kilombero	1986	2016	31	-1.122	-0.572
Short rains (OND) Kilombero	1986	2016	31	-0.748	-0.903
Intermediate (JF) Kilombero	1986	2016	31	0.986	1.119
Long rains (MAM) Kilombero	1986	2016	31	-1.870	-2.133
Dry season(JJAS) Kilombero	1986	2016	31	-1.19	-0.185
Annual Ifakara	1989	2016	27	-0.625	-0.438
Short rains (OND) Ifakara	1989	2016	27	1.167	1.367
Intermediate (JF) Ifakara	1989	2016	27	-0.125	-0.253
Long rains (MAM) Ifakara	1989	2016	27	-1.793	-3.875
Dry season(JJAS) Ifakara	1989	2016	27	0.67	0.106

Abbreviations represent months of the year.

Note: * Indicates significant trends at α=0.05levels of significance.

4.2.3 Temperature variations

The mean annual and seasonal maximum and minimum temperatures have been highly variable in Mahenge station. The maximum temperature varied from 28.23°C/year during short rains (OND) to 24.10°C/year during long rains (MAM) (Figure 5). Generally, higher maximum temperatures were experienced during short rains (OND) for nearly the entire period of 1994-2017 except in 2006. The minimum temperatures varied from 19.5°C/year during intermediate (JF) rains to 13.38°C/year during the dry season (JJAS) (Figure 5). Generally, higher minimum temperatures were experienced during the intermediate (JF) rains for the entire period of 1993-2017.

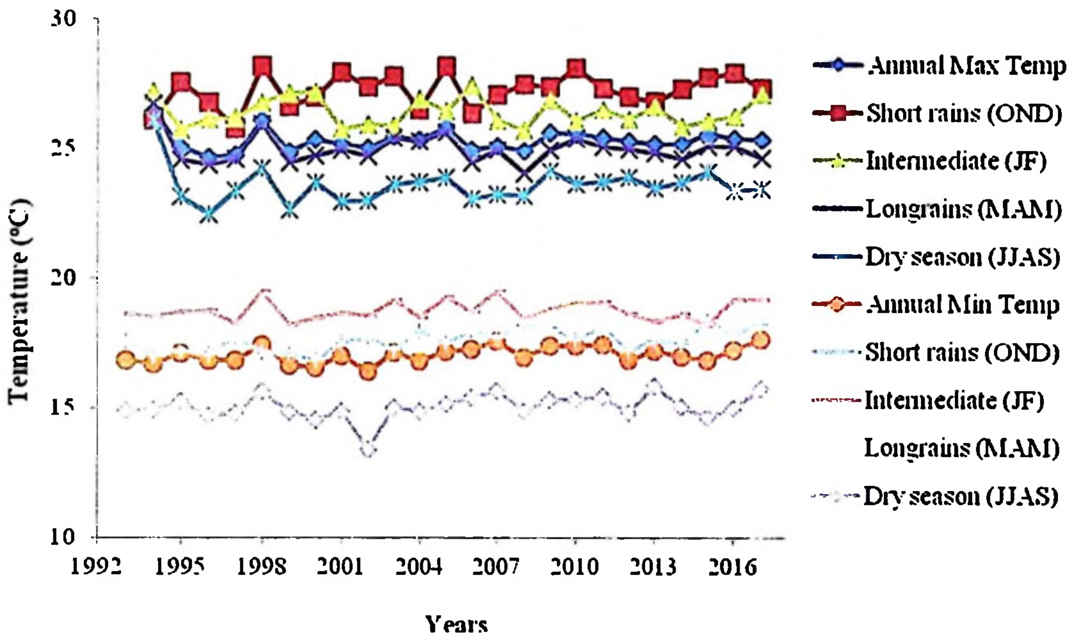

Figure 5: Annual and seasonal maximum and minimum temperatures for period 1993-2017 and 1994-2017 respectively in Mahenge

4.2.4 Inter-annual and seasonal temperatures trends

Results on trends analysis for inter-annual and seasonal temperatures are presented in Table 5. Results show that both the mean maximum and minimum temperatures had been increasing in Mahenge station for the period 1993 to 2017. However, significant trends were observed in annual minimum temperatures (Z= +2.500) and minimum temperatures during short rains (OND) (Z= +3.179) at 0.05 and 0.01levels of significance respectively. The magnitude of an increase of maximum temperatures ranged from 0.004°C/year during intermediate rains (JF) to 0.029°C/year during the dry season (JJAS) while minimum temperature ranged from 0.013°C/year during intermediate rains (JF) to 0.038°C/year during short rains (OND). These results are consistency with Conway *et al.* (2017) observations that there is a clear warming trend in annual temperature of roughly

0.03°C/year in Tanzania. However, they are in contrast with the global warming rate estimated at 0.6°C for the past century (Hayelom, 2017). This also implies that global warming has a significant impact on the regional climate (Hayelom, 2017).

Table 5: Mann-Kendall Test statistic and Sen's slope estimate for inter-annual and seasonal Temperatures in Mahenge

Time series	First Year	Last Year	n	Test Statistic (Z)	Sen's slope estimate (Q)
Annual Max Temp	1994	2017	24	1.340	0.021
Short rains (OND) Max Temp	1994	2017	24	1.416	0.036
Intermediate rains (JF) Max Temp	1994	2017	24	0.373	0.004
Long rains (MAM) Max Temp	1994	2017	24	0.522	0.007
Dry season (JJAS) Max Temp	1994	2017	24	1.389	0.029
Annual Min Temp	1993	2017	25	2.500*	0.025
Short rains (OND) Min Temp	1993	2017	25	3.179**	0.038
Intermediate (JF) Min Temp	1993	2017	25	1.030	0.013
Long rains (MAM) Min Temp	1993	2017	25	1.169	0.017
Dry season (JJAS) Min Temp	1993	2017	25	1.822	0.018

Abbreviations represent months of the year.

Note: * and ** Indicates significant trends at α=0.05 and 0.01 levels of significance.

These results agree with the respondent's observations from the three villages that temperature is increasing, rainfall was decreasing and incidences of droughts and floods were increasing in Kilombero River catchment (Figure 6). FGDs reported similar results in all villages, but a female respondent in Biro village gave an example, "There were excessive droughts in their village in 1988 which caused severe food shortage that strained some people to eat wild roots and leaves". Balama *et al.* (2016) reported that communities in Kilombero District attributed an increase in temperature and unpredictable rainfall events over the past few decades to changes in the local climate.

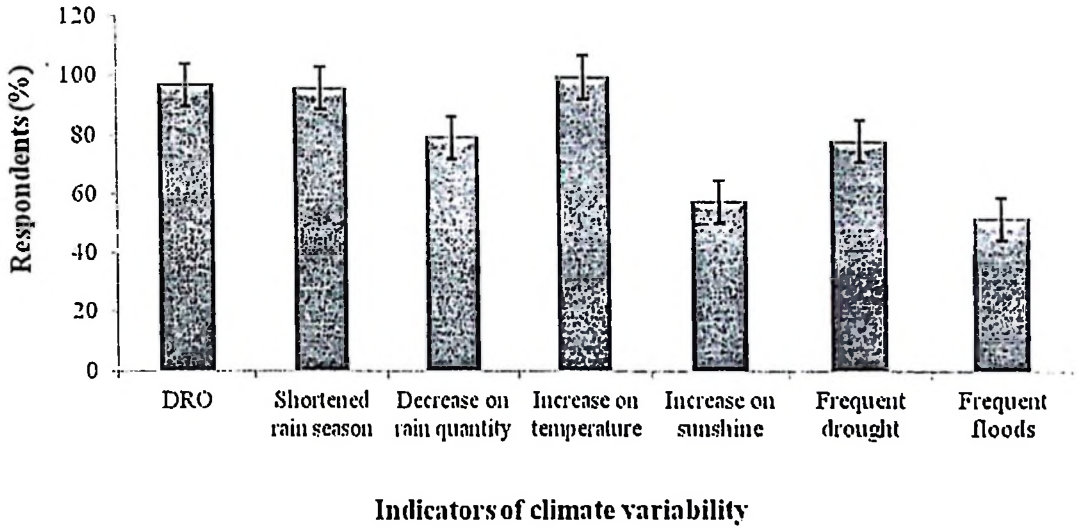

Figure 6: Indicators of climate variability as perceived by respondents in Kilombero River Catchment

4.2.5 Impacts of rainfall and temperature variations on water resources

Results of impacts on water resources are shown in Figure 7. The results show that majority of respondents considered the decrease in river flows 96.7 %, poor water quality 95.8 % and drying out of some streams and ponds 90.8 % as the main impacts of climate variability in Kilombero River catchment. These perceived impacts have led to shortages of water for every activity and an increase in water demands among different end users in the basin. The FGDs disclosed drying up of rivers and dams, a decrease in water flow in the rivers, the shifting of rivers due to excessive flooding and the damage of water resources infrastructures as the main impacts of climate variability and change on water resources.

These results are in line with Kangalawe (2017) who reported climate variability to have caused a progressive decrease of water flows in rivers and streams and the drying up of some wetlands leading to a decrease in the reliability of water sources in the southern highlands of Tanzania.

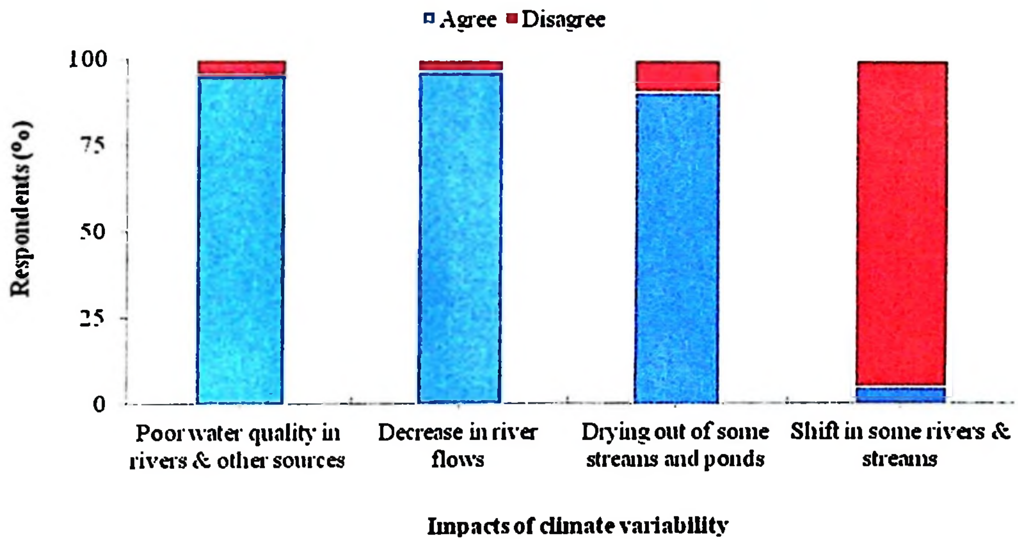

Figure 7: Perceptions on impacts of climate variability on water resources

4.3 Weather and Climate Information in Kilombero River Catchment

4.3.1 Availability of weather and climate information

Approximately 94.2% of respondents said weather and climate information is available in their villages and only 5.8% were uninformed (Figure 8). The weather and climate information available comprised of the daily forecasts 75.8%, information related with birds, insects and animal behaviours 66.7%, seasonal forecasts 60.8%, information related with astronomical indicators 50.8%, information related with phenological indicators 46.7% and information related with warning of potential disaster events such as droughts and flooding 24.2% (Table 6).

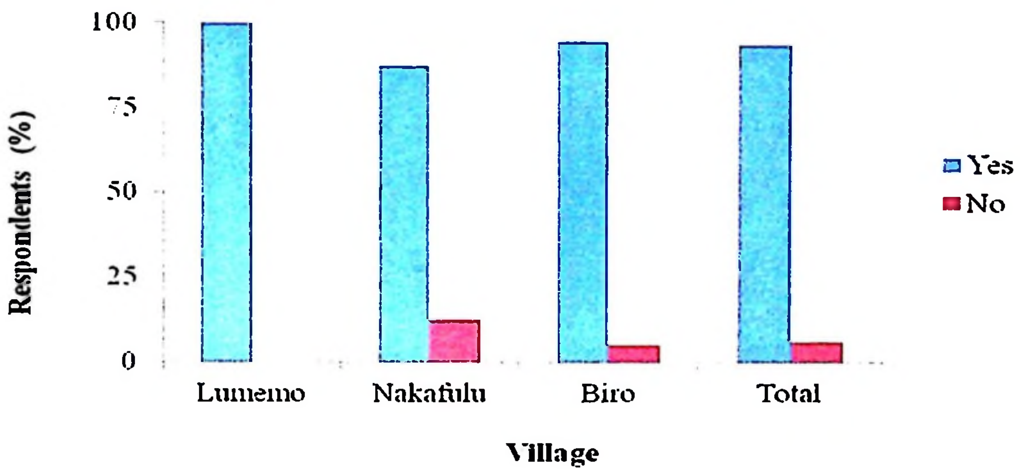

Figure 8: Perceptions on weather and climate information availability villagewise in Kilombero River catchment

The diversity of weather and climate information features in many parts of the country is a function of diverse demographic, social, cultural and economic factors (Lwoga *et al.,* 2010). Chang'a *et al.* (2012) on a study conducted at Mahenge and Isimani wards related the diversity of weather and climate information types with variability in local climate. FGDs in the area supported these observations with respondents pointing decrease in rainfall amounts, delays in the onset of rainfall and increase in temperatures as the main indicators. This was ascertained by results of historical rainfall and temperature data analysis which disclosed a decrease in annual rainfall and increase in both maximum and minimum temperatures (Table 4 and 5).

The plant phenology indicators, birds, insects and animal behaviours and astronomical indicators are classified as local because they are from traditional sources while daily forecasts, seasonal forecasts and early warning of potential disaster events are classified as scientific since they are from scientific sources according to Ambani and Fiona, 2014 (Table 6).

According to Ouedraogo *et al.* (2018) local or traditional climate forecasts are forecasts based on a system of knowledge that people in a particular geographical area use to predict weather and climate. It is embedded in art, history and culture and transmitted from one generation to another based on generations of experience.

Table 6: Type of weather and climate information available in study villages

S/n	Category	Attribute	Frequency	Percentage
1	Local	Plant phenology indicators	56	46.7
2		Behaviours of birds, insects or animal	80	66.7
3		Astronomical indicators	61	50.8
4	Scientific	Daily forecast	91	75.8
5		Seasonal forecast	73	60.8
6		Early warning of potential disasters	29	24.2

The phenological indicators observed in the area were fruiting of mangoes (i.e. fruiting of many mangoes in October/November predict early and adequate short rains while if it is fewer mangoes then it predicts drought) and shedding of leaves by some trees (i.e. Tamarind "Mikwaju" and Ficus "Mkuyu" indicates the coming short rains are fewer). The birds, insects and animal behaviours' used in predicting weather within the area include those of butterflies (i.e. butterflies seen herding in mountains indicates rains are near), ground hornbill (i.e. feeding of these birds in their villages indicates heavy rains will be experienced) and pangolin (i.e. a pangolin seen in the village is given spears which indicate war, water which indicate flooding, maize floor which indicate a good year in terms of yield to choose among others and they believe whatever chosen will come to pass). The astronomical indicators used in the area include the use of a group of small stars called "Kirimila" (i.e. once seen falling from the sky (April or May) at their villages indicates rainfall cessation) and heavy winds (i.e. experiences of heavy winds in their village indicates rains are near).

4.3.2 Sources of weather and climate information

Results on sources of weather and climate information are presented in Figure 9. According to West *et al.* (2018), the TMA is the primary way of delivering weather and climate information to district levels through formal government channels and mass media. However, respondents in the study area are not aware of the TMA but rather a number of intermediaries disseminating climate information grouped into formal and informal institutions as well as mass media (Daly *et al.*, 2016; West *et al.*, 2018). A total of eight intermediaries were identified as sources of weather and climate information by respondents. Out of the eight sources, radio 75% was the most common source followed by use of traditional methods 70.8%, neighbours and relatives 65.0% and television 56.7%.

The dominance of radio as a source of climate information was observed in Kenya by Koskei (2012) who noted the radio along with extension agents and fellow farmers as the major sources of information to farmers. The main reason for the dominance of radio is the presence of many free to air radio channels operating nationally and locally such as Tanzania Broadcasting Corporation (TBC) FM, Pambazuko FM, Ulanga FM and Malinyi FM. Traditional methods were chosen because rural populations still had a strong attachment to traditional beliefs in the country. Neighbours and relatives were chosen because fellow farmers had multiplier effects in disseminating agricultural information due to interpersonal interactions among farmers (Agwu and Adeniran, 2009).

Despite the lack of grid power in most of the areas in these villages, television was chosen by the majority because of specially designated joints called 'banda' where people would gather to watch news and football matches on television. Other sources chosen had lower preference rates and these include; extension visits 20.0% due to lower number of visits, village leaders with 19.17% due to their limited numbers compared to village population, village meetings with 17.5% due to limited public meetings held in the area and organizations with 17.5% due to small number of organizations operating in the area (Figure 9). Despite the potential of these sources in dissemination, the limited availability of power reduced the usefulness of some of these sources.

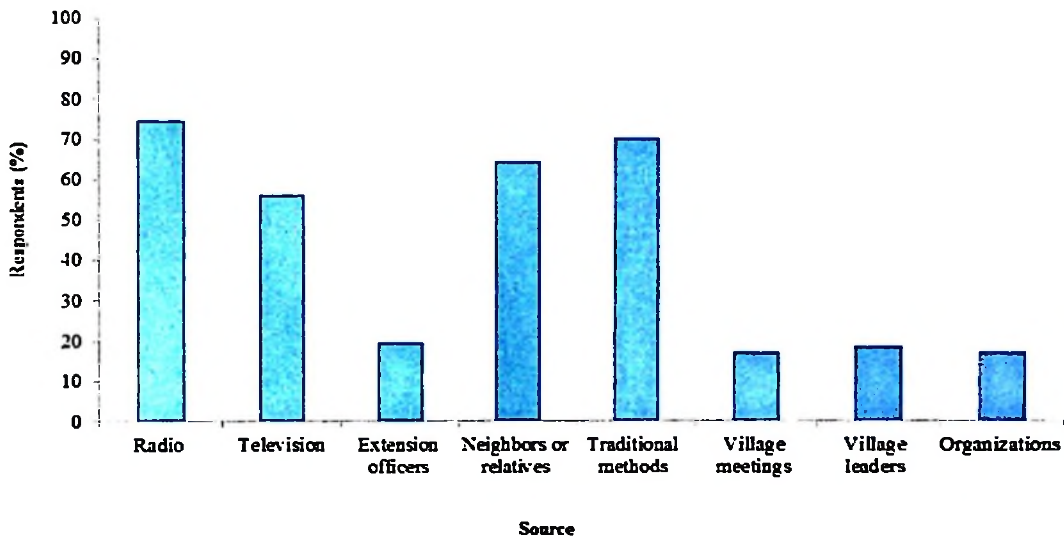

Figure 9: Sources of weather and climate information in Kilombero River catchment

4.3.3 Relationship between Types and Sources of Weather and Climate Information

The results on the relationship between sources and features are presented in Table 7. The radio positively correlated with daily forecast ($r=0.393$, $p<0.01$) and seasonal forecasts (0.404, $p<0.01$) because the radio is one of the most widely used media in rural areas which air weather and climate scientific information. The dominance of radio as a source of weather and climate information was also reported by Onyango *et al.* (2014) on information needs to farming and fishing communities in northern Kenya. However, the relationship between the radio and the daily and seasonal forecast was moderate as suggested by r-value.

Television was positively correlated with daily forecast ($r=0.253$, $p=0.05$) and seasonal forecasts ($r=0.297$, $p<0.01$) because daily forecasts are often broadcasted on television soon after the 08:00 hours news. Therefore, whoever watches the news is likely to watch the daily forecast. The relationship was weak as suggested by the low r-value. This might be because respondents were using other sources such as a radio for daily and seasonal weather and climate information. The traditional methods positively correlated with plant phenology indicators ($r=0.196$, $P<0.05$), birds, insects and animal's behaviours ($r=0.402$, $p<0.01$) and astronomy indicators ($r=0.286$, $p< 0.05$). This is because the traditional approach spread news quicker due to local beliefs and faith attached to in the area. FGDs with respondents in Biro village revealed that most respondents rely on information from traditional indicators such as fruiting of mangoes trees to predict rains and plan for their livelihood activities. In Kenya, it was observed that traditional methods are commonly used as the basis for farm-level decisions pertaining to the coming season in absence of meteorological forecasts together with previous experience (Onyango *et al.*, 2014).

Village meetings positively correlated with seasonal weather forecasts ($r=0.190$, $p<0.05$) because districts and village governments use village meetings to disseminate weather and climate information as well as emphasizing seasonal forecast which often depicts onset and cessations of rains and probable effects. The relationship was also weak because there were very few village meetings reported to have been taking place. Finally, organizations positively correlated with seasonal forecasts ($r=0.190$, $p< 0.05$) with the weak relationship because there are few organizations operating in the area which sensitize farmers on best farming practices and environmental conservation such as Kilombero Organization for Community Development (KOCD) and Community Environmental Management Development (CEMDO).

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Table 7: Relationships between sources and attributes of weather and climate information

Source /Attribute		Plant phenology	Birds, insects and animals behaviours	Astronomical indicators	Daily forecasts	Seasonal forecasts	Early warning of potential disaster events
Radio	*r*	0.000	0.000	-0.067	0.393**	0.404**	0.056
	P-level	1.000	1.000	0.465	0.000	0.000	0.542
TV	*r*	0.043	0.095	-0.086	0.253**	0.297**	0.140
	P-level	0.643	0.301	0.348	0.005	0.001	0.127
Extension officers	*r*	0.058	0.028	-0.107	0.064	-0.005	-0.045
	P-level	0.531	0.763	0.246	0.491	0.959	0.624
Neighbours/ relatives	*r*	0.056	0.037	0.082	-0.006	0.055	0.006
	P-level	0.543	0.688	0.373	0.947	0.547	0.947
Traditional methods	*r*	0.196*	0.402**	0.286**	-0.062	0.011	-0.023
	P-level	0.032	0.000	0.002	0.498	0.905	0.801
Village meetings	*r*	-0.035	0.000	0.058	0.004	0.190*	0.099
	P-level	0.703	1.000	0.528	0.967	0.038	0.284
Organizations	*r*	0.053	0.000	0.058	0.004	0.190*	0.150
	P-level	0.567	1.000	0.528	0.967	0.038	0.102
Village leaders	*r*	0.075	0.050	0.086	-0.035	0.146	0.090
	P-level	0.417	0.591	0.348	0.701	0.112	0.329

*Correlation is significant at 0.05 levels, **Correlation is significant at 0.01 levels - (2 tailed).

4.4 Weather and Climate Information Use for Water Conservation Decisions

4.4.1 Status on use of weather and climate information in Kilombero River catchment

Results in decisions on conservation of water resources made under influence of weather and climate information are presented in Table 8. Results show respondents of the study area made ten decisions which are to farm or other undertakings, change farming practices, protecting water resources, conservation actions, regulate water use, improve water irrigation systems, construction of small pans/boreholes, move to other areas, reduce the number of livestock and look for off-farm jobs. Among all decisions, 'farming or other undertakings' use is the highest and 'improve water irrigation systems' is the lowest in nearly all villages. Significant variations in use are observed in three water conservation decisions in the three villages; conservation actions (X^2=5.992, $p<0.05$), construct small pans/boreholes for water storage (X^2=6.580, <0.05) and reduce the number of livestock (X^2=5.889, $p<0.05$). The main reason is the variations in the socio-economic characteristics of the respondents of the three villages.

Apart from farming or engage in other undertakings (79.2%), decisions on changing farming practices (74.2%), conservation activities (71.7%) and protection of water resources (70.0%) were used by more than half of all the respondents. These observation are supported by FGDs which revealed that farmers use seasonal forecast to make decisions on whether to farm or do business and changing farm practices by choosing crops to grow (e.g. short term to drought-resistant crops such as millet and cassava), farms location (lowland where traditional irrigation system is practiced or the highlands) and farming dates (e.g. early or late growing).

They were also aware of the positive impacts of such decisions on limited available water resources. Van Aelst and Holvoet (2017) supports this observation through a study done in Morogoro rural and Mvomero districts which noted common climate change adaptation strategies by women to encompass; engage in undertakings such as work as a casual labourer on someone else's farmland in return for cash but occasionally for food or a share in crop yields, engage in income-earning activities outside the household and farm such as brick making, charcoal production, own business and changing farming practices by planting crops that are able to cope with drought conditions such as cassava and millet.

The conservation and protection of water resources decisions are implemented by individual respondents in the three villages. However, this has been under the influence of the village government through bye-laws and environmental legislation. During FGDs in Lumemo village, respondents recognized the Environmental Management Act (EMA) of 1997 to be widely used in regulating human activities near water resources to a distance beyond 60 meters as highlighted in 'Section 34'.

In Nakafulu village, respondent's awareness of the need to conserve water resources was high as observed by the researcher's in the field through actions taken by pastorals: *"Three fishermen were arrested at midnight by pastorals and brought to the village office for further legal action after they were trapped emptying water in one of few remaining water dams/pans in the village to catch catfish easily in November 2017".* This implies that communities were aware of appropriate adaptation strategies.

The KIIs also noted that most water conservation decisions implemented in the area were largely attributed by policies and regulations: *"Policies and regulations especially the National Environmental Policy (NEP) of 1997, NAWAPO of 2002, National Wildlife*

Policy (NWP) of 1997, Environmental Management Act (EMA) No. 20 of 2007, WRMA No. 11 of 2009 and Wildlife Conservation Act (WCA) of 2009 have been central in ensuring water resources such as the Kilombero wetland several rivers are conserved in the Kilombero River catchment" (Field data, KIIs of RBWB and KGCA, 2017).

Table 8: The water resources conservation decisions implemented in Kilombero River catchment (n=120)

S/n	Water conservation decisions	Lumemo	Nakafulu	Biro	Chi -square	P-value
1	Conservation actions e.g. trees planting	77.5	80	57.5	5.992	0.05
2	Protecting water resources e.g. restrict human activities	75	72.5	62.5	1.667	0.44
3	Change farming practices e.g. drought resistant cops	72.5	77.5	72.5	0.348	0.84
4	Regulate water use e.g. reduce irrigation rate	17.5	10	12.5	1.010	0.60
5	Improve water irrigation systems e.g. clearing of canals	17.5	12.5	12.5	0.548	0.76
6	Construct small pans or boreholes to store water	30	12.5	10.0	6.580	0.04
7	Farming or other undertakings	72.5	82.5	82.5	1.617	0.45
8	Move to other areas (for many reasons).	42.5	32.5	20	4.698	0.10
9	Reduce the number of livestock	37.5	35	15	5.889	0.05
10	Off-farm jobs e.g. employment on temporary basis	37.5	15	22.5	6.600	0.06

The least frequently adopted decisions on water resources conservation was the construction of small pans/boreholes for water storage (17.5%), improvement of water irrigation systems (14.2%) and regulate water use (13.3%). These three water conservation decisions were used by less than 20% of all respondents because the majority of respondents had low income and they could not afford such intervention. Household income was found to limit adaptations alternatives especially those associated with higher costs (Van Aelst and Holvoet, 2017).

4.4.2 Extent of use of weather and climate information in decisions to conserve water resources

The extent of the use of weather and climate information in decisions on conservation of water resources is shown in Figure 10. It is evident that the mean use score is 44% with a standard deviation of 23.5%. The figure also indicates that the use (adoption) quotient is 40 for more than forty respondents which were interviewed in the study area.

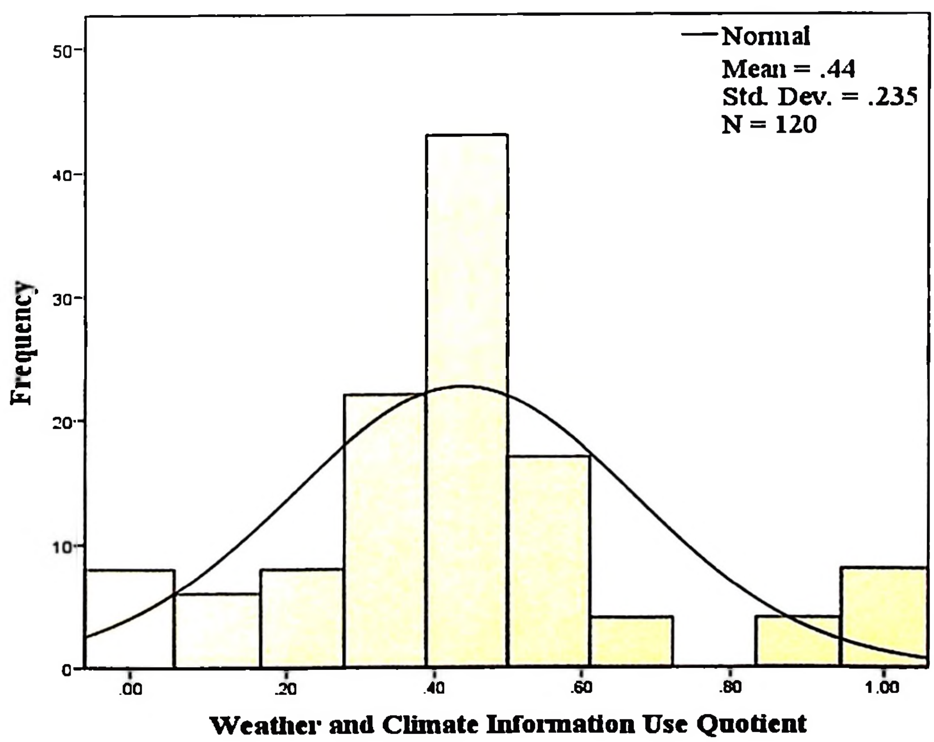

Figure 10: The extent of use of weather and climate information by respondents

From Table 9, results suggest there was overall medium use of weather and climate information that is 34.7 percent, 33.7 percent and 31.6 percent of respondents from Lumemo, Nakafulu and Biro villages although Lumemo village had a larger portion of respondents (50%) in the high use category. This is mainly because Lumemo village was more developed and near urban compared to Nakafulu and Biro villages. The Chi-square test (5.147, P>0.05) indicate there were associations on weather and climate information use among the three villages; Lumemo, Nakafulu and Biro.

Table 9: Distribution of respondents based on three categories of use of weather and climate information

Use category	Study villages			Total	Chi-square
	Lumemo	Nakafuru	Biro		
Low use	2(13.3)	5(33.3)	8(53.3)	15(12.5)	5.147
Medium use	33(34.7)	32(33.7)	30(31.6)	95(79)	
High use	5(50)	3(30)	2(20)	10(8.3)	

Note: Figures within parentheses indicate percent use

4.4.3 Factors affecting decisions to use weather and climate information in decisions to conserve water resources

The two limit Tobit regression model was used to determine the intensity of use for each decision and factors influencing the use of climate information for water resources conservation decisions (Table 10). The likelihood ratio χ^2 of 45.98 (14) with a ($p<0.05$) indicates that the model as a whole fits significantly while the coefficient of determination (R^2) of 0.75 indicating 75% of the total variation in use of weather and climate information is attributed to variables fitted in Tobit model. Fourteen explanatory variables were fitted in the model and six variables; scientific types, extension visits, traditional methods, household income, economic activity and education level were found to significantly influence the probability and extent of use of weather and climate information.

Table 10: Tobit model estimates of intensity and factors influencing use of weather and climate information

Variable	β	SE	t-value	Sig.	Probability	Unconditional Expected Value
Local attributes(X1)	-0.040	0.056	-0.70	0.486	-0.008	-0.038
Scientific attributes(X2)	0.182	0.056	3.24	0.002*	0.071	0.173
Access to radio(X3)	0.125	0.065	1.92	0.058	0.042	0.120
Access to television(X4)	-0.064	0.054	-1.18	0.239	-0.014	-0.062
Extension visits(X5)	0.079	0.022	3.51	0.001**	0.017	0.076
Traditional methods(X6)	0.114	0.057	2.01	0.047*	0.035	0.118
Village meetings(X7)	-0.106	0.065	-1.63	0.106	-0.036	-0.102
Wealth status(X8)	0.072	0.033	2.16	0.033*	0.016	0.070
Economic activity(X9)	-0.152	0.069	-2.19	0.031*	-0.033	-0.147
Position in community(X10)	0.013	0.081	0.16	0.87	0.003	0.012
Size of land owned(X11)	-0.030	0.020	-1.52	0.13	-0.007	-0.029
Age(X12)	0.035	0.032	1.05	0.296	0.008	0.033
Gender (X13)	0.009	0.047	0.18	0.855	0.002	0.008
Education level(X14)	-0.111	0.049	-2.26	0.026*	-0.025	-0.108
_Constant	0.315	0.157	2.01	0.047	-0.007	-0.038
Number of observations	120					
LR chi^2 (14)	45.98(14)					
Probability> chi2	0					
Pseudo R^2	0.75					
Log-likelihood	-7.52939					
Censoring observation	7 left-censored, 105 uncensored, 8 right-censored					

The information features from scientific sources such as TMA were important in influencing the probability of use in decisions which favour water resources conservation. This variable was significant and positively correlated ($ß=0.182$; $p<0.01$) with the use of weather and climate information. This implies that an increase in features of weather and climate information from scientific sources increases the probability of its use by 7.1% of farmers in decisions pertaining to farming which will ultimately contribute towards water resources conservation by 17.3% of the entire sample. Hansen *et al.* (2007) noted historic climate records obtained from real-time monitoring reduces uncertainties among farmers thereby increasing their use.

The extension visits had a significant and positive relationship with the use of climate information in the area ($ß=0.079$; $p<0.01$). This implies access to extension services and frequency of visits determines decisions made by farmers on the conservation of water resources and environmental protection in general. The model's results suggest that each additional contact increases the probability of use by 1.7% and intensify the use of water resources conservation decision by 7.6% of the entire sample. These findings are in line with Idrisa *et al.* (2012) who noted in Nigeria that farmers with access to extension contact adopt farming technologies by 72% more than farmers without access to extension contacts. In the study area, extension visits involve educating farmers on environmental conservation, environmental legislation and by-laws formulated by the village government to conserve water resources. Maponya and Mpandeli (2013) also observed that extension services expose farmers to new information and technical skills which enhances them to make decisions.

The use of traditional ways to disseminate climate information emanates from the fact that there are many people who do not depend on radios and televisions as a source of information due to lack of power for operating these sources. This variable was significant and positively correlated (ß =0.114; $p<0.05$). The model result suggests that the exchange of information through traditional ways increases the probability of use by 3.5% and intensity in decisions making on water resources conservation by 11.8% of the entire respondents. Onyango *et al.* (2014) observed high spread and use of traditional forecast through raditional means in absence of scientific forecast. In these areas, traditional forecast and previous experience remain the only basis for farm-level decisions pertaining to the coming season. The wealth status was significant and positively correlated (ß=0.072; $p<0.05$) with the use of weather and climate information for water resources conservation decisions. Even though the majority of the household had low income, the model suggests that they had the probability of use by 1.6% and increased intensity of decision to conserve water resources by 7% of the entire sample. This could be explained by other factors such as the size of land used for agriculture which when positively managed, it has a positive impact on the conservation of water resources.

The main socio-economic activity in the area was farming and this is hypothesized to influence negatively water resources conservation (ß-0.152; $p<0.05$). The possible explanation is that if farmers are not educated enough they may opt to maximize farming output in the expense of water resources which they solely depend for agriculture especially during dry season. For a unit increase in farm costs, the probability of use of weather and climate information declined by 3.3% and intensity in water resources conservation affected by 1.47%. The education level had a significant and negative influence on the use of climate information in conserving water resources (ß= -0.111; $p<0.05$). For a unit decrease in education level, the use of weather and climate information declines by 2.5% and the intensity of decisions appropriate for water conservation are affected by 10.8%.This observation is supported by Farid *et al.* (2015)

who noted to farmers of Northern Bangladesh that education level has a significant effect on the use of technology, that is, the rate of use is supposed to be higher with the increases of the level of education and vice versa. About 85 percent of people in study villages are low adopter because they have primary school education; hence the negative sign of coefficient implies that these farmers had lower probability and intensity in using weather and climate information to conserve water resources.

4.4.4 Measures for improving use of weather and climate information in Kilombero river catchment

The measures proposed by respondents for greater uptake of weather and climate information are presented in Table 11. The majority of respondents wished-for improved the accuracy of forecast message (70%), improving extension services (68.33%) and awareness raising to communities on weather and climate information in Kilombero River catchment. These three measures were proposed by more than half of the respondents. The measures are in line with Gunasekera (2010) who observed that quality, accuracy, timeliness and locational specificity affects the socio-economic value of climate and weather information. During FGDs respondents noted the current weather and seasonal forecast produced covers large areas while impacts are on smaller scales hence need for making area specific forecast. During FGDs improvement of extension services in terms of contact hours and frequency was also proposed in line with Bryan *et al.* (2009) who noted extension services have the potential to influence farmers' decision to increase probability climate change.

Extension services were hypothesized to positively relate to use of climate change adaptations strategies by exposing farmers to new information and technical skills (Maponya and Mpandeli, 2013). Need for raising farmers awareness on access and the potential of weather and climate information in making livelihood and water resources conservation decisions were discussed. Maponya and Mpandeli (2013) noted similar opportunities on the potential of awareness creation in influencing adaptations to climate change issues on the study done in Limpopo in South Africa. The least measure proposed by respondents was the dissemination of weather and climate information to district, ward and village levels (40.83%). During FGDs respondents felt that despite the presence of multi-sources, disseminating weather and climate information to wards and village levels is necessary since there is room for further clarifications.

Table 11: Proposed measures for greater use of weather and climate information

S/n	Measure	Frequency	Percentage (n=120)
1	Raise awareness on weather and climate information	65	54.17
2	Improve extension services	82	68.33
3	Improve availability and access	54	45.00
4	Improve the content of the forecast message	57	47.50
5	Improve accuracy of forecast message	84	70.00
6	Disseminate climate information to district, ward and village levels	49	40.83

4.5 Climate Change Adaptation Strategies in the National Water Policy of 2002

4.5.1 Policy environment for climate change adaptation and mitigation

The climate change at the national level is undertaken at the context of United Nations Framework Convention on Climate Change (UNFCCC) and is institutionally managed by the Division of Environment (DoE) in the Vice President's Office (VPO) which is the focal point of climate change under the UNFCCC (URT, 2012). DoE is also responsible for guiding the integration of climate change into domestic policies and regulations (Daly *et al.*, 2015). Climate change governance is undertaken within the context of NEP of 1997, EMA of 2004 and related legislation. However, there is the NCCS which was established to enhance climate resilience in Tanzania and reduce the vulnerability of natural and social systems to climate change. The NCCS has spelt out climate change adaptation strategic intervention by sectors in which five areas namely, protection and conservation of water catchments, rainwater harvesting; enhancement of water availability, conducting vulnerability assessments and management of water resources to improve sanitation and hygiene have been earmarked for water sector (Daly *et al.*, 2015). These areas were the basis for the analysis of NAWAPO of 2002.

4.5.2 The analysis of climate change adaptation strategies in NAWAPO of 2002

The main objective of this policy is to develop a comprehensive framework for sustainable development and management of the nation's water resources by putting valuable legal and institutional framework for its implementation in place (URT, 2012).The policy document has not specifically mentioned climate change or climate change concern. Pardoe *et al.* (2017) had a similar observation on the insight from policy and practice in Tanzania study. However, key areas addressing climate change adaptations as suggested by the NCCS have been to a certain extent addressed under water resources management (Section 1), rural water supply (Section 2) and urban water supply and sewerage (Section 3) sub-sectors as highlighted in the policy document.

The components addressing climate change adaptation strategies within the water resources management sub-sector include; fair procedures for access and allocation of water resources, effectiveness and efficiency on water resources utilization, management of water quality and conservation, conservation of ecosystems and wetlands and integrated planning and management of water resources.

The components addressing climate change adaptation strategies within rural water supply sub-sector include; enabling communities on choices of appropriate technologies, improvements of rural water supply and sanitation services, encouraging rainwater harvesting technologies, strengthen service delivery system to ensure efficient and equitable use of water and establishing institutional framework for management of rural water supply and sanitation.

The components addressing climate change strategies within the urban water supply and sewerage sub-sector include; improved infrastructures for sustainable and efficient water supply and sanitation services, protection of water sources from encroachment, prevention of wasteful water use and control of water leakages, improvement of water and sanitation services in low income and peri-urban areas, establish wastewater treatment system which are environmentally friendly, and efficient and comprehensive institutional framework for urban water supply and sewerage.

Given the multifaceted features of adaptations, it is fair to note that some of the issues are addressed by these components. But, it can be simply noted that they are not well linked to climate change as comprehensive in NCCS and do not focus on damages induced by climate change. Therefore, their implementation does not guarantee adjustment in the natural and human systems to a changing environment originating from climate change unless improved.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The annual and seasonal rainfalls in the Kilombero River catchment for the period 1986-2016 have been highly variable as depicted in temporal and spatial scales. Although annual and seasonal rainfall did not show consistence, significant trends were observed in annual and intermediate (JF) rainfalls in Mahenge at 0.05 α levels of significance. The magnitude of change varied from a maximum decline of 4.107mm/year in intermediate (JF) rains in Mahenge to a maximum increase of 1.367mm/year in short rains (OND) in Ifakara station. Trend analysis has shown that both maximum and minimum temperatures were increasing in Mahenge station for the entire period of 1993 to 2017. However, it is only the annual minimum temperatures and minimum temperatures during short rains (OND) and dry season (JJAS) which had significant trends at 0.01 and 0.05 levels of significance respectively. The magnitude of increase for maximum temperature ranged from 0.004°C/year during intermediate rains (JF) to 0.029°C/year during the dry season (JJAS) while minimum temperature ranged from 0.013°C/year during intermediate rains (JF) to 0.038°C/year during short rains (OND).

The weather and climate information was ascertained in the area with six types distinguished from local and scientific predictions. Majority of respondents in the area use weather and climate information in decisions on conservation of water resources with ten decisions identified in the area. The extent of use was medium and uniformly distributed in the study area. Scientific climate types, extension visits, traditional methods, wealth status, economic activity and education level were the only statistically significant factors ($p<0.05$) identified to influence the use of weather and climate information in decisions on the conservation of water resources. Most of these decisions are however implemented through legislation.

The study revealed that climate change has not been integrated into NAWAPO of 2002 because document guiding mainstreaming of climate change into sectoral policies and plans were developed after the policy document was prepared. However, the adaptation strategies to climate change based on the NCCS prioritized adaptations themes have been marginally covered by this policy but and lack a clear focus.

5.2 Recommendations

From the study findings, the analysis and discussions, the following were recommended;

i. In response to rainfall and temperature variability, the MAFC and MoW should improve the adaptive capacity of communities in the River catchment by raising awareness and developing coping strategies built upon the existing local livelihood such as growing drought resistant crops, implement soil and water conservation practices, regulate water use and water harvesting.

ii. Communities in Kilombero River catchment are aware and use weather and climate information. But in order to improve uptake, the local governments should address the three measures which were proposed by the majority of respondents which are improvement of forecast accuracy, improvement of extension services and raising awareness on climate information.

iii. The results indicated medium use of weather and climate information on decisions to conserve water resources in Kilombero River catchment. In order to improve use, the local governments should emphasize some of the factors which had a positive significant influence on the use of climate information for water resources conservation decisions. These factors were found to be, use of scientific climate types, number of extension visits and use of traditional methods.

iv. The climate change had not been integrated into NAWAPO of 2002 although some strategies have been addresses as per the NCCS prioritised areas. Lack of climate change in this main document may affect the implementation of climate change adaptations measures streamlined in lower documents. The MoW should, therefore, seek review of this policy document to integrate climate change matters among others.

5.3 Areas for Further Research

The study provides findings which are relevant for areas with similar characteristics. Based on actual findings, use of weather and climate information has been identified to be through legislation, by-laws and special campaigns. However, the contribution of each approach has not been examined and this has raised a question on "what is the actual contribution of each approach to the overall use of weather and climate information in water resources conservation". Exploration of the contribution of each approach merits the attention of future research.

REFERENCES

Agwu, A. E. and Adeniran, A. A. (2009). Sources of agricultural information used by arable crop farmers in Isale Osun farm settlement, Osogbo Local Government Area of Osun State. *Journal of Agricultural Extension* 13(1): 24 – 35.

Ambani, M. and Fiona, P. (2014). Facing Uncertainty: *The Value of Climate Information for Adaptation, Risk Reduction and Resilience in Africa.* Cooperative for Assistance and Relief Everywhere, Nairobi, Kenya. 23pp.

Balama, C., Augustino, S. Eriksen, S. and Makonda, F. B. (2016). Forest adjacent households' voices on their perceptions and adaptation strategies to climate change in Kilombero District, Tanzania. *Springer Plus* 5(1): 1 – 21.

Bates, B. C., Kundzewicz, Z. W., Wu, S. and Palutikof, J. P. (2008). *Climate Change and Water.* Intergovernmental Panel on Climate Change, Geneva. 210pp.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal* 9(2): 27 – 40.

Brath, B., Friesen, T., Guérard, Y., Jacques-Brissette, C., Lindman, C., Lockridge, K. Mulgund, S. and Walke, B. (2015). *Climate Change and Resource Sustainability: An Overview for Actuaries.* Canadian Institute of Actuaries, Canada. 57pp.

Bryan, E., Deressa, T. T., Gbetibouo, G. A. and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: Options and constrain ts. *Environmental Science and Policy* 12(4): 413 – 426.

CARIAA (2010). *Use and Communication of Climate Information to Support Uptake of Adaptation Action in Semi-Arid Regions in Africa and Asia.* Intensive Africa, Nairobi, Kenya. 58pp.

Chang'a, L. B. Kijazi, A. L., Luhunga, P. M. Ng'ongolo, H. K. and Mtongor, H. I. (2017). Spatial and temporal analysis of rainfall and temperature extreme indices in Tanzania. *Atmospheric and Climate Sciences* 7(4): 525 – 539.

Conway, D. Mittal, N. and Vincent, K. (2017). *Future Climate Projections for Tanzania.* Country Climate Brief, Cape Town, South Africa. 2pp.

Daly, M. E., West, J. J. and Yanda, P. Z. (2016). *Establishing a Baseline for Monitoring and Evaluating User Satisfaction with Climate Services in Tanzania.* Center for International Climate and Environmental Research, Oslo, Norway. 54pp.

Daly, M. E., Yanda, P. Z. and West, J. J. (2015). *Climate Change Policy Inventory and Analysis for Tanzania.* Center for International Climate and Environmental Research, Oslo, Norway. 33pp.

Farid, K. S. Tanny, N. Z. and Sarma, P. K. (2015). Factors affecting adoption of improved farm practices by the farmers of Northern Bangladesh. *Journal of the Bangladesh Agricultural University* 13(2): 291 – 298.

Gunasekera, D. (2010). Use of climate information for socio-economic benefits. *Procedia Environmental Sciences* 1: 384 – 386.

Hansen, J., Baethgena, W., Osgooda, D., Ceccatoa, P. and Ngugib, R. K. (2007). Innovations in climate risk management: protecting and building rural livelihoods in a variable and changing climate. *SAT eJournal* 4(1):1 – 38.

Harrison, P. (2006). *Socio-Economic Baseline Survey of Villages Adjacent to the Vidunda Catchment Area, Bordering Udzungwa Mountains National Park.* World Wide Fund for Nature Tanzania Programme Office, Dar es Salaam, Tanzania. 67pp.

Hayelom, B. Chen, Y. Marsie, Z. and Negash, M. (2017). Temperature and precipitation trend analysis over the last 30 Years in Southern Tigray Regional State, Ethiopia. *Journal of Atmospheric Pollution* 5(1): 18 – 23.

Idrisa, Y. L., Ogunbameru, B. O., Ibrahim, A. A. and Bawa, D. B. (2012). Analysis of Awareness and Adaptation to Climate Change among Farmers in the Sahel Savannah Agro-ecological Zone of Borno State, Nigeria. *British Journal of Environment and Climate Change* 2(2): 216 – 226.

IPCC (2013). Climate Change: The physical science basis. *In: Working Group I contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Edited by Stocker, T.),* Cambridge University Press, Cambridge, United Kingdom. 1535pp.

Kangalawe, R. Y. (2017). Climate change impacts on water resource management and community livelihoods in the southern highlands of Tanzania. *Climate and Development* 9(3): 191 – 201.

Kashaigili, J. J., Rajabu, K. and Masolwa, P. (2009). Freshwater management and climate change adaptation: Experiences from the Great Ruaha River catchment in Tanzania. *Climate and Development* 1(3): 220 – 228.

Koskei, R. C. (2012). Access and use of information by small holder tea farmers in Bureti District, Kenya. Dissertation for Award of MSc Degree at Egerton University, Eldoret, Kenya, 55pp.

Kothari, C. R. (2004). *Research Methodology. Methods and Techniques.* New Age International (P) Ltd., New Delhi. 401pp.

Lumosi, C. K. (2014). How community practitioners adapt to climate change: Integrating climate information in adaptation practices: Case Studies from Kenya. Dissertation for Award of MSc Degree at Wageningen University, Wageningen, Netherlands, 95pp.

Lwoga, E. T., Ngulube, P. and Stilwell, C. (2010). Information needs and information seeking behaviour of small-scale farmers in Tanzania. *Journal of Appropriate Librarianship and Information Work in Southern Africa* 40: 82 – 103.

Lyon, S. W., Koutsouris, A., Scheibler, F., Jarsjö, J., Mbanguka, R., Tumbo, M., Robert, K. K., Sharma, A. N. and Velde, Y. (2015). Interpreting characteristic drainage timescale variability across Kilombero Valley, Tanzania. *Hydrological Processes* 29(8): 1912 – 1924.

Maponya, P. and Mpandeli, S. (2013). The role of extension services in climate change adaptation in Limpopo province, South Africa. *Journal of Agricultural Extension and Rural Development* 5(7): 137 – 142.

Mason, S. Kruczkiewicz, A., Ceccato, P. and Crawford, A. (2015). *Accessing and Using Climate Data and Information in Fragile, Data-Poor States*. International Institute for Sustainable Development, Canada. 22pp.

Mignouna, D. B. (2011). Adoption and impact of improved agricultural technologies in developing countries: The case of Imazapyr-resistant maize in Western Kenya. Thesis for Award of PhD Degree at the Sokoine University of Agriculture, Morogoro, Tanzania, 194pp.

Minas, M. G. (2014). Characterization of plant-water interaction in Kilombero River Catchment in Tanzania using Normalized Difference Vegetation Index. Dissertation for Award of MSc Degree at Stockholm University, Stockholm, Sweden, 57pp.

Mosase, E. and Ahiablame, L. (2018). Rainfall and Temperature in the Limpopo River Basin, Southern Africa: Means, variations and trends from 1979 to 2013. *Water* 10(4): 348 – 364.

Mvungi, R. S. (2007). Managing Land use, protecting land and mitigating land degradation: Tanzania Case Study. In: *Climate and Land Degradation: Environmental Science and Engineering*. (Edited by, Sivakumar M. V. K. and Ndiang'ui, N.), Springer Ltd, Berlin, Heidelberg. pp. 437 – 445.

Onyango, E., Ochieng, S. and Awiti, A. O. (2014). Weather and climate information needs of small-scale farming and fishing communities in western Kenya for enhanced adaptive potential to climate change. *Proceedings of Sustainable Research and Innovation Conference* 4: 187 – 193.

Ouédraogo, M., Barry, S., Zougmoré, R. B., Partey, S. T., Somé, L. and Baki, G. (2018). Farmers' willingness to pay for climate information services: evidence from cowpea and sesame producers in Northern Burkina Faso. *Sustainability* 10(3): 595 – 611.

Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy* 11(7): 642 – 654.

Pardoe, J., Conway, D., Namaganda, E., Vincent, K., Dougill, A. J. and Kashaigili, J. J. (2017). Climate change and the water-energy-food nexus: Insights from policy and practice in Tanzania. *Climate Policy* 10: 1 – 16.

Salmi, T., Maattaa, A., Anttila, P., Ruoho-Airola, T. and Amnell, T. (2002). Detecting trends of annual values of atmospheric pollutants by the mann-kendall test and sen's slope estimates: The excel template application Makesens. *Publications on Air Quality* 31: 1 – 35.

Sileshi, M., Nyikal, R. and Wangia, S. (2012). Factors affecting loan repayment performance of smallholder farmers in East Hararghe, Ethiopia. *Developing Country Studies* 2(11): 205 – 213.

Smith, C. D. M. (2016). *Environmental Flows in Rufiji River Basin Assessed from the Perspective of Planned Development in the Kilombero and Lower Rufiji Sub-Basins*. United States Agency for International Development, USA. 46pp.

Onyango, E., Ochieng, S. and Awiti, A. O. (2014). Weather and climate information needs of small-scale farming and fishing communities in western Kenya for enhanced adaptive potential to climate change. *Proceedings of Sustainable Research and Innovation Conference* 4: 187 – 193.

Ouédraogo, M., Barry, S., Zougmoré, R. B., Partey, S. T., Somé, L. and Baki, G. (2018). Farmers' willingness to pay for climate information services: evidence from cowpea and sesame producers in Northern Burkina Faso. *Sustainability* 10(3): 595 – 611.

Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy* 11(7): 642 – 654.

Pardoe, J., Conway, D., Namaganda, E., Vincent, K., Dougill, A. J. and Kashaigili, J. J. (2017). Climate change and the water-energy-food nexus: Insights from policy and practice in Tanzania. *Climate Policy* 10: 1 – 16.

Salmi, T., Maattaa, A., Anttila, P., Ruoho-Airola, T. and Amnell, T. (2002). Detecting trends of annual values of atmospheric pollutants by the mann-kendall test and sen's slope estimates: The excel template application Makesens. *Publications on Air Quality* 31: 1 – 35.

Sileshi, M., Nyikal, R. and Wangia, S. (2012). Factors affecting loan repayment performance of smallholder farmers in East Hararghe, Ethiopia. *Developing Country Studies* 2(11): 205 – 213.

Smith, C. D. M. (2016). *Environmental Flows in Rufiji River Basin Assessed from the Perspective of Planned Development in the Kilombero and Lower Rufiji Sub-Basins*. United States Agency for International Development, USA. 46pp.

Sophia, K. and Emmanuel, M. (2017). Perception and indicators of climate change, its impacts, available mitigation strategies in rice growing communities Adjoining Eastern Arc Mountains. *Universal Journal of Agricultural Research* 5(5): 267 – 279.

UNDP (2013). Water Resources and Climate Change. *Mainstreaming Environment and Climate Change Adaptation in the Implementation of National Development Policies and Plans.* National Environment Management Council, Dar es Salaam, Tanzania. 7pp.

URT (2002). *The National Water Policy.* Ministry of Water and Livestock, Dar es Salaam, Tanzania. 49pp.

URT (2010). *An Ecological Monitoring Programme for the Lower Kihansi Gorge Ecosystem: Report for Lower Kihansi Environmental Management Project.* Vice President's Office, Dar es Salaam, Tanzania.159pp.

URT (2012). *National Climate Change Strategy.* Vice President's Office, Dar es Salaam, Tanzania. 116pp.

Van Aelst, K. and Holvoet, N. (2018). Climate change adaptation in the Morogoro Region of Tanzania: Women's decision-making participation in small-scale farm households. *Climate and Development* 10(6): 495 – 508.

West, J. J., Daly, M. and Yanda, P. (2018). *Evaluating User Satisfaction with Climate Services in Tanzania 2014-2016: Summary Report to the Global Framework for Climate Services Adaptation Programme in Africa.* Center for International Climate and Environmental Research, Oslo, Norway. 63pp.

APPENDICES

Appendix 1: Description of independent variables included in the two-limit Tobit model

Variable	Variable description	Expected sign
X1	Local climate attributes (1 if available, 0 if Otherwise)	+
X2	Scientific climate attributes (1 if available, 0 if Otherwise)	+
X3	Access to the radio (1 if yes, 0 if Otherwise)	+
X4	Access to television (1 if yes, 0 if Otherwise)	+
X5	Extension visits (number and frequency)(1 if yes, 0 if Otherwise)	+
X6	Traditional methods(number)(1 if available and used, 0 if	+/-
X7	Village meetings (number) (1 if often conducted, 0 if Otherwise)	+
X8	Household income (1 if low income, 0 if Otherwise)	+
X9	Main economic activity of respondent (1 if farmer, 0 if	+/-
X10	Position in community (1 if Ordinary citizen, 0 if Otherwise)	+
X11	Size of land owned or used in ha (1 if "3-5", 0 if Otherwise)	+/-
X12	Household age (category) (1 if "40-59", 0 if Otherwise)	+/-
X13	Gender of household head (1 if Male, 0 if Female)	+
X14	Education level in category (1 if primary, 0 if Otherwise)	+/-

Appendix 2: Household Survey Questionnaire

The purpose of this questionnaire is to collect data that will enable assessment of climate variability and availability and use of climate information for water resources conservation decisions.

A: Socio-Demographic Characteristics

<table>
<tr><td colspan="3">Name:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Village:</td><td>Ward:</td><td colspan="2">District:</td></tr>
<tr><td>No.</td><td>Item</td><td>Codes</td><td colspan="2"></td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Age of household</td><td>1) 20 -39 ( )</td><td colspan="2">2) 40-59 ( )</td></tr>
<tr><td>3) ≥60 ( )</td><td colspan="2"></td></tr>
<tr><td>2</td><td>Gender</td><td>1) Male ( )</td><td colspan="2">2) Female ( )</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Education level</td><td>1) Illiterate</td><td colspan="2">2) Primary</td></tr>
<tr><td>3) Secondary & High school ( )</td><td colspan="2">4) College & above ( )</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Marital status</td><td>1) Married ( )</td><td colspan="2">2) Single ( )</td></tr>
<tr><td>3) Divorced ( )</td><td colspan="2">Household size:</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">Wealth category</td><td>1) Low ( )</td><td colspan="2">2) Medium ( )</td></tr>
<tr><td>3) High ( )</td><td colspan="2"></td></tr>
<tr><td>6</td><td colspan="4">Access to extension services Yes/No [ ]</td></tr>
<tr><td>7</td><td colspan="4">Access to climate information Yes/No [ ]</td></tr>
<tr><td rowspan="2">8</td><td colspan="2" rowspan="2">Economic activities</td><td>1) Farmer ( )</td><td>2) Pastoralist ( )</td></tr>
<tr><td>3) Fisherman ( )</td><td>4) Others (specify)</td></tr>
<tr><td rowspan="2">9</td><td colspan="2" rowspan="2">Position in community</td><td>1) Ordinary citizen ( )</td><td>2) Headman ( )</td></tr>
<tr><td>3) Religious leader ( )</td><td>4) Others (specify)</td></tr>
<tr><td>10</td><td colspan="4">Do you have a radio? Yes/No [ ]
1) Yes ( )
2) No ( )</td></tr>
<tr><td>11</td><td colspan="4">Do you have a television? Yes/No [ ]
1) Yes ( )
3) No ( )</td></tr>
<tr><td>12</td><td colspan="4">Do you own land? Yes/No [ ] If yes what size:</td></tr>
</table>

B: Perception of Climate Change and Impacts on Water Resources

No.	Have there been any of the following changes in this village?		
1	Delays in the beginning of rain season		Yes/No [ ]
2	Shortened rain season		Yes/No [ ]
3	The decrease in quantity of rains		Yes/No [ ]
4	Increase in temperatures		Yes/No [ ]
5	Increase in sunshine		Yes/No [ ]
6	Frequent droughts & frequent floods		Yes/No [ ]
7	Increase of plants and animal pests		Yes/No [ ]
8	What causes climate variability and change in this area?		
9	How have these changes impacted your household?		
10	How has climate change impacted waters resources in this area?	Loss of water quality	
		Decrease in rivers flows	
		Dry out of some streams and rivers	
		Others (specify)	

C: Climate Information Attributes and Sources in Kilombero River Catchment

No.	Are the following attributes used in your area		Choices
1	Plant phenology indicators		Yes/No [ ]
2	Birds, insects or animals behaviours		Yes/No [ ]
3	Astronomical indicators		Yes/No [ ]
4	Daily weather forecasts		Yes/No [ ]
5	Seasonal forecasts		Yes/No [ ]
6	Others (specify):		
7	Sources of climate information in your villages?	1) TV ( )	2) Extension visits ( )
		3) Radio( )	4) Neighbours/relatives ( )
		5) NGOs ( )	6) Other (specify):

D. Use of Climate Information for Water Resources Conservation Decisions

No.	Water Conservation Decisions	Choice
1	Do you use climate information for making water conservation decisions?	1) Yes ( ). 2) No ( ).
2	What adaptation decisions do you implement relevant for water conservation?	
3	What regulations implemented in your areas which protect water resources?	
4	What can be done to improve uptake of climate information?	

THANK YOU

Appendix 3: Interview Guide for Focus Group Discussions

1. What are the main socio-economic activities in this area?
2. Water resources available in this village?
3. How do you compare current patterns of climate with the past?
4. What major events related to climate change occurred in this village? (Since the 1970s)
5. How have these changes affected your livelihood and water resources?
6. What are the climate information attributes available in the area?
7. What are the sources of these attributes?
8. How do you use climate information in making water conservation decisions (adaptation)?
9. What policies/regulations implemented which helps to conserve water resources?
10. What can be done to improve uptake of climate information?

THANK YOU

Appendix 4: Checklist for Interviews with Key Informants

1. What is the importance of water resources under your jurisdiction?
2. What indicators depict climate variability and change in your area?
3. What do you think are causes of climate variability and change in your area?
4. What are the impacts of climate variability and change on water resources?
5. Climate information availability and accessibility?
6. How do you use climate information to conserve water resources?
7. Which specific policies and regulations which you implement which help to conserve water resources?
8. The extent of climate change adaptations strategies in policies and regulations?
9. What opportunities are available for greater use of climate information?

THANK YOU