COMMUNITY ADAPTATION TO CLIMATE VULNERABILITY EFFECTS ON BANANA FARMING IN ZANZIBAR

BY

Haji, Thuwaiba Kassim

REG, 2015/02/0008/TZ

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ENVIRONMENTAL SCIENCES IN THE SCHOOL OF NATURAL AND SOCIAL SCIENCES OF THE STATE UNIVERSITY OF ZANZIBAR

NOVEMBER 2019
DECLARATION

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

........................................... ...........................................
Signature                                              Date

Thuwaiba Kassim Haji

Reg no: 2015/02/0008/TZ

Supervisors

We as supervisors confirm that the work in this dissertation was carried out by the candidate under our supervision.

........................................... ...........................................
Signature                                              Date

Dr. Rashid Juma

Department of sciences

........................................... ...........................................
Signature                                              Date

Dr. Abdallah Ibrahim

Directorate for Graduate Studies, Research and Consultancy
DEDICATION
To my mother Nyejua M. Hassan and my father Kassim Haji Ameir for their good foundation of learning.

And

My husband Khamis Sheha Khamis and my children for being a motivation of my inspiration to a better life.
ACKNOWLEDGEMENT

I wish to express my gratitude and appreciation to ALLAH for guiding me through this study. Special gratitude goes to my supervisors Dr. Rashid Juma and Dr. Abdallah Ibrahim for their patience, encouragement, guidance and concerned role they played in the completion of this course.

I appreciate the support by Prof. Mohammed Ali Shehe, Dr. Makame Omar Makame, and other academic staff of the Department of post graduate studies at the State University of Zanzibar for their contribution, constructive criticism and suggestions which helped to sharpen the focus of this study. Furthermore, my sincere thanks to the Director of Tanzania Meteorological Agency (Zanzibar office) Mr. Ngwali and Director of Kizimbani Agricultural Research Institute for the same.

My gratefulness to all district officers in the study areas including district agricultural officers, block extension officers (BEO) and shehas of Kajengwa, Kijini (Makunduchi), Kinyasini and Kizimbani for their guidance participation during data collection.

I further wish to express my sincere thanks to my husband who has been a constant source of my inspiration, moral support and patient heart till the end of my study. My fellow students, especially Mr. Sabri Idrisa Haji for his support and assistance in data analysis.

My sincere gratitude is extended to every person who contributed in one way or another to the successful completion of this study. May Allah almighty rewards you immensely. Thuwaiba Kassim Haji.
# TABLE OF CONTENTS

DECLARATION .................................................................................................................. i  
DEDICATION .................................................................................................................. ii 
ACKNOWLEDGEMENT ................................................................................................... iii  
LIST OF TABLES ............................................................................................................. viii  
LIST OF FIGURES .......................................................................................................... ix  
LIST OF PLATES ............................................................................................................ x  
LIST OF ABBREVIATION ............................................................................................... xi  
ABSTRACT ...................................................................................................................... xii 

## CHAPTER ONE ............................................................................................................. 1 
1.1 Background ............................................................................................................... 1  
1.2 Statement of the Research Problem and Justification ............................................. 4  
1.3. Research Objectives ............................................................................................... 5  
  1.3.1. General Objective ........................................................................................... 5  
  1.3.2. Specific Objectives ......................................................................................... 5  
1.4. Research Questions ................................................................................................. 6  
1.5. The Significance of the Study ............................................................................... 6  
1.6. Limitations of the study ....................................................................................... 7  

## CHAPTER TWO .......................................................................................................... 8 
LITERATURE REVIEW .................................................................................................... 8  
  2.1. Climate change and variability in Zanzibar ......................................................... 8  
    2.1.1. Rainfall ......................................................................................................... 8  
    2.1.2. Temperature ............................................................................................... 11  
    2.1.3 Wind ............................................................................................................. 12  
    2.1.4. Humidity ................................................................................................... 13  
    2.1.5. Impacts of Climate Change Variability ...................................................... 13
2.2. Effects of Climate Change and Variability on Banana Farming .............. 15
   2.2.1. Proliferation of Diseases and Insects ........................................... 15
   2.2.2. Optimum Climatic Conditions (OCC) for Banana Plantation .......... 16
2.3. Adaptation to Climate Change and Variability Impacts on Banana ........ 18
2.4. Banana for livelihoods of the people .................................................. 23
2.5 Farmers’ perception on the adequacy or satisfaction towards adaptation option taken .................................................................................................................. 23

CHAPTER THREE .................................................................................. 25
METHODOLOGY ...................................................................................... 25
   3.1. The Study Area ................................................................................. 25
     3.1.1 Climatic condition ................................................................. 25
     3.1.2. Soil ....................................................................................... 26
     3.1.3 Crops Production .................................................................... 26
   3.2 RESEARCH DESIGN FOR THE STUDY .............................................. 27
     3.2.1 Exploratory research design .................................................... 27
     3.2.2 Descriptive research design .................................................... 27
   3.3. Study area selection and justification .............................................. 27
   3.4 SAMPLE AND SAMPLING PROCEDURE .......................................... 28
   3.5 Data collection methods ................................................................. 29
     3.5.1 Primary data ............................................................................ 29
     3.5.2 Secondary data ........................................................................ 30
   3.6 Data analysis .................................................................................... 31
   3.7 Reliability and validity ..................................................................... 31

CHAPTER 4 ............................................................................................ 32
RESULTS AND DISCUSSION ................................................................. 32
   4.1. Socio Economic Characteristics of Banana Farmers ....................... 32
4.1.1. Years of Farming ........................................................................................................... 32
4.1.2. Reasons for Banana Farming ................................................................................... 33
4.2 Variability of Rainfall, Temperature and Wind in Zanzibar ........................................ 34
  4.2.1. Annual Rainfall in Zanzibar ................................................................................... 34
  4.2.2. Average Monthly Rainfall for Zanzibar ................................................................. 36
  4.2.3 Average Monthly Temperature for Zanzibar ......................................................... 37
  4.2.4: Wind for Zanzibar ................................................................................................. 38
4.3. Variability of Climate Change Factors ......................................................................... 41
  4.3.1 Impacts of rainfall pattern ....................................................................................... 41
  4.3.2 Average Monthly Rainfall in the study Areas ......................................................... 42
  4.3.3 Average Monthly Temperature in the Study Areas ................................................. 45
4.4 Climate Change and Variability Impacts on banana farming ........................................ 45
  4.4.1 Rainfall Impacts on banana .................................................................................... 45
  4.4.2 Temperature impacts on banana ............................................................................. 46
  4.4.3 Wind Impacts on banana ....................................................................................... 46
  4.4.4 Effects of Variability of Climate Change Factors on Banana Farming ................. 47
  4.4.5 Observed changes on banana production ............................................................... 51
4.5 Adopted Measures to Climate Change and Variability Impacts ..................................... 52
4.6 Perception of Farmers on Adopted Measures ............................................................... 59
4.7 Achievement of the Adopted measures ......................................................................... 59

CHAPTER FIVE ....................................................................................................................... 62

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION ....................... 62
  5.1. Summary of findings and conclusions ...................................................................... 62
  5.2 Recommendations ....................................................................................................... 63
  5.3 Recommendation for further studies .......................................................................... 63

REFERENCES ......................................................................................................................... 65
APPENDICES .................................................................................................................. 73

Appendix 1: Interview for banana farmers in the selected regions......................... 73
Appendix 2: Interview for other key informants in institution in the selected regions. ........................................................................................................................................ 76
LIST OF TABLES
Table 1.1: Potential Agricultural Intervention in Integrating Climate Change Adaptation in Tanzania .......................................................... 20
Table 4.1: Relationship between banana yields and climate factors from 2010 - 2014 .................................................................................................................. 40
Table 4.2: Analysis of Annual Rainfall Data from the Study Areas ......................... 46
LIST OF FIGURES

Figure 2.1: Time series of rainfall pattern in Unguja Island 1961-2011 (TMA, Zanzibar) ................................................................. 10

Figure 2.2: Projection of temperature change from the current climate to the future climate (2050’s) of Zanzibar.......................................................... 11

Figure 2.3: Annual monthly mean wind speed ........................................... 18

Figure 3.1: Maps of Unguja Island in Zanzibar showing the study areas .............. 28

Figure 4.1: New farming experience in the study sites ........................................ 32

Figure 4.2: Reason of planting banana ................................................................ 33

Figure 4.3: Annual Rainfall Trend for Zanzibar (TMA, 2017) ......................... 35

Figure 4.4: The Annual Monthly Average Rainfall for Zanzibar (TMA, 2017) ....... 36

Figure 4.5: Annual Average Monthly Temperatures in Zanzibar (TMA, 2017) .... 37

Figure 4.6: Annual Average Wind Pattern for Zanzibar 1986 to 2014 (TMA, 2017). 39

Figure 4.7: Annual average Monthly Wind for Zanzibar. (TMA, 2017)............. 39

Figure 4.8: Banana Production in Zanzibar (in Tonnes)..................................... 40

Figure 4.9: Annual Rainfall in the Study Areas from 2009 - 2015 (TMA, 2017)...... 42

Figure 4.10: Average Monthly Rainfall at Makunduchi (TMA, 2017)................. 43

Figure 4.11: Average Monthly Rainfall at Kizimbani (TMA, 2017) .................... 44

Figure 4.12: Average Monthly Rainfall at Kinyasini (TMA, 2017).................... 44

Figure 4.13: adaptation options agreed by farmers........................................... 58
LIST OF PLATES

Plate 4.1: Rotten Banana Plants .................................................................48
Plate 4.2: Banana Plant Diseases Infections ................................................48
Plate 4.3: Breakage of Banana Plants ..........................................................49
Plate 4.4: The Growth of Banana Plants .......................................................50
Plate 4.5: Irrigation Measures to Banana Farming ........................................53
Plate 4.6: Fertilization in Banana Farming ...................................................54
Plate 4.7: New Banana Varieties .................................................................56
Plate 4.8: Others Useful Adopted Measures .................................................57
### LIST OF ABBREVIATION

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Musa acuminata</td>
</tr>
<tr>
<td>AAA</td>
<td>Triploid Musa acuminata</td>
</tr>
<tr>
<td>ABB</td>
<td>Triploid Musa acuminata × Musa balbasiana</td>
</tr>
<tr>
<td>ASSP</td>
<td>Agricultural Services Support Programme</td>
</tr>
<tr>
<td>BB</td>
<td>Musa balbasiana</td>
</tr>
<tr>
<td>BEO</td>
<td>Block Extension Officer</td>
</tr>
<tr>
<td>DADO</td>
<td>District Agricultural Development Officer</td>
</tr>
<tr>
<td>GDP</td>
<td>Growth Domestic Production</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>NBS</td>
<td>National Bureau of Statistics</td>
</tr>
<tr>
<td>SLFFS</td>
<td>Season Long Farmers Field School</td>
</tr>
<tr>
<td>TCZ</td>
<td>Tanzania Coastal Zone</td>
</tr>
<tr>
<td>TMA</td>
<td>Tanzania Meteorological Agency</td>
</tr>
<tr>
<td>URT</td>
<td>United Republic of Tanzania</td>
</tr>
<tr>
<td>ATI</td>
<td>Agricultural Transformation Initiatives</td>
</tr>
</tbody>
</table>
ABSTRACT

Banana production declined due to change of rainfall regularity of season and intensity, rising temperature and wind, that affect banana productivity. The aim of this study is to examine climate change impacts and adaptation measures to banana farmers. Data on rainfall, temperature and wind were observed, as well as adaptation measures taken by farmers towards the climate changed and variability impacts and to determine farmers’ perception on the adequacy or satisfaction towards adaptation option taken. To attain the study objectives a survey method includes, questionnaires to the farmers, in depth interview to the key informant of institute of agriculture and ASSP officers, documentary to the climate data at TMA and observation to the farming block was employed at Makunduchi, Kinyasini and Kizimbani from three different regions of South, North and Urban West in Zanzibar. The SPSS computer programme was used to obtain descriptive statistics of the collected data and Microsoft excel was used to analyze climate data using one sample t-test method. The result shows that banana farming suffer from insufficient rainfall and high dry spells as annual monthly rainfall is (p-value 0.03948) which means that there is a significant difference from the base line of 60 mm per month. However, there is no significant difference for average monthly temperature and annual monthly wind, in which p-value =3.528e^{-07} for a minimum temperature of 24°C and 8.599e^{-10}, for a maximum temperature of 33°C and annual monthly average wind has p-value of8.42e^{-12}. It is concluded that adaptation to reduce rainfall impacts is necessary to improve production, as observed at Makunduchi where technical and institutional changes able to manage a good farming practice, especially irrigation, to increase production, while in Kinyasini and Kizimbani the inadequate water supply could not sustain banana production. Overall, water infrastructure or irrigation should be improved to promote high production so as to maintain livelihood and ensure enough food supply.
CHAPTER ONE

1.1 Background

Climate change adaptation aims to mitigate and develop appropriate coping measures to address the negative impacts of climate change on agriculture (Ziervogel, et al., 2008). The policy debates has increasing focus on adaptation to climate change, thus referred differently in articles by UNFCC and the Kyoto protocol (Adger, et.al; 2006). The altered climate condition forces farmers to adopt new farming practices in response to climate’s direct impacts to livelihood (Molua, 2007). Adaptation measures help to reduce negative climate change impacts to agriculture which is highly vulnerable due to rising of temperature and decreasing of rainfall, apparently destroying farming communities around the world (UKAID, 2011; Borroughs, 2007; IPCC, 2007). Technical, institutional and educational changes are crucial for stimulating agricultural development in maintaining livelihood and food security which continue to deteriorate in Sub Saharan Africa where the number of people living in poverty has increased in the last decade (Olsson et al., 2014; Norton et al., 2010; Thornton et al., 2008; IPCC, 2007:). Therefore adaptation is among focal area of the special work programmed assist to Least Developed countries supported by Least Developed Countries Fund from Global Environmental Fund (Adger, et. al., 2006).

The 21st century global challenge is the increasing of food supply to sustain a world growing 10 billion or more people under the climate change succession (Esterlling, 2007). To meet this challenge, it requires enough techniques and institutional innovation to supplement food production and simultaneously adapting to the change of climate condition. Therefore, under the supervision of United Nation, The Intergovernmental Panel on Climate Change (IPCC) assembled a team to conduct a
comprehensive assessment on the state of knowledge of climate change sciences, the potentials impacts and adaptation to climate change that provide new insights about climate change and its effects on natural and human system (Esterling, 2007). In Kenya, climate change lead to increase in prices of agricultural commodities including basic staple food due to climate change impacts on productivity which decline food affordability as trade increased simultaneously with increased food demand (Herrero et al., 2010). Moreover, a yield for bananas, sweet potatoes, yams and cloves has been declining in Zanzibar from 1999 (Mdoe, 2003). All these have impact on human being as a result of climate change.

Africa is among the continents which is more vulnerable to climate change and variability impacts (Hulme. et al., 2001). Currently, the African climate is warmer than it was in 100 years ago. A warming climate not only leads to scarcity on water resources, but rainfall is significantly altered, which is among the major influences to the suitability for the growth of banana production (Hulme. et al., 2001). The findings of the study covering almost all regions of Tanzania show that change of climatic condition is a key driver for farmers to change crops they prefer to farm before including banana, disappearance of old types of seeds while other change the type of seeds example for banana use Fundación Hondureñ de Investigación Agrícola (FHIA) new variety like in Bukoba and Arusha as well as use irrigation (Mbiliji et al., 2013). In addition there are air borne vector population that influences spread of banana diseases such as Xanthomonas wilt diseases that affect eastern, central and southern African countries (Smith et al., 2008; Boko et al., 2007; and Hulme et al., 2001). This results into a large economic impact to these countries because their economies are dependent on sectors that are vulnerable to climate condition through which agriculture
employs 60% - 90% of the total labor force in sub-Saharan African (Toulmin and Huq, 2006).

In Tanzania agriculture is the dominant sector accounting for 75.1% of the employment (NBS, 2007). Moreover, agriculture is by far the most important source of employment in Zanzibar; whereby more than 70% of the population depends directly in the agriculture for their livelihood (ATI 2009). This sector contributed to an average of 25% of the total GDP within eight years period from 2000 to 2007, which is attributed by its dominance in foreign exchange earning which currently accounting to over 70% of Zanzibar economy (ATI, 2009).

Banana in Tanzania considered as a valuable food and cash crop (Pedersen, 2012). It takes up to 60% of the daily per capita calorie intake in the most productive regions of Western Tanzania (Abele et al., 2007). It is also considered to be the second important food crop to 35.2% of farmers from all districts in Zanzibar compared to cassava (43.1%). Banana is also considered an important cash crop (15.5%), the third to cassava (18.9%) and vegetables (16.4%) (Mdoe, 2007). Zanzibar possesses 22 banana varieties growing on various locations. The most predominant varieties are those with genomic AAA and AAB sub group with seven and eight varieties respectively, the AA sub group with three varieties, the ABB sub group with three varieties and the AB with one variety (Rajab, 1999).

The threatening aspects of climate change in Zanzibar includes in-adequate rainfall, increase in temperature and change regularity of the seasons, which are all extremely detrimental to the survival of agricultural success on the island (UKAID and Global Climate Adaptation Partnership, 2012b). It is noted that seasons are getting less and less
predictable. Example rainfall during Masika and Vuli has shifted intensity and in some places in the island, the Vuli season has completely disappeared (Makame et al., 2015 and Reid, 2012). The scarcity of rainfall leading to water stress due to prolonged droughts results into higher wilt incidences causing banana plants more vulnerable to banana *Xanthomonas* wilt diseases infection during and after inoculation periods (Ochola et al., 2015). This relatively leads to decreases in yield of banana in Zanzibar (UKAID and Global Climate Adaptation Partnership 2012b).

For banana and plantains, climate change and variability may alter both yield as well as vulnerability to diseases affecting farm output, which consequently threaten livelihood of farmers (Mbiliji et al., 2013; ATI, 2009 and Lusty et al., 2002). Some indicative studies estimate up to 10% reduction in suitability, as well as loss in soil fertility for banana in the regions (UKAID and Global Climate Adaptation Partnership, 2012b and ATI, 2009). This condition endangers the livelihood of Zanzibaris since banana ranked the third major produced crop in Zanzibar after cassava and rice (ATI, 2009). Therefore, adaptation to climate change and variability is required to reduce vulnerability to banana farming so as to sustain livelihood and prevent extreme poverty of Zanzibar’s (Howden et al., 2007).

**1.2 Statement of the Research Problem and Justification**

In Zanzibar, banana is considered as essential staple food ranked third in terms of use, after rice and cassava. It is also an important source of trade and income generating crop especially in small scale business. From 1999, banana production in Zanzibar has been decreasing due to poor use of farming materials includes manure as well as
availability and supply of improved seed varieties, which cannot resist climate change impacts.

Several studies have reported the decline of banana productivity in many areas. The studies show close linkage between variation in banana yields and non-climatic factors including variation in soil fertility, nematodes like *Radopholus similis*, *Helicotylenchus multicintus* and *pratylenchus coffeae* and diseases such as sigatoka, batobato and panama, which lead to decline of banana productivity. However, few researches have been focusing on impact of increased climatic variability and role of weeds to crops health. High vulnerability to climate change is being observed in Zanzibar, but farmers are not well aware on adaptation measures to sustain and improve yield. They are still using traditional farming methods. Therefore, adaptation to anticipate climate change is essentials and possible strategies for improving productivity is clearly identified.

Therefore, this study examines the variability of climate change factors (rainfall, temperature and wind patterns) and their effects on banana production in Zanzibar.

1.3. Research Objectives

1.3.1. General Objective

The main objective of this study is to examine the adaptation to the impacts of climate change and variability impacts on banana farming in Zanzibar.

1.3.2. Specific Objectives

The study was guided by the following specific objectives: -

1. To examine the observed data of temperature, rainfall and wind and their impact on banana farming in the study areas.
2. To identify adaptation measures taken to banana farming towards the climate change and variability impacts.

3. To determine farmers’ perception on the adequacy or satisfaction towards adaptation option taken.

1.4. Research Questions

The study was guided by the following questions: -

1. What are the observed impact of temperature, rainfall and wind on banana farming in the study areas?

2. What are the adaptation options taken to reduce climate change and variability impacts on banana farming?

3. What are farmers’ perceptions towards adequacy or satisfaction of adaptation options taken?

1.5. The Significance of the Study

The study intends to develop knowledge on climate change adaptation options to farmers in order to cope with associated variability impacts. This is due to the fact that there is direct relationship between the risk of climate change and increasing loss of major crops in agricultural sector, hence the economy of Zanzibar. The adaptation options are inevitable at the moment due to the vulnerability of agriculture as the priority sectors to the adverse effects of climate change since they facilitate the increasing of agricultural output and maximize efficiency on the management options to reduce negative impacts on climate change variability. This study will strengthen adaptation knowledge and understanding that will help farmers understand ways to improve their crop production and henceforth standards of living.
1.6. Limitations of the study

The major limitations of the study were on availability of historical data on variability of temperature and wind on the study sites. This delayed accomplishment of research objectives related to climate factors (wind and temperature). Therefore, Zanzibar general climate data has been used instead. Furthermore, inadequate data on banana yield at the study sites limited comparison between yields and farming practices undertaken as well as their relationship with climate variability alternatively the data on trend of production for Zanzibar was used. Financial constraint was also noted and hit severely during data collection to the point of prolonging data collection time estimated earlier.
2.1. Climate change and variability in Zanzibar

IPCC (2007) define climate change as the change attributed directly or in direct to human activity that alter the composition of the global atmosphere and that is to an addition to natural climate variability observed over comparable time periods. As for climate variability, URT 2012 has defined it as the variation in mean state and their statistics (such as standard deviation, the occurrence of the extremes etc) of the climate on temporal and spatial scale beyond that of the individual on weather events.

Climate change operates over decades as a result of both internal variability within the climate system and external factor, the climate record shows that climate is always change (Ebi, et.al; 2003).

There is strong observational data to suggest that Zanzibar climate is changing, with evidence that extreme events are intensifying. The meteorological data from the island show the following changing trends:-

2.1.1. Rainfall

From 1961 to 2000 Zanzibar rainfall ranged from 150mm to 260mm (March - May) and 220mm (October - November) during rainy season, and dry seasons ranges from 70mm to 180mm in (June to September) (UKAID and Global Climate Adaptation Partnership, 2012c).

Currently Zanzibar climate model shows more complex change in precipitation. All climate models show that the rainfall regime will change but the projections varies
between the models and seasons. Nonetheless, there are consistent projected trend of increasing rainfall between 200 mm to 290 mm (March and May) and 210mm to 270mm (October – November) as well as increase between January and February. There is also trend of decreasing rainfall of between 130mm to 40mm during dry season around June to October (UKAID and Global Climate Adaptation Partnership, 2012c).

These changes would exacerbate existing trends i.e. increasing rainfall during the rainy season (UKAID and Global Climate Adaptation Partnership, 2012a). Also, there are many subjective reports of changes in rainfall patterns in term of greater variability and in particular the onset of the rainy season. Several reports highlight that farmers used to know the likely onset of the March to May season (Masika) almost down the date in late March when the rain would arrive (UKAID and Global Climate Adaptation Partnership, 2012a). Figure 2.1 shows rainfall pattern in Unguja Island for the period of 50 years from 1961 to 2011.
Interannual rainfall variability is larger over the most of African and for some regions. The variability observed illustrated in the Sahel, East African and Southern African which differ in rainfall variability characteristics (Hulme et al., 2001). The Sahel is multi decadal with recent drying, East Africa is relatively stable regime with long term wetting and southern African basically stable regime but marked with interdecadal variability (Hulme et al., 2001). Tanzania experiences unimodal and bimodal pattern of rainfall. Unimodal rainfall occurs in November to December and April in southern, south western, central and western areas. The bimodal rainfall regime has two rain seasons the long rainfall (Masika) experienced between March and May and the short rain season (Vuli) occurring between October and December, over the north coast, north eastern highlands, Lake Victoria basin and isles of Unguja and Pemba (NBS, 2004).

Figure 2.1: Time series of rainfall pattern in Unguja Island 1961-2011 (TMA, Zanzibar)
2.1.2. Temperature

From 1961-2000, highest temperature ranged from 31.2°C to 31.5°C and the lowest temperature ranged from 28.2°C to 29°C. (UKAID and Global Climate Adaptation Partnership, 2012c). The climate models for Zanzibar project significant increases in average temperature, with increases in maximum monthly temperature of 1.5°C – 2°C by 2050’s (2045-2065) to reach 33°C to 33.6°C highest temperatures and 30.5°C to 31.5°C the lowest temperature (Figure 2.2).

![Image of temperature projection]

Figure 2.2: Projection of temperature change from the current climate to the future climate (2050’s) of Zanzibar.

(Source: UKAID and Global Climate Adaptation Partnership, 2012c).

It is projected that there will an increased change in temperature between 2°C to 4°C by the 2090's (2081-2100) with a fairly similar increase across the months of the years (UKAID and Global Climate Adaptation Partnership, 2012a). This increase exceeds the rates of change seen in the past 50 years and would significantly shift the climate of the islands (UKAID and Global Climate Adaptation Partnership, 2012a).
The model base prediction of African suggests that warming will continue and accelerates to almost 2°C to 6°C average in 100 year’s time (Hulme et al., 2001). Although in 20th century warming increased at the rate of 0.5°C, warming is slightly larger in June to August and also in September to November seasons (Hulme et al., 2001).

2.1.3 Wind
Zanzibar is among the coast region of Tanzania. It is affected by prevailing monsoon wind system, which is influenced by seasonal shift in the Inter-Tropical Convergence Zone (ITCZ). When the ITCZ is in the south, wind blow from the north east and when it is in the north the wind comes from the south east (Mahongo et al., 2010). The north east wind extends from December to February characterized by higher air temperature and lower wind speed, while south east wind monsoon begins in April and ends in November (Mahongo et al., 2011). Winds in Zanzibar have been changing steadily over 20 years study period as a consequence of the changing global climate (Mahongo et al., 2010). The annual rate is increasing with over the 28 years period it was 0.07m.s⁻¹ (Mahongo et al., 2010).

The global change of mean wind speed noted in different regions in the world. For instance, in Europe, over the Arctic Ocean wind speed may increase due to change in sea ice and associated changes in sea surface temperature (Kjellström et al., 2018). Moreover, a larger part of South Africa (including Northern Cape and Western Cape) expects a 10% relative increase in wind speed from 1981 - 2100 (McInness et al., 2011).
2.1.4. Humidity
In Zanzibar relative humidity is high, of about 75% throughout the year, with average monthly ranging from 87%, in April (Masika) range 76% and a minimum 60% during dry season to a values range of 80% (Kakaire, 2018).

The change in atmospheric humidity as a consequence of climate change still is under debate. Although more studies suggest that relative humidity will remain more or less constant and could decrease by 10 to 20% by the end of 21st century (Moratiel et al., 2010). In Zanzibar the change of relative humidity is not well discussed, however the prevalence of black sigatoka diseases to banana indicates the rise of relative humidity above 90%, since black sigatoka spread under a maximum of 92 - 95% relative humidity (Jacome et al., 1991). Banana production needs moderately high humidity of between 74% to 79% and declines as humidity decreases (Salau et al., 2016).

2.1.5. Impacts of Climate Change Variability

2.1.5.1 Rainfall

The length of crop cycles and the seasonality of bunch production will be affected due to greater irregularity of rainfall. Low rainfall slow leaf emergence, which affect bunch size. Yield declines due to increased length of the vegetative period under below optimum moisture, which largely affects small holders due to high dependency on rainfall (Thornton, 2012). In many region banana productions limiting with more than three month dry spell (Sabiiti et al., 2016)

Nearly all information indicate the intensification of heavy rainfall especially during rainy season and thus greater flood risks, also indicates an increase intensity of the dry
spells during the dry season. This trend suggests possible intensification of extreme events (UKAID and Global Climate Adaptation Partnership, 2012a).

Most crop are less resilient to this climatic factor including cassava, which has no resistant to drought and flooding when exposed to saturated soil for extended periods as much affected by root rots (Thornton, 2012). This is also a reality to other crops such as watermelon, tomatoes, onion and capsicum.

2.1.5.2. Temperature

The increase in average annual temperature restricts delicate balance to banana, as it increases rate for banana pests and diseases. *M. fujimensies* for Black Sigatoka grows faster at higher temperature of 20°C to 35°C (Marin et al., 2003; Jacome et al., 1991). And banana bunch top viruses vectored by banana aphid as well as accelerate the reproduction rate of banana weevil and nematodes in higher altitudes and sub tropic involve Zanzibar (Thornton, 2012).

2.1.5.3. Humidity

The production of banana increases with increased relative humidity (Salau et al., 2016), though poses greater risk on spread of conidia and ascospores causing Black Sigatoka (Marin et al., 2003). This can lead to reduced production. Germination of black sigatoka causing agents occurs at above 95% relative humidity in the free water condition, with the germination rate of ascospores being higher than conidia. No agent germination is observed at less than 95% (ascospores) and 88.5% (conidia)(Jacome et al., 1991). Moisture deficit relates to reduction of production to 46% optimal yield (Sabiiti et al., 2016).
2.2. Effects of Climate Change and Variability on Banana Farming

Climate change and variability are one of the greatest environmental and developmental challenges that poses major threats in the African countries. Tanzania like other Africans countries experiences climate change impacts which includes frequent and prolonged droughts, in-adequate water availability, severe floods and an increase in vector and water borne diseases (URT, 2012). These affect crop productivity as well as economy of a country at large. Banana, like other crops, is negatively affected by threats and variability of climatic change leading to loss in crop yields as follows: -

2.2.1. Proliferation of Diseases and Insects

There are general perceptions by the majority of farmers that incidence of crop pests has increased over the past few decades and that the pests have become more prevalent with time (Hossain, 2014). As a result, emergence of diseases such as batobato (banana Xanthomonous wilt, Panama diseases or Fusarium wilt), plants parasitic nematodes (Rastolnia solanacearum) pose serious damage and yield loss to banana (Hossain, 2014; Rajab, 1999). The invasion of these pests and diseases result into yellowing and wilting of leaves which eventually dry up resulting into death of plants. Moreover, fungal diseases such as Mycosphaerella fijiensis causing black sigatoga and Mycosphayrella musicolla causing yellow Sigatoga (leaf sport), as well as post-harvest yield diseases such as Anthractose, crown rot, fruit rot and neck rot result into loss of crop yield. However, precautionary measures and chemical control are being taken sustain livelihood of farming communities in Zanzibar (Hossain, 2014; Bellamy, 2013; URT, 2012).
2.2.2. Optimum Climatic Conditions (OCC) for Banana Plantation

2.2.2.1. Temperature

Banana is a tropical fruit of which its productivity is influenced by temperature. It is observed that for normal growth and development, the crop needs the temperature below 38°C, above which stops the growth and development. If the temperature falls below 10°C, yield is extended with reduced bunch weight as the inflorescences fail to emerge completely from the top of the stems (Hossain, 2014; Acland, 1971). Furthermore, increased temperature has potential effects on banana in influencing prevalence of pathogens such as *Fusarium oxysporum* and *Mycosphaerella fijiencies* caused by reduced relative humidity (Ghini, 2011). Thus, in order to attain good harvest, the temperature should stay to a minimum of 18°C and the maximum of 33°C. There is a very low or no productivity when the temperature range falls below 25°C – 26°C (Salau et al., 2016). Negative impacts on highly temperature sensitive crops are projected in the long term in the islands. There is relatively low production of banana yield among countries affected by climate change, and some regional studies indicate decreases in crop yield (UKAID and Global Climate Adaptation Partnership, 2012a).

2.2.4.2. Rainfall

Patterns of rainfall play a greater role in banana crop production. The optimum yield of banana crop requires a constant supply of soil moisture with abundant rainfall, which helps banana to achieve its potential height from sprouting stage through growing periods (Salau et al., 2016). To attain a better yield, a minimum of 1500mm is needed throughout the year, with plentiful moisture supply during flowering time, while above 1500mm per year is more favorable. Banana requires about 60mm monthly rainfall, thus the month below this amount is considered dry (German et al., 2015). More than
three dry months without irrigation, makes impossible for banana growth and makes it favorable condition for banana diseases (German et al., 2015).

2.2.4.3. Drought:
Drought leads to increased cost of living due to increases in food prices (Farrel et al., 2010). This is an important factor, coupled with high temperature stress and soil salinity, favoring biotic constraints that restrict banana cultivation. Drought causes plant to suffer from dehydration and overheating of its cells and tissue (Ravi et al., 2013). The increasing spell of extreme events, including droughts, has been reported in Zanzibar ((UKAID and Global Climate Adaptation Partnership, 2012a). Zanzibar Islands are considered the most affected areas of extreme drought to 52% of 48% non-drought events in the Tanzania Coastal Zone (TCZ) (Hassan et al., 2014). Drought pattern in the TCZ shows an increase of drought magnitude with time in a manner that can cause severe effects to important sector of economy including agriculture, especially when subjective adoptive plans to drought are not taken (Hassan et al., 2014).

2.2.4.4. Winds:
Banana can be considerably damaged by wind. Adverse winds cause toppling of plants by fissuring the pseudo stem and uprooting, as well leaf tearing and removal of whole lamina section (Parra et al., 2001). Winds at the speed of 40-72 km/hr (25-45mph) equivalent to 21.5053-38.7096 knots can topple plants when they bear banana bunch (Nelson et al., 2006).. They can also cause more damage if the ground corm is weakened by insect pests resulting to reduced productivity ((Nelson et al., 2006; Salau, et al., 2016). Leaf tearing has effects on transpiration rate by loosing water through the edge of tearing leaves and use only one half of water required by a similar un-teared
leaves (Brun, 1961; Taylor 1970). These effects can be observed in Zanzibar since wind speed data indicates an increased speed over the past 20 years as shown in Figure 2.3.

Figure 2.3: Annual monthly mean wind speed.

Source (UKAID and Global Climate Adaptation Partnership, 2012a).

Thus, strong wind, rainfall amount and temperature ranges affect banana productivity as the crop tends to produce less under these climate conditions. Generally, high levels of banana productivity are associated with moderately optimum rainfall, temperature and good relative humidity (Salau et al., 2016).

2.3. Adaptation to Climate Change and Variability Impacts on Banana

According to IPCC (2007), adaptation refers to the adjustment in natural or human system in response to actual or expected climatic stimuli or their effects which moderate harm to exploit beneficial that opportunities.
There are high confidences that there are viable adaptation options that can be implemented with high benefit ratios (IPCC, 2007). Agriculture is clearly a key priority for adaptation, especially in relation to existing climate variability (UKAID and Global Climate Adaptation Partnership, 2012b). Agriculture in many regions remains sensitive to climatic variability and the ability to manage these risks, given that climate change can be expressed via changes in variability at several temporal ranges, in enhancing capacity to manage climate risks is a core adaptation strategy (Howden et al., 2007). Developing this capacity involves increasing climate knowledge to decision makers so they become more cognizant of climate impact and use management options to intervene, thereby reducing negative climate change impacts (Howden et al., 2007).

Farmers and households are viable to adopt new practices and coping to new strategies in response to climate change in various ways including shifting crop mix between drought tolerant and short season varieties, reducing the areas planted initially and increasing them gradually depending on the nature of seasons, staggering planting dates (early or late planting) against scarce rainfall and increasing plant spacing, maximize the use of clay soils (which have high water capacity), implementing soil water conservation techniques (pot holing and weeding) and timing of fertilizers so as to supplement soil nutrients and moisture (to moderate temperature and relative humidity (Molua, 2007). These adaptation measures have been described in different countries (Ahile et al., 2014; Temesgen, 2014 and Gang et al., 2013). Based on reviewed sectoral policies, programmed plans and strategies as well potential sectoral climate change and institutional situation analysis, in Tanzania adaptation measures are clarified to provide potential intervention for climate change adaptation at each level. Also measures for enhancing institutional adaptive capacity in areas such as human resources, finance,
institutional arrangement or organization, technology, legislation and awareness are taken into consideration (URT, 2012), with potential agricultural intervention in integrating climate change adaptation, have been suggested (Table 1.1).

Table 1.1: Potential Agricultural Intervention in Integrating Climate Change Adaptation in Tanzania

<table>
<thead>
<tr>
<th>INTERGRATION PROCESSS</th>
<th>STRATEGIES INTERVENTION</th>
<th>POLICY</th>
<th>STRATEGY</th>
<th>PROGRAMMES</th>
<th>PLANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessing crop suitability cropping pattern for different agro ecological zones.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Promoting appropriate irrigation system.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promoting early maturing and drought tolerant crops.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promoting diseases resistant crops</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enhancing agro infrastructural (input, output, marketing) system.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promote appropriate indigenous knowledge practices</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promote effective use of weather forecasts, improve data collection network and early warning system</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve agriculture productivity through increased use of manure and appropriate agriculture input.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


For banana farming, potential intervention in integrating climate change adaptation to agriculture could be applied to reduce risks in production through Promoting appropriate irrigation systems to avoid significant losses, especially during dry periods (Ravi et al., 2013), which aims at ensuring attainment of maximum quality yields. Inefficient irrigation management can lead to reduced bunch size, weight and plant vigour (Diczballs et al., 1993). Other interventions include promoting early maturing and use
of drought tolerant varieties in the range of AA, AAA, BB, AAB; ABB, ABBB etc genomic institution (Ravi et al., 2013).

Banana has derived from two major ancestors, Musa acuminata (AA) and M. balbasiana (BB). In particular banana with ABB genomes are more tolerant to drought and other abiotic stress than other genotypes (Ravi et al., 2013). Adaptation of banana varieties with a capacity to tolerate water deficit has successfully allowed banana cultivation in non-convectional zones to be possible. Moreover, breeding banana for drought tolerance is an important alternative strategy to combat production constraints such as dwindling due to water resources (Reid, 2012). In promoting diseases resistant crop varieties, production of Musa species is limited by scarcity of quality planting materials (Howden et al., 2007). For instance, banana with AAA genome composition in East African highland has low natural proliferation ability leading to inadequate production of suckers to meet farmers demands (Howden et al., 2007).

From early 1950’s to late 70’s, the introduction of new plant varieties and farming methods resulted into increased agricultural production worldwide (Enger and Smith, 2013). Enhancing agro infrastructure (input, output, and marketing system) this has been a green revolution since 1950’s, in both developed and developing world, by using highly mechanized farming methods. Labour intensive farming is typical have benefited from these and therefore food production has increased significantly (Enger and Smith, 2013). Researchers have continued to improve varieties of crops, effective irrigation techniques and better farming methods by using more effective use agricultural chemicals and efficient machinery (Enger and Smith, 2013).
Important coping strategies implemented in other countries such as Costa Rica include establishment or replanting of improved banana varieties, fertilization, managing irrigation canals, managing banana bunch, hanging bags around the banana maturing bunches and controlling pests. After the banana bunches emerges a bag is tied around. The bag serves a multi-function ranging from providing physical barrier to protect against insect damages, barrier when treated with insecticides chlopyrifos, a chemical barrier to insect damages and creating microclimate that allow banana bunch to mature more rapidly (Bellamy, 2013).

Promoting the effective use of weather forecasts, improve data collection network and early warning system. This can facilitate risk reduction for corporation and partnering farmers if unfavorable conditions are predicted short term investment on site. Measures can increase resilience on farmers and water management for irrigation (Concha, 2015).

Presence of current climate variability impacts provides strong evidence that Zanzibar experience adaptation deficit associated with climate extreme increased. Addressing these deficits is a priority for early adaptation, because it could lead to immediate benefits by reducing current economic losses as well as providing greater resilience to future climate change. However, taking advantage of many of such measures requires better capacity and institutional strengthening that could be supported by central government through awareness and data availability (UKAID and Global Climate Adaptation Partnership, 2012a).

This research was able to access the adaptation option taken to banana farming and show the gap of needs to farmers so that decision makers will be cognizant and set
priorities towards improving banana crop production, thus improve community livelihoods and the country’s economy at large.

2.4. Banana for livelihoods of the people.

Banana is an edible fruit produced by several kinds of large herbaceous flower plants of the genus *Musa*. The fruit is usually elongated and curved. Banana pulps are composed of soft easily digestible flesh with sugar like fructose and sucrose. It contains good amounts of soluble dietary fiber that helps bowel movements, thereby reducing constipation problems (Kalogbor *et al*., 2014). It is a rich source of potassium which helps control heart rate and blood pressure, countering bad effects of sodium (Ravi *et al*., 2013). It provides adequate levels of minerals like copper (Cu), magnesium (Mg) and manganese (Mn), as well as banana is a rich source of calorie, vitamins A, C and B6, which are all essential for human nutrition. They are good of dietary fiber and are free often the first solid food fed to infant (Hossain, 2014 and Ravi *et al*., 2013).

Banana is produced all around the world, but much considered as a tropical crop due to the uniform warm and rainy climate throughout the year. They produce both cooking banana and plantains in countries such as Mozambique, Ivory Coast, Guinea, Central Africa Empire, Zambia and all East African countries. (German *et al*., 2015). In Tanzania banana is a key food and commercial crop (Luzi- Kihupi *et al*., 2015), while Zanzibar banana is considered by farmers as the second important food crop and the third important cash crop (Mdoe, 2003).

2.5 Farmers’ perception on the adequacy or satisfaction towards adaptation option taken.

Several studies shows that farmers use various adopted measures (Howden *et al*, (2007); Molua 2007; Luzi- Kihupi *et al*., 2015), others findings based on determinants
of farmers choice towards adopted measures taken (Komba and Muchapondwa, 2012; Atenihu et al. 2013; Temesgen et al. 2014) However there is lack of information on farmers’ perception on the adequacy or satisfaction towards adaptation option taken, this study intended to cover in their objective.
CHAPTER THREE

METHODOLOGY

3.1. The Study Area
Zanzibar has a population of 1.3 million with estimated growth rate of 3% whereas large population (approx. 0.9 million) live in Unguja Island (Mwinyi, 2016). The average per capita gross domestic product (GDP) was only 935 US dollars in 2014 (UN, 2016) and roughly 30% of the population falls below the basic needs poverty line, most of which lives in the rural regions (Mwinyi, 2016). Zanzibar consists of two main islands, Unguja and Pemba.

3.1.1 Climatic condition.

Zanzibar has a tropical climate, with four major seasons of the year. It receives high levels of precipitation and strong rains (Masika) from the end of March to mid-May, cool season (Kipupwe) with intermittent showers from June to August. The short rains (Vuli) from the end of September to December and the dry season (Kaskazi) which start soon after short rains to the onset of long rains. The annual rain fall is about 1700mm for Unguja and 1800mm for Pemba (UKAID and Global Climate Adaptation Partnership, 2012a). The temperature ranges between 29°C to 32°C on average and influenced by monsoon wind system with south easterly (stronger wind) between April and October reaching a maximum speed of 4.5 knots and northeast monsoon (weaker wind) between November -March reaching a maximum of 2 knots (Nowell, 1959).
3.1.2 Soil
According to FAO and UNESCO, Zanzibar soil classification has three main group of soils; kichanga, kinamo and kinongo (GTZ, 1982). The soil is deeper and richer in western side and shallower towards the eastern side. The Eastern and Southern parts of Unguja is a karsts coral region (maweni) and the rocky plateau at different levels found in south west of island. The deep soil of Western part of Zanzibar is the semi coral rag region which makes a boundary between the coral rag and plantation areas (Bron Sikat L. 2011).

3.1.3 Crops Production.
Zanzibar grows a wide range of crops for food and income generation. These crops include cloves, coconuts, cassava, sweet potatoes, bananas, yams, rice, maize, vegetables, beans, peas, pineapples, oranges, tomatoes and eggplant. While cassava, banana/plantain, sweet potatoes, maize, vegetables, yams and rice ranked as important food crops; cassava, banana/plantain, sweet potatoes, coconut, vegetables, fruits, yams, rice and cloves are the important cash crops (Paula, 2016; Mdoe, 2003)

Banana grown in all agro-ecological zones of Zanzibar islands, at the estimated coverage of 6,580 ha in Unguja and 6,990 ha in Pemba, which adds up to the total of 13,570 ha. The cost-benefit analysis shows that banana farming is more profitable for farmers and entrepreneurs if more investment is made, in which net returns could reach between Tsh 2,067,500 and Tsh 4,083,500, in contrast to between Tsh 194,650 and 3,196,250 for cassava and between Tsh 776,875 and 1,376,875 of rice (ZATI, 2009)
3.2 RESEARCH DESIGN FOR THE STUDY

3.2.1 Exploratory research design.
This research was achieved by surveying to the farmers who are experiencing the problem with the practical experience in their farming activities. This study involved farmers and skilled persons from various institutions including ministry of agriculture and Tanzania Meteorology Agency Zanzibar office and to seek knowledge and experience on banana plants varieties, farming activities, diseases and yield attained relative to implemented adaptation options. Also, observations were made on the soil types in the farms by testing and take photos to determine its appropriateness.

3.2.2 Descriptive research design.
Descriptive research design was used to describe characteristics of a particular individual group (Kothari, 2007). In this study were applicable in describing climatic variation of Zanzibar experienced with banana farmers as well as adaptation taken in farming system for banana. In this research design questionnaires and interview method was employed.

3.3. Study area selection and justification
The islands are located at 39°E and between latitude 50°S and 60°S (Figure 3.1 ), with a total area of 2,332 km² (Unguja 1,461 km² and Pemba 868 km²). The study was done in three regions of Unguja Island, North, Urban-West and South regions. Selection of the study areas was based on the high intensity of banana crop plantation where these regions import much banana to the market areas and the significant difference in rainfall pattern and temperature patterns experienced. In addition, these are the areas which exhibit the presence of meteorological stations which helped to observe the rainfall and temperature patterns for the study. The study was conducted at Kinyasini area (North region), Kizimbani area (Urban- West region) and Makunduchi area (South region).
The areas are characterized with high rainfall (Kinyasini), moderate rainfall (Kizimbani) and low rainfall (Makunduchi).

Figure 3.1: Maps of Unguja Island in Zanzibar showing the study areas

3.4 SAMPLE AND SAMPLING PROCEDURE

Non probability sampling was made by using semi structured questionnaires by using purposive sampling techniques to the banana farmers so as obtain the target populations which are the banana farmers from each village. The random sampling procedure would provide the respondents which are not farmers. And in depth interview to key skilled informants to attain factual and detailed information at the Institute of Agriculture, the questionnaire and interview focused on the climate change variability, adaptation measures and attainable yields. To achieve the goals the formula below was used to determine a sample size.

\[ n = \frac{N}{1 + N (e^2)} \]
Where \( n= \) sample size; \( N= \) sample frame; and \( e= \) error significant level (Ahuja 2001). In this study \( N=5121 \) and \( e = 0.10 \). By substituting these figures into the above formula the sample size \((n)\) of 98 is obtained, and therefore sample for each village is also obtained (14 banana farmers from a sample frame of 726 at Kizimbani, 31 from a sample frame of 1622 at Kinyasini and 53 at Makunduchi from the most two productive shehias, (34 from a sample frame of 1763 at Kajengwa and 19 from a sample frame of 1010 at Kiongoni shehias) were selected and 13 district officers including 3 District Agricultural Development Officers (DADO) 4 Block Extension Officers (BEO), 3 Agricultural Services Support Program (ASSP)-Program District Officers 3 (PDO) were selected at each region.

3.5 Data collection methods

3.5.1 Primary data

The quantitative methods involved banana farmers interviews were conducted to get information on climate change and variability impacts, adaptation measures and perception of farmers on adopted measures undertaken. The interviews were made possible through a semi structured questionnaires tool designed for that purpose. Moreover, in order to get qualitative information in-depth interviews were conducted to collect information from key informants under the Ministry of Agriculture, and participatory observation inventory to banana farmers was used in this study. These methods discussed in the section below.

3.5.1.1 Banana farmer’s interview

The banana farmer’s interview was administered to 98 farmers from all 4 shehias. They were selected from a list of 5121 banana farmers obtained from Block Extension
Officers. The meeting with participants the researcher visited in their farm and communicated with mobile phone for those out of their farms. The target age group was 18 and above who expected to complete ordinary education level. The interview was covered climate change impacts, adaptation measures and their satisfaction toward adopted measures taken.

3.5.1.2 In depth interview

This is done to key information interviews intended to validate the information collected through farmer’s interviews on climate change impacts, adaptation measures and their satisfaction toward adopted measures taken. The interviews were structured, based mainly on the key issues emerged during field work. The study key informants were interviewed in the study areas. The interviews covered District Agricultural Development Officers (DADO), 4 Block Extension Officers (BEO), 3 Agricultural Services Support Program (ASSP)-Program District Officers 3 (PDO) were selected at each region.

3.5.1.3 Participatory observation inventory

Observation involved recording of events and inspection of farmland. This was done during or after banana farmers interviews to validate their responses. The observations involve robbing questions on observed issues concerning the study. On climate impacts and adaptation measures applied.

3.5.2 Secondary data:

Secondary data were obtained from published and un-published reports related to the study, so as to understand the background of the study and obtain factual information to the study. The data on climate change and variability impacts were collected from
Kizimbani Institute of Research, The climate data on rainfall, temperature and wind per month were obtained from Tanzania Meteorology Agency (Zanzibar office), the data on rainfall range in 29 years from 1985-2014; temperature in 30 years from 1985-2015 and wind range in 28 years from 1986-2014 for Zanzibar; rainfall data in the study areas covered the period of 7 years from 2009-2015 and the data on banana production were obtained from Office of Chief General Statisticians (OCGS). The data were essential in this study in order to evaluate the climate change and variability impacts on banana production.

3.6 Data analysis.

Different methods of data analysis were employed to meet objectives of the study. Data collected were summarized, coded and analyzed using Statistical Packages for Social Sciences (SPSS) Computer programmes to calculate frequencies, means, percentage and correlation coefficients so as to make task easy for inferences. Microsoft excel computer program was used to convert climate data from monthly to annual average, compute climate data using one sample t-test method to obtain their difference from the base line from alpha 0.05 and to plot graph. R. statistical software was used for analysis of correlation between climate change factor and banana yield.

3.7 Reliability and validity

Reliability test analysis was used to test the reliability of the data collected, the results from this test showed that Cronbach’s Alpha is 0.84, this mean that 81% of variance in the scores is reliable variance and only 16% is error variance. The validity of these data is considered as good since Cronbach’s alpha is greater than 8 (George and Mallery, 2003). Cronbach’s Alpha measures the internal consistency of the data.
CHAPTER 4
RESULTS AND DISCUSSION

4.1. Socio Economic Characteristics of Banana Farmers

4.1.1. Years of Farming

Farmers in the study areas have been engaged in banana farming at different years. This study shows that, at Makunduchi about 72% are new farmers experiencing of 6 - 12 years of banana farming. While Kizimbani exhibits about 57% of new farmers, Kinyasini has only 19% new farmers. This information implies the number of old farmers at Kinyasini is higher than the new farmer’s, with about 35% of farmers having an experience of more than 30 years.

Figure 4. 1: New farming experience in the study sites

The study reveals that banana farming at Makunduchi and Kizimbani has positively improved comparing to Kinyasini. This indicates that the number of youth involved in the business is higher than aged people, due to high dependency of agriculture as a main activities and access of farming services. Furthermore, education level is an important
factor since majority of new farmers are of primary and secondary education levels. This is contrary to Ahaibwe’s (2013) suggestion that educated youth are less involved in agriculture.

4.1.2. Reasons for Banana Farming

About 49% of the respondents in Makunduchi are planting banana for income generation. This is due to the fact that most farmers get good price per banana bunch ranging between 10,000/- to 30,000/-. The prices are even getting higher during the needy month of Ramadhan and reach up to 50,000/- per bunch. In contrast to Kinyasini, about 70% of respondents are growing the crop mainly for food to support their families, where as 29% of respondents have reported that they grow the crop for both food and income generation. Only 10% grow the crop for income purpose. Additionally, more than 50% of respondents at Kizimbani are engaged in spices tours and rice farming.

Figure 4.2: Reason of planting banana
This confirms that banana farming at Kizimbani is considered as an additional activity for economic income generation, though is not able to meet all the farmer’s basic needs. This result is in line with Thiele et al. (2017) findings that banana farming is unable to reduce poverty and reduce food insecurity under harsh climate change scenario, although it is among the important value chains for food security, nutrition and income.

4.2 Variability of Rainfall, Temperature and Wind in Zanzibar

4.2.1. Annual Rainfall in Zanzibar

The result of analysis of rainfall data obtained from TMA (Zanzibar office) shows that there are fluctuations in rainfall with the highest amount being 2459.7mm in 1997 and 2370.8mm in 1986 (Figure 4.3). The lowest rainfall amount of 704mm was observed in 2004 (TMA, 2017). The analysis of a sample t-test shows that the p-value for annual rainfall in Zanzibar is 0.1909, which means that there is no significant difference from the base line of 1500mm this means that the average rainfall is enough to support banana production, with a slight challenge on rainfall pattern where maximum rainfall rained only during Masika.
With some fluctuations in 1987 and 1999, the rainfall amount experienced was 1450mm and above, which is good for banana farming. However, from 2008 the rainfall status started to experience higher fluctuations which are below average (1500mm) for more than 3 consecutive years. This kind of fluctuations is not promising and healthy for banana farming. Previous study by German, et al. (2015) suggests for a better banana yield, the crop needs at least an annual minimum of 1500mm, while above 1500mm is more favorable. However, high intensity during and low frequency of rainfall during rainy seasons restrict better growth of banana plants due to rotting and falling (UKAID and Global Climate Adaptation Partnership, 2012c).
4.2.2. Average Monthly Rainfall for Zanzibar.

The data analysis obtained from TMA shows that, the monthly rainfall ranges between 28mm to 382mm (Figure 4.4). There is higher rainfall in the months of January, March – April and October to December. For normal growth the crop needs between 73.44mm to 382 mm, which is available during the mentioned months, but then lower rainfall of between 28mm to 54.92mm is experience during the months of February and June to September. Low amounts of rainfall lead to stunting growth of banana plants.

![ANNUAL MONTHLY AVERAGE RAINFALL FOR ZANZIBAR 1985-2014](image)

Figure 4.4: The Annual Monthly Average Rainfall for Zanzibar (TMA, 2017)

This indicates that there is favourable rainfall pattern for banana farming only in three months. However, the time period of farming extends up to one year. For that matter, depending on the rainfall patterns, farming might not be profitable, suggesting for adaptive measures to improve productivity and hence profitability.

One sample t-test result for average monthly rainfall shows the p-value of 0.03948, which is significant from the base line of 60mm per month and the mean value of 135.2742. This suggests that banana production suffer from inadequate rainfall. Banana
production requires at least 60mm per month for better growth, any month below 60mm is considered dry month for banana production and production is almost impossible with three consecutive dry months without irrigation (German, et al., 2015). Zanzibar experiences long dry periods during February and June – September. Irrigation initiatives are compulsory for good harvest during this period. The correlation is negative and not significant as shown in (Table 4.1) that, production increase as rainfall decreases. This result lined with respondents responses that high rainfall causes a lot of impact include falling of banana plants.

4.2.3 Average Monthly Temperature for Zanzibar.

The results of the analysis on average monthly temperature data obtained from TMA shows, temperature ranges between 28°C from January to May, 27°C June - July, 26°C August - October to 25°C in November - December. This indicates that low production of banana in Zanzibar is not influenced by temperature change as moderate temperature is available a year-round (Figure 4.5).

![Annual Average Monthly Temperatures in Zanzibar (1985-2015)](image)

Figure 4.5: Annual Average Monthly Temperatures in Zanzibar (TMA, 2017)
Studies suggest that the temperatures above 24°C, banana stem will produce a bunch one year around (German et al., 2015). However other studies show that temperature rise leads to reduction of production as it exceeds 33°C influenced by long dry spells (Salau et al., 2016) and physiological heat stress (German et al., 2015). This suggests that, considering temperature alone, Zanzibar has a very conducive environment for banana farming.

4.2.4: Wind for Zanzibar

The wind patterns for Zanzibar are south east (strong wind), which can lead to falling of banana plants when reaches 40-72km/hr (Nelson et al., 2006) and north east (light wind) (Nowell, 1959). The monthly mean wind velocity shows an increasing trend (Mahongo et al., 2011). However, wind gust is rarely recorded, when it has been only recorded at 39 knots or greater on five occasions on 8 June 2011 (highest recorded gust at 52.1 knots) and on 26 February, 10 October, 19 October and 15 November 2012 (Geere, 2014). The average wind speed pattern shows that the highest wind speed knots are 12.6 on 2013 equivalent to 6.77 km per hours (Figure 4.6) with the monthly average wind ranges between 7.74-10.88 s (Figure 4.7). Generally, the south east is the highest wind pattern while north east is the wind pattern with a minimum level. These results imply that wind is below the approximation to affect production. According to Kepler et al., (2006), wind speed of 40-72 km/hr (25-45mph) equivalent to 21.5053-38.7096 knots can topple plants when they bear banana bunch, as well as cause more damage if the ground corm is weakened by insect pests. The correlation of wind to banana yield, indicates that south east wind is positively correlated, meaning that the increase in wind leads to increase in production. North east wind shows negative correlation which is
not significant, meaning that the increase of one factor decreases another factor (Table 4.1).

Figure 4.6: Annual Average Wind Pattern for Zanzibar 1986 to 2014 (TMA, 2017)

Figure 4.7: Annual average Monthly Wind for Zanzibar. (TMA, 2017)
Table 4.1: Relationship between banana yields and climate factors from 2010 - 2014

<table>
<thead>
<tr>
<th>Years</th>
<th>Variables</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>P-value</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Banana yield (tones)</td>
<td>15047</td>
<td>15044</td>
<td>13492</td>
<td>13230</td>
<td>10778</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rainfall (mm)</td>
<td>1207</td>
<td>1749</td>
<td>1030</td>
<td>1082</td>
<td>1784</td>
<td>0.6513</td>
<td>-0.277469</td>
</tr>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>27.9</td>
<td>27.7</td>
<td>27.6</td>
<td>28</td>
<td>27.8</td>
<td>0.9401</td>
<td>-0.047058</td>
</tr>
<tr>
<td></td>
<td>South east wind (knots)</td>
<td>10.29</td>
<td>10</td>
<td>10.43</td>
<td>10.64</td>
<td>9.86</td>
<td>0.6422</td>
<td>0.2849018</td>
</tr>
<tr>
<td></td>
<td>North east wind (knots)</td>
<td>8.5</td>
<td>8.6</td>
<td>9</td>
<td>9.1</td>
<td>8.8</td>
<td>0.4141</td>
<td>-0.479213</td>
</tr>
</tbody>
</table>

Figure 4.8 shows banana production decrease trend due to inconvenient climate condition, mostly low rainfall from 2010 to 2015.

Figure 4.8: Banana Production in Zanzibar (in Tonnes)

(Ministry of Agriculture, Natural Resources, Fisheries and Livestock, 2018)
4.3. Variability of Climate Change Factors

4.3.1 Impacts of rainfall pattern
The annual rainfall pattern shows variability in all study areas in general (Figure 4.9), with fluctuations from year to year and from one place to another. This is a result of difference in geographic features with Kizimbani being surrounded by vegetation cover including dense trees, spice farms and wetland portions. Moreover, Kinyasini is covered by scattered trees with some wetland areas and Makunduchi is found along the coral rag zone with scattered vegetation.

Results indicate that Makunduchi area has experienced high rainfall (above 1500 mm), which led to for good harvest in 2014 and 2015, but most of the years the area has been receiving not enough rainfall for cultivation. Despite being on the rainfall zone of Zanzibar, Kizimbani and Kinyasini areas have received plenty rainfall only during year 2011, which supported well the production. Rainfall in the remaining years has been less than 1500 mm. These results agree with the Hassan et al., (2014) that 2011 is year with extreme event as indicated by 3- and 12-months Standardized Precipitation Index for Zanzibar.

However, the year with enough rainfall could not experience an increased production due to falling and rotting of banana corm, as rainfall rained with high intensity in a few days. Generally, the annual average rainfall in the study areas is not enough for good harvest since it is only few years that reach the average rainfall required. This supports German et.al., (2015) result that for the rainfall below 1500mm banana growth is being reduced, depend on the length of dry months. Zanzibar experiences strong rains only between March - May.
Figure 4.9: Annual Rainfall in the Study Areas from 2009 - 2015 (TMA, 2017)

4.3.2 Average Monthly Rainfall in the study Areas.

The average monthly rainfall results analysis from TMA indicate that Makunduchi and Kizimbani experience dry months for banana production during January – February and July to October (Figure 4.10 and 4.11), with Kinyasini experiencing less month of drought, October (Figure 4.12). The average monthly rainfall reveals long dry periods, of four to five months (July – October), which affect banana growth in all the study areas. The areas receive rainfall below 60mm (Figure 4.10, 4.11 and 4.12), with January to February being also two consecutive dry months. Three months rainfall shortage is linked to yield reduction to more than 35% (Sabiiti et al., 2016). In contrast, Makunduchi is the lowest rainfall receiving area among the study sites, but the area
experiences good banana production results due to irrigation interventions applied. In Kinyasini the situation is not promising as the area is hit by low rainfall with inadequate water supply for irrigation. Kizimbani, on the other hand experiences good production as rainfall amount in the area is nearly at the optimum levels throughout. The combination of dry months and rainfall below 1500mm leads to the prevalence of leaf diseases (German, et al., 2015), with observed prolonged water stress being the cause of higher wilting incidences (Ochola, 2015). Therefore, adaptation measure such as irrigation and mulching, aiming at conserving soil moisture and minimizing water shortages, are paramount for coping with long dry spells in all banana farming (Sabiiti et.al., 2016).

Figure 4.10: Average Monthly Rainfall at Makunduchi (TMA, 2017)
Figure 4.11: Average Monthly Rainfall at Kizimbani (TMA, 2017)

Figure 4.12: Average Monthly Rainfall at Kinyasini (TMA, 2017)
4.3.3 Average Monthly Temperature in the Study Areas

With reference to annual average monthly temperature (Figure 4.5), the average monthly temperature ranges between 28°C from January to May, 27°C June - July, 26°C August - October and 25°C on November - December. This indicates that low production of banana in the study areas not influenced by temperature change due to moderate temperature around the year.

4.4 Climate Change and Variability Impacts on banana farming

The climate factors show the variations from one region to another in banana production include rainfall, temperature and wind as shown below.

4.4.1 Rainfall Impacts on banana

At Makunduchi, majority of respondents (89%) agreed that the area receives very low amount of rainfall throughout the year. Similarly, about 77% of Kinyasini respondents commented the same. Only Kizimbani respondents commented lightly about rainfall amount with only 43% saying that the area receives very low amount of rainfall. Contrary to that, about 43% of respondents at Kizimbani commented to have experienced high rainfall which is far away from only 23% and 2% for Kinyasini and Makunduchi respectively. The one t-test results from the annual rainfall (Figure 4.9) shows that Kinyasini area exhibits significant difference from the alpha p-values of 0.05 to 0.012 compared to Makunduchi with a p-value of 0.113. Kizimbani has the greatest p-value of 0.4449 (Table 4.2). These translates that Kinyasini is the only area with significant difference from the base line, meaning that production of banana is impossible without irrigation interventions, while Makunduchi and Kizimbani might be able to produce some yield even at a very small amount.
Table 4.2: Analysis of Annual Rainfall Data from the Study Areas

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>p-values</th>
<th>Mean Values</th>
<th>Significant</th>
<th>Alpha values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makunduchi</td>
<td>0.113</td>
<td>1198.286</td>
<td>NO</td>
<td>0.05</td>
</tr>
<tr>
<td>Kinyasini</td>
<td>0.012</td>
<td>1222.142</td>
<td>YES</td>
<td>0.05</td>
</tr>
<tr>
<td>Kizimbani</td>
<td>0.4449</td>
<td>1383.714</td>
<td>NO</td>
<td>0.05</td>
</tr>
</tbody>
</table>

4.4.2 Temperature impacts on banana

Majority of respondents at Makunduchi (72%) and Kinyasini (81%) have revealed that the areas exhibit very high temperature climate in contrast to Kizimbani where majority (86%) of respondents described that the area is characterized by moderate temperatures. The t-test results on average monthly temperatures (Figure 4.5) show the p-value of $3.528 \times 10^{-7}$ from the minimum temperature of 24°C and p-value of $8.599 \times 10^{-10}$ from the maximum temperature of 33°C, which don’t show any significant difference from the baseline of 24°C – 33°C. The available average temperature favors the production due to its suitability (German, et al., 2015).

4.4.3 Wind Impacts on banana

‘Moderate wind’ has been the favored response in all study sites supported by 77%, 65% and 64% of respondents at Makunduchi, Kinyasini and Kizimbani respectively. The t-test results show no significance difference from the baseline with the p-value of $8.42 \times 10^{-12}$ for annual average wind speed. Under normal condition, wind results do not seem to affect banana production. However, south easterly winds between Junes to September are associated with difficulty in obtaining enough food in the east coast of Zanzibar each year (Makame, et al., 2015). Therefore, minor impacts exist including falling of bunch banana plants in a rare high-speed wind days.
4.4.4 Effects of Variability of Climate Change Factors on Banana Farming

As results of climate change and variability in temperature, rainfall and wind farmers have noted various climate change impacts that include diseases (Plate 4.1 and 4.2), breakage (Plate 4.3) and stunting growth (Plate 4.4). A disease such as ‘Black Sigatoka’ has been evidenced at Kizimbani affecting ‘ntwike’ (Luzi- Kihupi et al., 2015). This confirms that Zanzibar Islands are among the coastal areas of Tanzania mainly affected by the Black Sigatoka, which has the potential to reduce crop yield by up to 30% - 40%.

Panama disease, which mostly affects ‘koroboi’ and ‘pukusa’ varieties, has been witnessed in all study areas together with the presence of white fliers at the leave canopy and bites of banana bunch. The effects are mostly common during hot periods. Majority of respondents at Kinyasini (74%), Kizimbani (71%) and Makunduchi (64%) concurred with the prevalence of these diseases. The diseases prevalence is an implication of scarcity of rainfall and long periods of dry spells, since the epidemiology of sigatoka is widely occurring during dry seasons when humidity is a limiting factor (Khan et al., 2015). This case observed at Kizimbani where sigatoka mostly cover after rainy season.
Plant breakages were observed in the study areas believed to have been resulted from diseases infection and wind blowing (Plate 4.3). This has been supported by
respondents at Kinyasini (65%) and Kizimbani (57%) while Makunduchi (81%) did not support the effect.

The study witnessed stunting growth as a result of prolonged dry periods and low rainfall supported by most respondents in the study areas (Makunduchi 68%, Kizimbani 51% and Kinyasini 55%).

Plate 4. 3: Breakage of Banana Plants

Banana plant falls due to diseases infection
Banana Plant falls due to wind blows
Flooding was not seriously observed with only 6% of respondents from Makunduchi noticed it. No respondent mentioned flooding as a challenge for banana farming at Kizimbani and Kinyasini. Similarly, no other climate change impact was observed at Kizimbani, while only 19% and 1.9% of respondents at Kinyasini and Makunduchi, respectively, observed other climate change impacts including shrinking and rolling of leaves, as well as failure of banana plants to produce female bud. Moreover, drought was not observed as the challenge for the crop by a majority (87%) of respondents in the study area.

Therefore, diseases, breakage of plants and stunting growth have been observed as the main climate change and variability impacts influenced by water shortages. These impacts are related to each other in their impacts to plant growth. Since plants which
affected by diseases experience stunting growth, then becomes weak and susceptible to wind blow or high rainfall due to water logging condition. In agreement with (Sayyari et al., 2013) these effects are associated with scarcity of water supply due to prolonged dry periods which decrease water content, resulting to declining of growth attributes including salicylic acid, which is considered the most potential growth regulator for improving plant growth.

4.4.5 Observed changes on banana production

Over the past decade there has been observed changes on banana production in Zanzibar. Production has improved in Makunduchi due to an increased number of farmers applying improved banana production techniques motivated by high return income generation. Contrary to Kizimbani, production is moderate, while the situation at Kinyasini is not good. They experience low productivity at Kinyasini to the extent that farmers are opting out of the business while those still engaged in farming are highly doing it mainly for family consumption. This result is in line with Thiele et al., (2017) finding that banana production is unable to reduce levels of poverty and combat food insecurity under the negative climate change scenario. Though, it’s among the important value chains for food security, nutrition and income, when the climate impacts are controlled. However, Makunduchi is highly depending on banana production for income generation due to availability of water services for irrigation as observed in this study, of which about 94% of respondent confessed to have applied irrigation measure in their farming. These changes affect household income positively and make the crop the main source of income in the families. At the same time, income from the crop income has gone down at Kizimbani and Kinyasini due to low
productivity resulted from poor access of farming facilities including water for irrigation.

4.5 Adopted Measures to Climate Change and Variability Impacts

In order to cope with climate change impacts hitting the study areas, respondents have adopted various measures in the like of irrigation techniques, mulching, cover cropping, replanting, fertilization, change of planting pattern, use of short season varieties, use of drought resistant varieties, mixed farming, pot holing, and increase plant spacing. Howden et al; (2007) and Molua (2007) identified the same measures for the same purpose.

The study reveals that majority (94%) of respondents at Makunduchi area use irrigation as a farming technique to boost banana production (Plate 4.5). Unfortunately, less than 15% and zero percent of respondents do irrigate their crops at Kizimbani and Kinyasini respectively. Irrigation techniques are believed to be the main reason for improved production at Makunduchi area.
As a soil management practice, mulching has been widely used by banana farmers in the study area. The study found that majority (77%) of respondents use mulch in preserving moisture, fertilization and defensive mechanisms to disease vectors, though some had different opinion towards facilitating breeding of disease vectors.

Replanting of new banana plants is another adopted measure used to replace the old ones after 3-5 years or after being affected with climate change impacts. About 86% of respondents at Kizimbani reported to have adopted the measure with 85% and 68% respondents reported the same at Makunduchi and Kinyasini respectively. On the other hand, fertilization has been opted by majority (83%) of farmers in the study area whereby compost and household wastes have been mainly used (Plate 4.6).
Changing planting pattern has started being used in the study area by shifting planting from short rain season to long rain season. About 61% of respondents at Kinyasini, 26% at Makunduchi and 14% at Kizimbani have shifted to new planting pattern. The pattern is common to farmers who depend on irrigation at Kizimbani and Makunduchi while Kinyasini farmers still depend on rain fed system for better growing.

Use of short season varieties is another potential adaptation technique that could be opted by farmers in the study area. When prompted on the applicability of this measure,
majority (97%) of farmers responded negatively on the use of short season varieties because they are not yet available.

The use of drought resistant varieties is common throughout the study area as mentioned by 93% of respondents at Kizimbani, 74% at Kinyasini 74% and 72% at Makunduchi (Plate 4.7). The commonly used varieties include *Yagambi km5, pelipeter, koroboi, mtwike, kachako* and most of ripen banana varieties such as *pukusa* and *kisukari*. *Yangambi, pelipita* and *kachako* are among the 14 new registered East African high land banana hybrids introduced by International Institute of Tropical Agriculture that have led to higher yields (Luzi- Kihupi *et al.*, 2015). The use of these varieties has been widely observed at Kizimbani and Kinyasini compared to Makunduchi. At Makunduchi they mostly use varieties which catch better market prices including *mkono mmoja, msinyori* and *Ali Hassan Mwinyi* under irrigation. However, of the most commonly used varieties, *koroboi* and *pukusa* are highly susceptible to diseases, thus necessitate for the need of more resistant varieties.
Mixed farming for banana production is not preferred in the study area as majority of respondents could not establish beneficial link to their production. Few respondents commented that the practice could avail options for food security, while improving soil nutrients.

About 74% of respondents at Kinyasini, 64% at Kizimbani and 60% at Makunduchi apply pot holing and weeding for preserving water in banana stool as well as protecting breeding of vector for diseases and unnecessary nutrients absorption. Moreover, increased plant spacing between banana stools is applied for better growth attainment. Respondents from Kizimbani (86%), Kinyasini (65%) and Makunduchi (51%) reported to have used these techniques, with those not applying them aiming at creating shades in order to reduce direct sun rays at banana corm.
Apart from the identified adaptation option suggested by Howden *et al.*, (2007), other adopted measures noted in the study areas include paring and hot water treatment (Plate 4.8) to avoid diseases infection, reducing banana suckers to prevent over absorption of soil nutrients, cutting of female bud for better banana bunch and polling of banana plants to avoid breakage of plants (Plate 4.8).

**Plate 4.8: Others Useful Adopted Measures**

- Banana Field Treated by Paring and Hot Water Treatment Against Pests
- Poling of Bunch of Banana to Resist Wind Break
Generally, most respondents are aware on the importance of application of adaptation measures in their farming practices though unable to apply them. This situation is caused by lack of capital needed to invest in farming technologies including water facilities, fertilizer and availability of quality suckers. According to Temesgen et al. (2014) and Atenihu et al. (2013), access to credit determines the use of agricultural technologies to adopt the climate change risks. Therefore, banana farmers are unable to effectively apply adaptation measures due to lack of access to credits. Alternatively, they concentrate on the use of mulching to preserve moisture, manure and compost as a means of fertilizing the farms.
4.6 Perception of Farmers on Adopted Measures

Respondents in the study areas have different perceptions towards adoption measures taken. Some measures such as replanting (88%), irrigation (87%), mulching (85%), fertilization (84%), pot holing and weeding (78%), planting of drought resistant varieties (69%) and use of increased spacing (64%) were perceived very effective by farmers. However, measures such as changing of planting patterns (26%), use of short season varieties (19%) and use of mixed farming (10%) were perceived in-effective by majority of respondents. Farmers individual perception influences farmers coping strategies, as well as having information formulate their adaptive capacity (Miller et.al., 2013). Good perception on adoptive measure determines a good access to information on adaptation measures to banana farmers.

4.7 Achievement of the Adopted measures

In general, those who responded positively on the effectiveness of adopted measures have observed good results on their production. However, farming infrastructure are not well improved, especially Kinyasini and Kizimbani, where water services were found to be poor. Majority of farmers have low income to invest on farming for buying fertilizer and good banana planting materials (suckers). Moreover, from key informant interviews, agricultural development officers (DADO) and Block Extension Officers (BEO) revealed that banana production becomes worse without adoptive measures. These results concur with those of Teressa et al., (2013), Komba and Muchapondwa (2012) who found that lack of farming input including (seeds, and chemical fertilizer), lack of money, and water are main constraints to adaptation on climate change impacts. These a lined with (Miller et.al., 2013) to the importance of institutional arrangement to support farmers action especially to construction of necessary facilities.
The question number 19 asked about cooperation with other institution. And their responses are negatively to the majority of farmers. They have no support from other institution, while others said they cooperate with Agricultural Services Support Programme (ASSP) from all districts in the all regions, they give them a training on better farming practice through Season Long Farmer Fields Schools (SLFFS) to the group of twenty peoples which is among the activities established by banana IPM group of the Plant Protection Unit (Rjab et.al., 1999), giving them loans by coordinating to the fund for self-reliance from Ministry of Labor, Empowerment, Elders, Youth, Women and Children and incentives. And Institute of Research of Kizimbani at Kizimbani by gives them a good banana sucker. This supported by (Hassan, 2008) that access to extension and credit ensures farmers to have information to decision making and means to take up adaptation measures. Also, is a means for government to assist farmers on the use of adaptation measures. Agricultural financing, training, and advise considered as most crucial input to enhance adaptation to the farmers and should be priority to policies that promote adaptation measures to climate change (Diencere, 2009) For those who get support they are achieved by increasing production after managing good farming practice. Therefore, there suggestion to the government and other stake holders is to provide them with incentives like farming tools, improve water services for irrigation, and give those loans with low interest for fund. Their suggestion similarly to those provided by (Komba and Muchapondwa, 2012). Their views also supported by DADO and BEO from the study areas and add their views on improvement of tissue culture experiments by providing laboratory equipments and chemicals in order to produce a good banana suckers. These implied to the role of government in promote adaptation measures appropriate for particular circumstances.
and agro ecological zone (Komba and Muchapondwa, 2012). Farmers advised to follow the trainer’s instruction.
CHAPTER FIVE
SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

5.1. Summary of findings and conclusions
Among the climate factors includes rainfall, temperature and wind discussed in this study, rainfall was found as the major constraints affecting banana production leads to decline of production. It is the main sources of climate change impacts observed in this study to banana growing. Banana growths are in harsh condition due to low rainfall with a long dry spell. Wind speeds have a little effect to the rare days with a high-speed wind in affected areas while temperature is more suitable for growth of banana. Therefore adaptation measures especially irrigation to manage water stress and mulching to preserve soil moisture are crucial to the farmers so as to sustain banana growing and slow incidence of diseases increased during dry period, as directly observed at Makunduchi through which dependency of banana production for income generation frequently has been increased due to improved water infrastructure for irrigation and reduce prevalence of diseases, while Kizimbani and Kinyasini were only able to sustain meals of their family due to low production and high incidence of diseases due to poor water infrastructure for irrigation as a result fail to cope with long dry spells affecting production. Stakeholders includes Agricultural Services Support Programme (ASSP), Plant Protection Unit, fund for self-reliance from Ministry of Labor, Empowerment, Elders, Youth, Women and Children and Institute of Research of Kizimbani aim to improve banana production through education and fund should pay more special attention to preserve the role of banana production in serving the communities to secure food security and income generation to the family as tourism activities grow correspond to the establishment of traditional food festival unities,
mostly in enabling them to invest in water facilities which are the main obstacle due to poor financial support to the farmers to solve this problem. This implied to the means of implementation of adaptation policy in Zanzibar. Indeed, extension services and incentives are the most crucial inputs play a greater role to assist farmers on the use of adoptive measures, as it enables farmers to identify, mobilize and use right knowledge on adaptation measures (Diencere, 2019; Ubisi, 2016; Boron, 2006). Therefore, could solve farmer’s constraints to the application of adaptation measures.

5.2 Recommendations
To invest on better farming mechanization and infrastructure like water management facilities and conservation measures to avoid climate change constraints, so as to implement the adopted measures and to reach better farming practice since it is the best ways of saving the farming communities.

Building the capacity with knowledge provision through mass media, television and radio programmed, magazine, fliers and developing Season Long Farmers Fields Schools (SLFFS) that could help farmers to improve their farming practices for better production all country sides.

Training to local people support needed for empowerment of locals in terms of alternative income generation in order to afford the means which require money to improve farming activities.

5.3 Recommendation for further studies.
To expand research fields and knowledge on banana production the study below must be conducted:
o Factors determine the use of adaption measures to the farmers.

o Assessing determinant of profitable production to the farmers under the climate change century.

o Appropriateness of the suggested adopted measures such as optimal fertilization and watering.

o Determination of resistant varieties to climate change impacts on food crops. Determination of minerals composition and deficiencies for effective banana plants growth.
REFERENCES


FAO. (2009). *Tanzania report on the state plant genetic resources for food and agriculture:* Tanzania. DSM.


Thornton, P.K., (2012). Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR’s mandate.


URT Division of environment., (2012). Guidelines for Integrating Climate Change Adaptation into national sectoral policies, plans and programmes of Tanzania. URT Vice presidents office.

APPENDICES

Appendix 1: Interview for banana farmers in the selected regions

1. Residence : i) Kinyasini  ii) Kizimbani  iii) Makunduchi

2. Shehia

3. Gender : i) male  ii) female

4. Age _______________________  5. Education level____________________________

6. Marital status : Tick the appropriate response in the provided space
   i) married ( )  ii) unmarried ( )
   iii) widows ( )  iv) divorced ( )

7. Household numbers

8. For how many years has banana farming been your occupation?

9. What reason you are planting banana?
   i) income ( )  ii) meals for the family ( )
   iii) both ( )  iv) others ( )

Climate change and variability impact.

10. What are the climate change variability in rainfall, temperature and winds to banana farming observed in your areas?

<table>
<thead>
<tr>
<th></th>
<th>1. rainfall</th>
<th>2. temperature</th>
<th>3. wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very low rainfall</td>
<td>Very low temperature</td>
<td>Very low wind</td>
</tr>
<tr>
<td>B</td>
<td>Low rainfall</td>
<td>Low temperature</td>
<td>Low wind</td>
</tr>
<tr>
<td>C</td>
<td>moderate</td>
<td>Moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>D</td>
<td>Very high rainfall</td>
<td>Very high temperature</td>
<td>Very high wind</td>
</tr>
<tr>
<td>E</td>
<td>High rainfall</td>
<td>High temperature</td>
<td>High wind</td>
</tr>
</tbody>
</table>
11. How do these variability impacts affect banana farming?

<table>
<thead>
<tr>
<th>OBSERVED EFFECTS</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Diseases and pests (examples)</td>
<td></td>
</tr>
<tr>
<td>B Drought</td>
<td></td>
</tr>
<tr>
<td>C Break of plant</td>
<td></td>
</tr>
<tr>
<td>D Floods</td>
<td></td>
</tr>
<tr>
<td>E Stunt its growing</td>
<td></td>
</tr>
<tr>
<td>F Others</td>
<td></td>
</tr>
</tbody>
</table>

12. Has the productivity of banana changed over the past 10 years? How? Why?

13. How these changes affect your income?

**Adopted measures to climate change and variability impact.**

14. What adaptation options undertaken to cope with changes to banana farmers?

<table>
<thead>
<tr>
<th>Adopted measures</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Irrigation</td>
<td></td>
</tr>
<tr>
<td>B Mulching</td>
<td></td>
</tr>
<tr>
<td>C Replanting</td>
<td></td>
</tr>
<tr>
<td>D Fertilization</td>
<td></td>
</tr>
<tr>
<td>E Change of planting pattern</td>
<td></td>
</tr>
<tr>
<td>F Planting short season varieties</td>
<td></td>
</tr>
<tr>
<td>G Planting drought tolerant crops</td>
<td></td>
</tr>
<tr>
<td>H Mixed farming</td>
<td></td>
</tr>
<tr>
<td>I Pot holing and weeding</td>
<td></td>
</tr>
<tr>
<td>J Increase plant spacing</td>
<td></td>
</tr>
<tr>
<td>K Others</td>
<td></td>
</tr>
</tbody>
</table>
Perception of farmers on the adopted measures taken.

15. How would you describe achievement of the adopted measures?

<table>
<thead>
<tr>
<th>Adopted measures</th>
<th>i) very effective</th>
<th>ii) effective</th>
<th>iii) ineffective</th>
<th>iv) very effective</th>
<th>v) unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Irrigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Mulching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Replanting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Fertilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Change of planting pattern</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Planting short season varieties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Planting drought tolerant crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Mixed farming</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Pot holing and weeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Increase plant spacing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


17. Without adopted measures how do you think the state of banana farming would be today?

18. What are the challenge do you face in implementing adopted measures?

19. How do you cooperate with others institutions like Tanzania meteorology and institute of agriculture in accessing better farming practices? What are the other institution do you cooperate with?

20. Is there any achievement from the cooperation with that institution? Explain.

21. What are your suggestions to the government and other stake holders to support adaptation measures to improve banana production?

Thank you for your participation
Appendix 2: Interview for other key informants in institution in the selected regions.

Personal information

1. Residence : Kinyasini ( ) Kizimbani ( ) Makunduchi ( )
2. Gender : male ( ) female ( )
3. Age
4. Work place

5. Working experience

6. Position

Climate change and variability impact.

7. What are the climate change variability in rainfall, temperature and winds to banana farming observed in your areas?

<table>
<thead>
<tr>
<th></th>
<th>1. rainfall</th>
<th>2. temperature</th>
<th>3. wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very low rainfall</td>
<td>A Very low temperature</td>
<td>A Very low wind</td>
</tr>
<tr>
<td>B</td>
<td>Low rainfall</td>
<td>B Low temperature</td>
<td>B Low wind</td>
</tr>
<tr>
<td>C</td>
<td>Moderate</td>
<td>C Moderate</td>
<td>C Moderate</td>
</tr>
<tr>
<td>D</td>
<td>Very high rainfall</td>
<td>C Very high temperature</td>
<td>D Very high wind</td>
</tr>
<tr>
<td>E</td>
<td>High rainfall</td>
<td>E High temperature</td>
<td>E High wind</td>
</tr>
</tbody>
</table>

8. How does climate change and variability affect banana farming?

<table>
<thead>
<tr>
<th>Observed Effects</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Diseases and pests (examples)</td>
<td></td>
</tr>
<tr>
<td>B Drought</td>
<td></td>
</tr>
<tr>
<td>C Break of plant</td>
<td></td>
</tr>
<tr>
<td>D Floods</td>
<td></td>
</tr>
<tr>
<td>E Stunt its growing</td>
<td></td>
</tr>
<tr>
<td>F Others</td>
<td></td>
</tr>
</tbody>
</table>
Adopted measures to climate change and variability impact

9. What are adaptation options undertaken to cope with changes to banana farmers? Why?

<table>
<thead>
<tr>
<th>Adopted measures</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Irrigation</td>
<td></td>
</tr>
<tr>
<td>B Mulching</td>
<td></td>
</tr>
<tr>
<td>C Replanting</td>
<td></td>
</tr>
<tr>
<td>D Fertilization</td>
<td></td>
</tr>
<tr>
<td>E Change of planting pattern</td>
<td></td>
</tr>
<tr>
<td>F Planting short season varieties</td>
<td></td>
</tr>
<tr>
<td>G Planting drought tolerant crops</td>
<td></td>
</tr>
<tr>
<td>H Mixed farming</td>
<td></td>
</tr>
<tr>
<td>I Pot holing and weeding</td>
<td></td>
</tr>
<tr>
<td>J Increase plant spacing</td>
<td></td>
</tr>
<tr>
<td>K Others</td>
<td></td>
</tr>
</tbody>
</table>

Perception on the adopted measures taken.

10. Without adopted measures how do you think the state of banana farming would be today?

11. How do you cooperate with farmers in accessing better farming practices?

12. What changes observed to the farmers from the cooperation?

13. What are the challenge do you face in cooperating with farmers?

14. What are your suggestions to the farmers and other stake holders to support adaptation measures to improve banana productivity?

Thank you for your participation