THE IMPACT OF CLIMATE VARIABILITY ON MAIZE (*Zea mays*) PRODUCTION AND FARMERS COPING STRATEGIES IN HANDENI AND KILINDI DISTRICTS, TANGA, TANZANIA

BY

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ABSTRACT

This study was conducted in Handeni and Kilindi districts, Tanga region in Tanzania to assess the effect of climate variability on maize production and farmers' coping strategies. It aimed at giving baseline data for future planning in improving rain-fed agriculture. Rainfall data and maize production data for the past thirty years were assessed for trends. Correlation analysis was used to asses the relationship between rainfall and maize production trends. A representative sample of 420 households from six villages were randomly sampled and interviewed for their coping strategies (short term intervention) and adaptation strategies (long term solution) and their perspective on climate variability using a structured questionnaire. Focus group discussions with key informants were conducted to enrich the questionnaire data. Data were analysed using Statistical Package for Social Sciences (SPSS) computer program and Microsoft Excel. Both rainfall and maize production showed decreasing trends while temperature showed increasing trend. The correlation between rainfall and maize production was significantly high ($p<0.001$, $R^2 = 0.745$). Given the high correlation between rainfall and maize production and the decreasing trends for both, it can be argued that rainfall was a major factor in the trend shown by maize production. This is a clear evidence of the impact of climate variability on maize production in Handeni and Kilindi districts. Farmers responded to those impacts by adopting different coping strategies. The major coping strategies were to resort into wage labour, collecting wild roots /fruits and sale of livestock and the major adaptation strategies was to grow drought tolerant crops, rainwater harvesting and cultivation along bottomland wetlands.

DECLARATION

I, Kidagho Mohamed Kutua, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has neither been submitted nor concurrently being submitted for a higher degree award in any other University.

Kidagho Mohamed Kutua, (MSc. Candidate)	11/11/2008 Date

The above declaration is confirmed

Prof. Pantaleo K T Munishi (Supervisor)	14/11/2008 Date
Dr. Peter W Mtakwa (Supervisor)	13 November 2008 Date

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DEDICATION

This dissertation is dedicated:

To Almighty God, the creator and giver of knowledge

To my mother, Rehema Nyange

To the victims of climate change and variations all over the world

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LIST OF ABBREVIATIONS AND ACRONYMS

AIACC	Assessments of Impacts and Adaptations to Climate Change
CBOs	Community Based Organizations
CCSP	Climate Change Science Program
CEEST	Centre for Energy, Environment, Science and Technology
DADP	District Agriculture Development Plan
DALDO	District Agriculture and Livestock Development Officer
DCs	District Commissioners
DWEs	District Water Engineers
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GIS	Geographical Information System
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
MAC	Ministry of Agriculture and Cooperatives
MAFS	Ministry of Agriculture and Food Security
MOW	Ministry of Water
NBS	National Bureau of Statistics
NGOs	Non-governmental Organizations
NPES	National Poverty Eradication Strategy
NRI	Natural Resources Institute
PRA	Participatory Rural Appraisal

RELMA	Regional Land Management Unit
REPOA	Research for Poverty Alleviation
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
TMA	Tanzania Meteorological Agency
Tshs	Tanzania Shillings
UNESCO	United Nations Education and Scientific Organization
URT	United Republic of Tanzania
USD	United States Dollar
VEOs	Village Executive Officers
WCED	World Commission on Environment and Development
WEOs	Ward Executive Officers
WMO	World Meteorological Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Climate affects crop production directly by influencing physiological processes and indirectly by influencing soil characteristics, pests and disease incidences, and timing of farm activities. Climate, however, is not static; it is subject to fluctuations of different scales in time and space (Hare, 1981). Climatic variations usually are variations in temperature or precipitation or both as manifested by wet and dry geological episodes. Climate is one of the key factors that determine plant growth, and hence the climate is directly involved in the basic production of plant matter through mass and energy exchanges. Oxygen and carbon dioxide (CO_2) are exchanged between the atmosphere and plants and rainfall provides water for nutrient uptake by plant roots through the soil (Hare, 1981).

The World Bank (1984) reported that Tanzania is a country relatively well endowed with natural resources. Particularly noted was its large agricultural potential, which in Africa is possibly matched by only Nigeria, Sudan and Zambia. The majority of Tanzanians derive their livelihood from crop and livestock production and most livestock owners (80%) are also farmers (URT, 1989). However, Tanzania's agriculture and the rest of the rural economy have performed very poorly, especially in the 1970s and 1980s (Maghimbi, 1992).

Maize is an important staple food in many tropical, subtropical and warm temperate countries. It is almost replacing traditionally grown cereals such as sorghum and millet (Onwueme and Sinha, 1991).

Maize accounts for twenty per cent of domestic food production in Africa (CABI-ARC, 2002). According to Oerke *et al.* (1995), Tanzania produced about 34.906 millions tones of maize in 1990, ranking fourth after South Africa, Egypt and Kenya. Maize is the first priority staple food in Tanzania and it is followed by rice, wheat and sorghum (MAFS, 2002). It accounts for 60 percent of the dietary calories for the majority of the rural population, covers about 45 percent of the area under annual crop cultivation and contributes about 90 percent of the national strategic grains reserve (Lymo and Lamboll, 2003).

An analysis of recent climatic trends reveals that climate change poses significant risks for Tanzania. While projected changes in precipitation are uncertain, there is a high likelihood of temperature increases as well as sea level rise. Climate change scenarios across multiple general circulation models show increases in country average mean temperature (URT, 2003, Swai *et al.*, 2004; Munishi *et al.*, 2006). The predictions show that the mean daily temperature will rise by 3°C – 5°C throughout the country and the mean annual temperature will rise by 2°C– 4°C. Predictions further show that areas with a bimodal rainfall pattern will experience decreased rainfall of 5% - 45% and those with unimodal rainfall pattern will experience decreased rainfall of 5%-15%, as shown in Tanzania's Initial National Communication (Munishi *et al.*, 2006). Based on the Initial National Communication assessment of vulnerability and adaptations to climatic change in Tanzania (INCR) report, Annual Crop Forecasts and Food Security Assessment reports and Disaster Vulnerability Assessments (VAR) conducted in 2002 and 2003; it has been established that climate change is variably affecting Tanzania and for the purpose of future national interest there is a pressing need to examine from amongst available options ways to cope and remain safe, secure and sustainably productive (CEEST, 2003; Munishi *et al.*, 2006).

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According to INCR findings (Munishi *et al.*, 2006), changes in climatological patterns have implication on hazards at village, district and national levels associated with prolonged heavy rains or drought. The *VAR* identified the top three hazards in the country as drought (47%), floods (13%) and pest/vermin/plant diseases (30%). These high ranked hazards are classified as commonly occurring in a period of less than five years, and have a positive correlation to climatic changes/variability. Among all three hazards drought is the most severe and can cause hunger to all people in the study area.

1.2 Problem Statement and Study Justification

About 85% of the population in Tanzania depends on agriculture as a source of food, income and employment. The average annual precipitation is 937 mm, but about 50% of the country receives less than 750 mm per annum with total rainfall declining from north and south to the central plateau. The central plateau receives 200 to 600 mm and is classified as semi-arid, while the coastal zone and southern and northern highlands receive abundant rainfall of between 1400 and 2000 mm annually. The dry season lasts six months, but is shorter and less severe in the northeast than in the south (Hatibu *et al.*, 2000). Rainfall in semi-arid areas is described as relatively adequate, highly variable with great uncertainty (Hatibu *et al.*, 2000). Nearly throughout the country potential evaporation exceeds rainfall for more than nine months in a year. However, in the past few years some areas have received less rainfall compared to previous years causing crops to dry out before maturity. Handeni and Kilindi districts are among the areas where rainfall seems to have failed to sustain crop production. Over the past five years Handeni and Kilindi districts have experienced crop failure at a frequency of 1-3 years resulting into food shortages of at least 50% (MAFS, 2005). Further, this climate variability is likely to have induced coping strategies by local communities to mitigate such impact. Little or no research has been done in Handeni and Kilindi district to assess the real effect of climate variability on crop production and the coping strategies developed by the local people to address impacts of climate variability. It was for this reason that this study assessed the impact of climate variability on maize production and local people's coping strategies and adaptations to these impacts as a basis to mitigate (reduce the severe ness) impacts of climate variability.

1.3 Objectives

1.3.1 Overall objective

The overall objective of the study was to assess and evaluate the impact of climate variability on maize production and the coping strategies taken by local people as a basis for mitigating climate variability impacts in Handeni and Kilindi districts.

1.3.2 Specific objectives

The specific objectives of the study were to:

1. Assess the trends in rainfall and maize production for the last thirty years
2. Assess the relationship between maize production and rainfall trends for the last thirty years
3. Assess farmer's perceptions on climate change/variability
4. Assess the coping and adaptations strategies taken by the local people to mitigate experienced climate impacts on crop production.

1.4 Hypothesis

This study was conducted with the hypothesis that;

- Climate variability has had no negative impacts on maize production in Handeni and Kilindi Districts.
- The local people did not develop any coping/adaptation strategies to deal with the impact of climate variability.

1.4.1 The study questions

The followings were the research questions that were to be answered by this study:

- What is the rainfall trend for the last thirty years in Handeni and Kilindi Districts?
- What has been the trend in maize production for the last thirty years?
- What is the relationship between trends in maize production and rainfall trend?
- What coping strategies and adaptations have been developed by the local people to mitigate impact of climate variability?

1.5 Conceptual Framework

The impacts of climate variability have direct affects on crop production and land resource management. These effects in turn lead to farmers develop coping and adaptation strategies. These coping and adaptation strategies which help a society to adjust to the impacts which may often lead to land resources degradation if not well planned and managed.

The impact of coping and adaptation strategies can be positive or negative. The negative effects lead to land resource degradation that limits the sustainable land utilization and impede the development process.

It is rational to develop coping and adaptation measures which will bc technically feasible, environmentally friendly and that will lead to sustainable agriculture and hence sustainable development. Fig.1 bellow summarizes the conceptual framework.

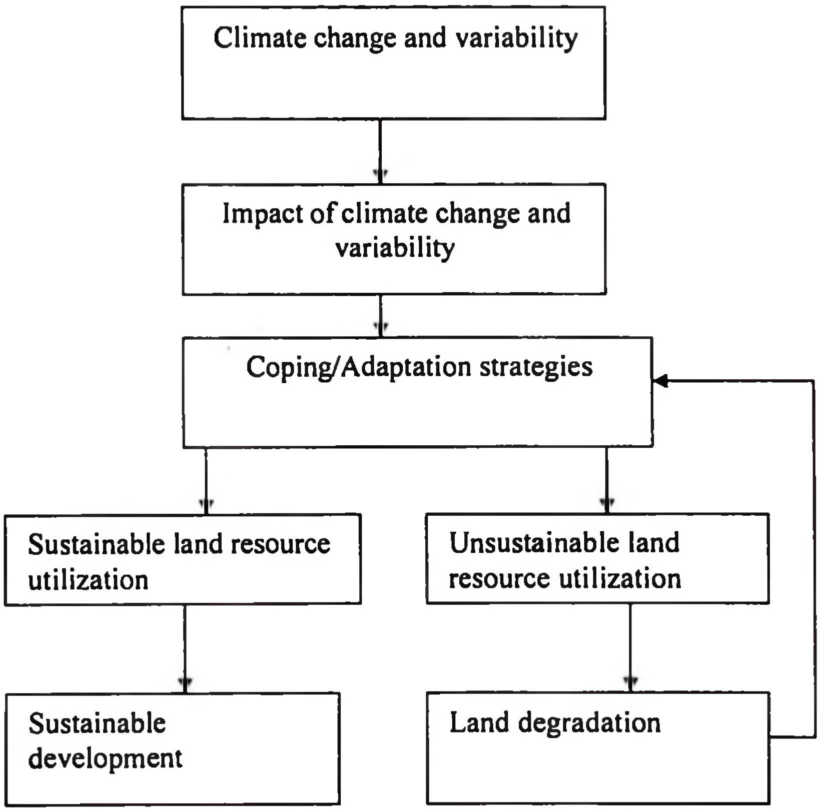

Figure 1: Conceptual framework of the impact of climate variability on crop production

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of the Key Concepts

Climate change was defined by Wilson (2006) as "the changes in long-term trends in the average climate, such as changes in average temperatures". The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "any change in climate over time, whether due to natural variability or as a result of human activity". In the United Nations Framework Convention on Climate Change (UNFCCC) usage, climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition (Olmos, 2001).

Global average surface temperature has increased over the 20^{th} Century by about 0.6 °C (Barber, 2004). During this period of global temperature increase there has been a decrease in the extent of snow and ice cover, a rise in the average sea level and the heat content of the oceans, and a number of changes in weather patterns that can also be associated directly or indirectly with the rising temperatures and reduced the rainfall intensity (Barber, 2004; CCSP, 2004; Majule *et al.*, 2004).

Climate variability refers to changes in climatic patterns, such as precipitation, weather and climatic patterns (Wilson, 2006). It is the variation around the average climate, including seasonal variations in atmospheric and ocean circulation such as the El Niño. According to Orindi and Murray, (2005), climate variability is the shift from the normal experienced rainfall pattern of seasons to abnormal rainfall pattern. Some evidence of climate variability includes the decline in food harvests and water resources due to prolonged drought and daily shift of seasons as well as too much and unexpected rainfall, but, with the assumption that, all other climatic factors (like land management) remains constant.

Adaptation is defined as "adjustments in social or economic systems made in response to actual or expected climate effects in order to reduce the vulnerability of society to changes in the climate system" (Olmos, 2001). It is the ability of a system to cope or absorb stress or impacts and to "bounce back" or recover. However, adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of changes in conditions (IPCC, 1996; Olmos, 2001). Feenstra *et al.* (1998) define adaptation to climate variability as "the process through which, people reduce the adverse effects of climate variability on their health and well-being, and take advantage of the opportunities that their climatic environment provides".

Adaptive capacity refers to the ability to cope with impacts of climate variability and change (Smit, 2001 in Galvin *et al.,* 2001). Normally regions and socioeconomic groups with the least capacity to adapt are the most vulnerable to impacts of climate change and variability. However, growing populations and low agricultural production, contribute to low adaptive capacity and, ultimately vulnerability (Finan and Nelson, 2001; Little *et al.*, 2001 in Galvin *et al.,* 2001). Most of the developing countries especially in the semi-arid regions have low adaptive capacity because they depend on climatic resources, and have high growing populations and low technological capabilities (Magistro and Roncoli, 2001 in Galvin *et al.,* 2001).

Coping strategies refer to the alternative activities in which households engage in order to secure food or income during drought (Low, 2005). It is the short-term response to the effects of extreme events during the shock period. However, these activities are not restricted to drought episodes, but they are intensified during such instances, and they differ among households and communities depending on the available resources and social capacity of the household, family, society or community (Orindi and Murray, 2005).

Local knowledge refers to "a collection of facts and relates to the entire system of concepts, beliefs and perceptions that people hold about the world around them" (FAO, 2005). It includes the way people observe and measure their surroundings, how they solve problems, validate new information and also the processes whereby knowledge is generated, stored, applied and transmitted to others (FAO, 2005).

The dynamics of knowledge systems differentiate the adaptation capacity. People adapt to changes in their environment, absorb and assimilate ideas from a variety of sources and may have different objectives, interests, perceptions, beliefs and access to information and resources. According to FAO (2005), knowledge is generated and transmitted through interactions within specific social and agro-ecological contexts, and is linked to access and control over power. Differences in social status can affect perceptions, access to knowledge and, crucially, the importance and credibility attached to what someone knows (FAO, 2005).

2.2 Impacts of Climate Change and Variability and Farmers Coping Strategies

The term climate was defined by Marsh (2005) as "the representative or general conditions of the atmosphere at a place on earth"; it is more than the average conditions of the atmosphere, for climate may also include extreme and infrequent conditions. Easterling

(1996) and Smith (1997) have described the effects of global climate change and possible adaptation measures. Davies *et al.* (1998) and Lal *et al.* (1999) have conducted also several assessments on climate variability in United Kingdom.

2.2.1 Impacts of climate change and variability at global and national level

According to IPCC (1996) climate change due to doubling of CO_2 or radioactive equivalent will warm the lower atmosphere and cool the stratosphere. The rate of temperature increase will range between 0.2°C and 0.5°C per decade. Global average precipitation and evapotranspiration are estimated to increase by 3 to 15%.

Worldwatch Database (Vital Sign, 2000) reported that global average temperature increased from 13.84 degree Celsius in 1950 to 14.35 degree Celsius in 1999 (Appendix 11). Economic losses from weather related natural disasters worldwide increased from 2.8 billion dollars in 1950 to 67.1 billion in 1999 (Brown *et al.*, 2000).

According to (INCR) findings (Munishi *et al.*, 2006) changes in climatological patterns have implication on hazards, whereby one of the major causes of these hazards at village, district and national levels is attributed to climatic changes associated with prolonged heavy rainfall or drought. The VAR identified the top three hazards in the country as drought (47%), pest/vermin/plant diseases (30%) and floods (13%). These high ranked hazards have been classified as commonly occurring in a period of less than five years, and have a positive correlation to the predicted climatic changes.

2.2.2 Impacts of climate variability on crop production

In the last half of the 20^{th} century, global warming has increased the intensity of heat and reduced the reliability of rainfall in East Africa (Majule *et al.*, 2004). According to the

"Climate Change Science Program" (CCSP) the seasonal and annual climate fluctuations strongly affect agriculture, the abundance of water resources, and the demand for energy, while long-term climate change may alter agricultural productivity, land and marine ecosystems, and the goods and services that these ecosystems supply (CCSP, 2004; Yanda *et al.*, 2006).

Alexandrov and Hoogenboom (1999) observed that decreases in annual precipitation during the 20th century in Bulgaria and precipitation deficit and high air temperature during the critical periods of maize development, limited growth development and final yields of maize. Chen (1996) found that fluctuations in maize production correlated significantly with areas that suffer from extreme weather.

Marison and Lawlor (1999) observed that in general, an increase in mean seasonal temperature of 2 - 4 °C reduces the annual crop yield. Ferris *et al.* (1999) observed that an increase in temperature by 10^{0}C for 8 days during the late flowering stage of soybeans decreases seed yields by 29% due to the high temperature episode. Prasad *et al.* (2000) observed that the effect of the duration and magnitude of hot temperature on flower survival of groundnuts was a simple negative function of air temperature between 28^{0}C and 48^{0}C. According to National Sample Census of Agriculture 2002/2003 survey report (URT, 2006) maize is the most important crop in the country and it has planted area 4.25 times the area planted with cassava which is the second largest area.

A total of 2 613 970 tones of maize was produced from a planted area of 3 465 173 ha (2003/2003 seasons), and the yield was 0.75 tones per hectare. Time series shows that since the last agriculture census in 1994 there has been a large increase in the planted area for maize from 1 202 000 hectares to 3 465 173 (URT, 2006).

However, there has been only a small increase in production over the same period and as a result of this, there has been a rapid decline in the yield from around 1.25 tones per hectare to 0.25 tones per hectare in 2003 with the main period of yield reduction occurring between 1994 and 1998 (URT, 2006).

The total land allocated to smallholders is 11 997 071 ha. However, only 75 percent of the total land (9 521 592) is utilized for agricultural production. The national average land area utilized for agriculture per household was only 2.0 ha (include area under fallow and 1.9 percent if the fallow area excluded). The area of land utilized per household has increased by 186 percent since 1993/94. Most of the increase was between 1994 and 1999 and the rate of increase diminished sharply over the period 1999 to 2003. The total area with annual crops was 9 521 592 (about 76 percent of total land area with crops). Maize production is higher than any other cereals in Tanzania with a total production of 2 617 115 tones and it represents 74 percent of the total cereal production. This followed by paddy (17%), Sorghum (6%), finger millet (1.6%), bulrush millet (1.1%), Wheat (0.7%) and barley with only one percent (URT, 2006).

The short rainy season was relatively not much important as long rain season for cereal production; for example in 2002/2003 seasons only 19% of the total area was planted. The number of households growing maize in Tanzania during the long rainy season and short rains was 3 103 925 households and 1 425 630 households, respectively. The total number of households growing cereals represents 65 percent of the total crop growing households in Tanzania for the long rainy season and 30 percent in short rainy season. The total production of maize during the 2002/2003 census was 2 617 115 tones. Maize production has increased gradually by over 1 x 10^6 tones since 1987 which was equivalent to an increase of about 142 865 tones per year. The area planted with maize remain almost constant over the period from 1986 to 1994 after which, the area under production expanded rapidly until 1998 and then remain again almost constant. Over the period 1988 to 1996 the field of maize remained constant at around 1.25 tones per hectare. However, there was a sharp decline in yield over the period 1996 to 1998 (down to 0.6 t/ha) and it has remain at this low level since then (URT, 2006).

Effect of climate change on maize yields through simulations by Crop Environment Resources Synthesis Model (CERES-Maize) showed that maize yield will be lower as a result of higher temperatures and, where applicable, decreased rainfall (Munishi *et al.*, 2006). The average decreases over the entire country will be 33% with decreases as a high as 84% in the central regions of Dodoma and Tabora. Yields in the northeastern highlands will decrease by 22% and in the Lake Victoria region by 17%. The southern highland of Mbeya and Songea are estimated to have decreases of 10 – 15%. These results suggest that climate change may significantly influence future maize yields in Tanzania and reduce production in some zones relative to baseline levels. These reductions are due mainly to increases in temperature that shorten the lengths of growing season and decreases in rainfall. Consequently, the continued reliance on maize as a staple food crop over wide areas of the country could be risky. However, maize production in particular might require special attention for adaptation and mainstreaming responses, given that it is a critical food crop (Munishi *et al.*, 2006).

Crop production forecast and food security assessment reports produced by the Ministry of Agriculture and Food Security annually have established that weather dependent crop production has continued to fail especially in the semi-arid central Tanzania and northern zone comprising Kilimanjaro, Arusha and Tanga regions which used to be the northern grain granary for the country. The bimodal pattern of its rainfall distribution is also gradually switching to unimodal tendency as the short rainy season slowly fades away. Arusha and Kilimanjaro regions are now the hardest hit regions although they used to be heavy rainfall areas (Munishi *et al.*, 2006). Two food assessment reports conducted by the Food Situation Investigation Team (FSIT) for 2003 showed that north eastern and coastal regions received very little or no rains in *vuli* season, a situation which led to food relief distribution to more than 56 districts out of 120 (Appendix 8).

2.3 Impacts of Climate Variability on Farmers

Both climatic and environmental changes have resulted in declining agricultural productivity, deterioration of water quality and quantity and loss of biodiversity. The increasing populations, livestock and other activities have resulted in changes in land use, land cover, desertification and other environmental degradation (AIACC, 2006; Yanda *et al.*, 2006). Climate variability is one of the most significant problems facing human societies especially in developing countries and the most vulnerable to the impacts of climate change are rural areas (IPCC, 2001). Most of the rural people located in the high-risk areas and they lack economic and social resources. These situations lead to failure in adjustment on long-term changes in climate variability (Orindi and Murray, 2005).

In East Africa climate change and variability is likely to alter temperatures and distribution of rainfall, which contributes to sea-level rise and increase the frequency and intensity of extreme weather events (Low, 2005; Orindi and Murray, 2005). The intensity of droughts, floods and changes to growing seasons have significant effects for soil productivity, water supply, food security and in turn human welfare as well as harmful on land resources and, otherwise, can lead to irreversible impacts on biological diversity (AIACC, 2006 and Yanda *et al.*, 2006). The ecological gradient that ranges from higher rainfall potential to lower rainfall potential where livelihood systems interact across the different zone have been affected hence influencing land management (Majule *et al.*, 2004). Some of the extreme weather in Tanzania has been the droughts of 1974, 1983, and 1994, which were followed by abnormal climate conditions of El Nino of 1982 - 83 and 1997 - 98 (Majule *et al.*, 2004 and Yanda *et al.*, 2006).

2.4 Adaptation to Climate Change and Variability

Adaptation to the current climate variability needs useful and preparatory steps that strengthen current capacity to deal with future situations with regard to current and future land resources conservation (Feenstra *et al.*, 1998; IPCC, 2001). There are general and specific adaptation measures depending on spatial-temporal (space and time) and the affected sector. The followings are some adaptation measures as outlined by Olmos (2001), Orindi and Murray (2005) and Low (2005): The increase in irrigation to boost crop production, introduction of low water use crops and adoption of sustainable water resource management policies such as seasonal rainfall harvest. Increased capital investment in reservoirs and infrastructure, reduction of water loss through water conserving technologies and to make water resource management an attractive career and field of investment are further adaptation measures. Other adaptation mechanisms include institution policy mechanism to control unsustainable forest clearing and forest consumption; promotion of techniques for tackling emergency food shortages; adjust farming areas and control overgrazing; promotion of the use of alternative source of energy such as solar cookers instead of inefficient woodstoves and charcoal stoves (Olmos, 2001; AIACC, 2006; Yanda *et al.*, 2006).

2.4.1 Adaptation to climate variability in agriculture

Adaptation in agriculture involves improvement of crop management due to the fact that climate variability leads to changes in cropping systems through shifting of agricultural zones and increased incidence of pests and diseases (Orindi and Murray, 2005). In adapting to climate variability, small scale farmers grow drought resistant and fast maturing crop varieties that grow well in areas of low rainfall (Low, 2005). This needs the identification of the most suitable drought resistant crops in consultation with local communities to ensure the acceptability to people (Olmos, 2001; Orindi and Murray, 2005).

Other agricultural strategies include planting cover crops and the use of green manure to restore soil fertility especially in areas where leaching occurs due to increased rainfall (Orindi and Murray, 2005). Many farming communities grow more than one crop of which one drought resistant as a form of insurance against total crop failure. Making better use of climate and weather data and forecasts and adjusting crop rotation practices to fit the new conditions could help to ensure sustainability of production systems.

2.5 Coping Strategies

Coping and adaptive strategies are inevitable in reducing impact of climate change/variability, particularly for the most vulnerable regions and social groups. Households and communities are known to have developed some alternative activities in which households engage in order to secure food or income during extreme climate events

(Low, 2005). These coping measures can only assist families in the short-term and some cannot deal with more severe shocks.

According to Low (2005), many of the coping mechanisms comprise activities that do not have formal systems recognition by government agencies. However, better achievement is only possible if disaster management agencies first understand local people's vulnerability, capacities and risks (Orindi and Murray, 2005) although local level coping strategies to shocks such as drought and floods differ among households and communities depending on the resources available and social capacity. The same author suggests some coping mechanisms during drought and other climate extremes as: receiving remittances from migrant household members; collecting wild fruits, switching to non-farming activities or, in extreme cases, selling assets, offering casual labour, brick making, handicraft, collecting honey and charcoal burning. These activities provide an important source of cash to allow households to purchase food and cater for other necessities at such difficult times.

According to Orindi and Murray (2005) coping strategies for seasonal food shortages include petty business, changes in diet, fewer meals, and loans from traders. However, some people migrate to urban areas in search of paid employment. In Handeni and Kilindi coping strategies for seasonal food shortages includes all mentioned above and the use of wild roots, leaves and fruits (Giblin, 1986).

2.6 Implication of Coping Strategies and Adaptation on Land Resources Management

Any development set of response to climate variability includes present stress as well as future complications from human activities (Ning *et al.,* 2003). The implications of coping and adaptation mechanisms are both negative and positive; it has an effect on soil, water, land and livelihood systems.

Farmers replace the natural woodland with herbaceous crops, or fast growing wood species (Fondazion, 1990) and sometimes rid the woodland in order to acquire multipurpose products which leads to hydro-geologic disorder, water table pollution, loss of biodiversity, landscapes degradation and reduction of river flow (Tschakert, 2006).

Unwise management of coping and adaptation options can result into habitat changes, and those changes could affect wetland, soil structure, nutrients and moisture, species biodiversity and reduction of food supply means through direct or indirect (Ning *et al.*, 2003).

Short term changes in the soil-water regime and turnover of organic matter and related mineralization or immobilization of nitrogen and other nutrients will have the greatest effect on ecosystem functions (Watson *et al.*, 2006). The ability for soil to support particular natural or agricultural communities is fundamental in any future scenarios of ecosystem development. However development is slow and will likely lag climate and vegetation change. Unwise coping and adaptation activities can have direct influence on organic-matter processes in the soil and nutrient fluxes (Watson *et al.*, 2006).

A combination of climatic variations and inappropriate human land-management practices can lead to excessive land degradation, eventually leading to desertification (Watson *et al.*, 2006). In developing coping and adaptation strategies to climate variability land management should be regarded otherwise people will degrade the environment and due to poor coping and adaptation measures, land resources will be degraded and then land degradation will increase vulnerability to the climate variability.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The research was conducted in Kilindi and Handeni Districts, Tanga Region. The area extends between latitudes 37.02'E to 38.03'E and longitudes 5.20'S to 6.02'S covering an area of 13 209 km^2, nearly half of the region's total area, which is 26 808 km^2. Before the government's decision to separate the two districts in the year 2002, this area was one district known as Handeni district.

The new Handeni District is in the east of Kilindi District. Geographically, it is located south west of Tanga region covering an area of 7 080 km^2 with a potential arable land of about 340,470 hectares and grazing area of about 367 530 hectares. Land under crop production is estimated to be 102 144 hectares which is about 30% of the district's total area. The district lies within an altitude ranging from 200 to 800 metres above sea level and has two important agro-ecological zones including plateaus and lowland areas. The district experiences a bimodal rainfall pattern with the short rains normally falling from mid - October to mid - January. The long rains start from mid - March and ends in June. The mean annual rainfall varies between 800 mm to 1000 mm.

Kilindi District is located south west of Handeni District covering an area of 6 129 km^2. It has a potential arable land of about 290 030 hectares and grazing land of about 216 240 hectares. Land under crop production is estimated to be 101 935 hectares, amounting to 35% of the District area. The District lies within an altitude of 500 to 1 600 m above sea level, with the Nguu Mountains and plateaus covering the southwestern part of the District.

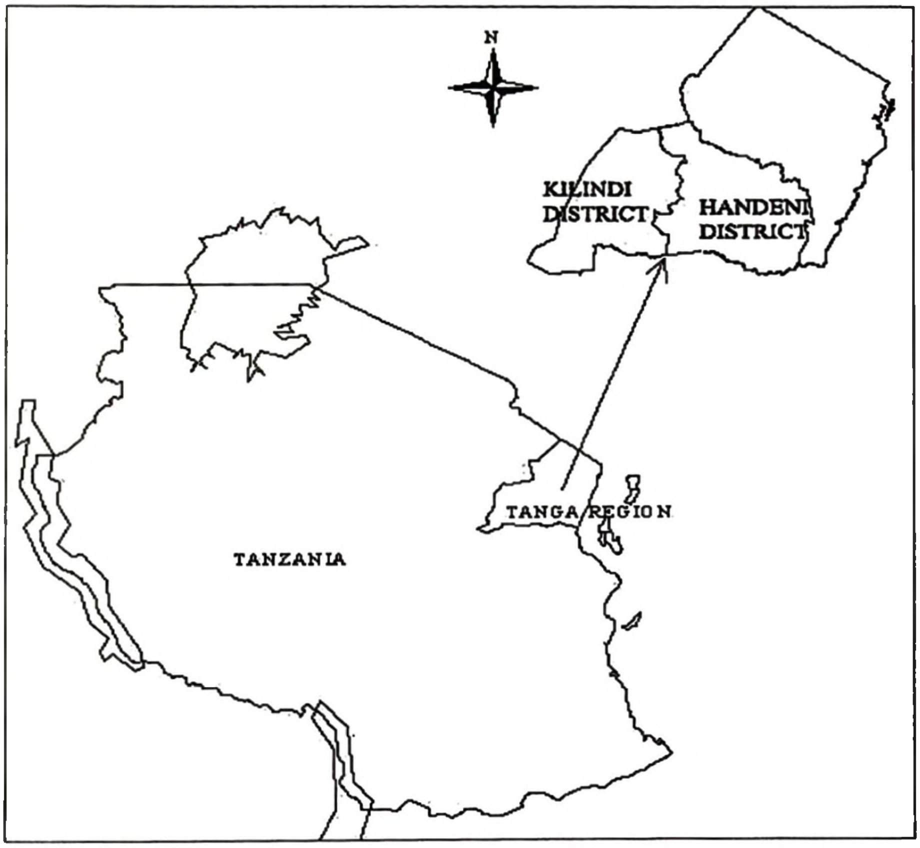

Figure 2: The study area

The districts have five agro-ecological zones based on variations in topography, climate, soils, vegetation and crop production possibilities (Handeni District Investment Profile, 2005). The agro-ecological zones have the following characteristics:

3.2 The population

There were 144 349 people in Kilindi district and 246 572 in Handeni district with an average household size of 4.9 and 4.6 respectively in 2002 (National Census, 2002). The population density for both districts was 32 persons per square kilometre (National Census, 2002). The dominant ethnic groups in the districts are Zigua, Nguu and Maasai. The number of households for both districts was 81 648 in 2002 (National Census, 2002).

3.3 Livelihood

Like most other Tanzanians in the mainland, the majority of the residents of Kilindi and Handeni also live in rural areas, and are engaged in crop production and livestock keeping as their major activities. The main food crops grown are maize, beans, and cassava. Important livestock species are cattle, sheep, goats and chickens. Cotton and tobacco were once the major cash crops, but their production was stopped after the collapse of the cooperative unions and the crop authorities, leaving the farmers without a guaranteed market (URT, 2005).

3.4 Climate

Handeni and Kilindi districts experience a diversity of climatic conditions. The western sides, especially around the Nguu Mountains, experience lower temperatures than the eastern areas. The average temperature for the district is about 24^0C. The area usually has two rainy seasons per year (bi-modal); the short rains (*Vuli*) from October-January, while the long rains (*Masika*) fall from March to June. The average annual rainfall is between 500 and 1000 mm. The northern parts are drier than the rest of the districts. The monsoons, especially the southeasterly monsoons, are the main source of rainfall (URT, 2005).

3.5 Research Design

A cross-sectional research design was used because it allows data to be collected at a single point in time and can be used for a descriptive study as well as for determination of relationship between variables (Bailey, 1998). The study targeted farmers who grow maize in Handeni and Kilindi districts. The sampling unit was the household, and a total of 420 households were selected: 210 from each district. Three Divisions and three Wards were randomly selected from each district and three villages were randomly selected from each Division. The sample size was about 9% of 4684 households in the six villages. A uniform number of 70 households were selected from each village. The study covered the following villages, Misima (Sindeni Division), Kideleko (Chanika Division), Kabuku ndani (Mzundu Division) and Msente (Mswaki Division), Kwediboma (Mgera Division), Songe (Kwekivu Division) in Handeni and Kilindi districts respectively. The mode of selection was, two districts, six division, six ward and six villages from each district.

Historical data on rainfall and maize production were collected form Handeni meteorological station and Handeni agricultural office respectively.

3.5.1 Socio-economic data collection

The methods employed in gathering socio-economic data and information in the field included household interviews and Participatory Rural Appraisal (PRA). This is data triangulation, an essential technique for improving the reliability of data and information. Questionnaires were administered to farmers to get information on coping and adaptation strategies to climate variability and perceptions on climate variability (Appendix 1).

Particular attention was paid to households with long residence and aged people (above 50 years). Interview method was preferred in this study because of its flexibility in exploring specific issues in-depth (Kitchin and Tate, 2000). The study sought to capture and examine the experiences, practices and opinions of the respondents with regard to the effects of climate variability in maize production and their coping strategies.

PRA techniques used were focus group discussions and participant field observations. The PRA techniques were used to triangulate information gathered from questionnaires. The focus group was composed of the District Natural Resources Officer, District Water Engineer, District Planning Officer, District Agricultural and Livestock Development Officer and District Land Officer for Handeni and Kilindi districts, Ward Executive Officers and Village Executive Officers of the study wards and villages, respectively, were also interviewed. The PRA sought to collect information on the effects of climate variability on maize production and local people's coping strategies.

3.6 Data Analysis

Socio-economic data were analyzed using the Statistical Packages for Social Sciences (SPSS) and excel computer program. Descriptive statistics such as frequency distribution and cross tabulation were used to make comparisons. Rainfall and maize production data for the past 30 years were analyzed for trends and correlation. Different local people's coping strategies mentioned by respondents were summarized into coping and adaptation strategies.

The effect of climate variability on maize production was explained by relationships between trends in rainfall and maize production over thirty years period. In the regression analysis annual maize yields was the dependent variable while mean annual rainfall and temperature were the independent variables. A linear regression analysis was used to elucidate the relationship between maize production, rainfall and temperature (Gujarati, 1995).

The model

$Yi = a + b_1X_1 \ldots\ldots\ldots + bjXj + E$ (Bryman and Crammer, 1992).

$Yi = a + b_1X_2 + \ldots\ldots\ldots + bjXj + E$

Where:

Yi	=	Annual maize production (tones)
a, $b_1 \ldots b_j$	=	constants
X_1	=	Annual rainfall
X_2	=	Mean annual temperature
E	=	a random error for any given set of values x_1, x_2---, x_n, which is normally distributed with mean 0 and variance δ.
i	=	1, 2, 3...

CHAPTER FOUR

4.0 RESULTS

This chapter presents the major findings of the study. The first part gives the socio economic characteristics of the sample population that include age, sex, marital status, education and occupation. The second part presents the trends in rainfall and maize production while the third part provides information on the perception of local people on climate variability and their coping strategies in Handeni and Kilindi districts and summarizes the coping and adaptation strategies.

4.1 Socio economic Characteristics of the Population

Table 1 shows the socio economic characteristics of the sample population. The mean age of all respondents was 57 years. Less than 65% of household heads were between the age of 50 and 60 years, 28% between 61 and 70 years, 6% between 71 and 80 years while 1% was above 80 years. About 94 % of the population are inhabitants of the area and 6 % are migrants from other areas mostly neighbouring districts. About 97% of the respondents have been resident of the area for more than 30 years while 3% have been residents for 10 to 30 years. This indicates respondents' familiarity of the areas especially in the context of climate variability.

It was observed that 74% of the households were male-headed while 26% were female-headed (Table 1). Of the male-headed households 98% are maize producers while 43% female-headed households are maize producers.

Majority of respondents (95%) are married while relatively low proportion are either widows or divorced. The study also found that more married couples were both crop producers and livestock keepers.

Majority of the households (56%) were crop producers and 43% were both livestock keepers and crop producers and 1% were sole livestock keepers (Table 2). About 70% of all the livestock keepers are Handeni district residents.

Many respondents were primary school leavers while small proportion were either secondary school leavers or had no formal education Despite of wide range of household size majority of households in the sample population had an average of 4-6 members or an average household size of 5 people.

Table 1: Socio economic characteristic of the respondents in Handeni and Kilindi Districts Tanga, Tanzania

Socio economic characteristic	% of response	Maize producer
Age		
Between 50 and 60	65	272
Between 61 and 70	28	119
Between 71 and 80	6	25
Above 80	1	4
Sex		
Male	74	307
Female	26	113
Marital status		
Married	95	397
Single	3	11
Divorced	1	6
Widowed	1	6
Level of education		
No formal education	4	17
Primary school	95	398
Secondary school	1	5
Main occupation		
Crop producers	56	235
Livestock keepers	1	5
Both crop producer as well as Livestock keeper	43	180
Household size		
1 – 3	7.4	31
4 – 6	47.4	199
7 – 9	44	185
10 and Above	1.2	5
Main occupation		
Crop production	56	237
Livestock production	1.2	5
Both crop and livestock production	180	42.8

4.2 Trends in Maize Production

Maize production in Handeni and Kilindi districts showed a decreasing trend over the thirty years period (1976-2005) (Fig. 3). According to the Ministry of Agriculture and Food Security there has been a fluctuation in maize production per hectare in Handeni and Kilindi. Production area increased from 47 866 ha in 1976 to 114 148 ha in 2005 though the planted area changed according to fluctuations in climate variability. The maximum total annual productions per ha in the two districts was 1.36 t/ha in 1978, which dropped to 0.26 t/ha in 2005 (Fig.3). Despite increase in production area maize yields have been decreasing over the same period.

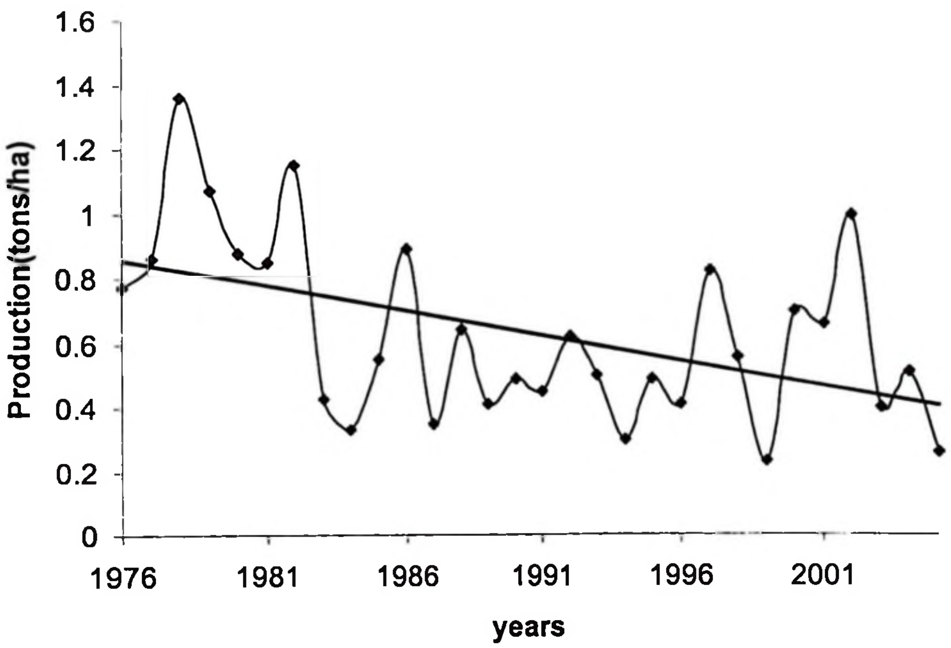

Figure 3: Maize production trend in Handeni and Kilindi districts (1976-2005).

Average annual maize production in the districts for the past three decades is 0.631 t/ha. Average annual maize production for the decades 1976 – 1985 and 1986 – 1995 was 0.825 t/ha and 0.514 t/ha respectively while the average annual maize production for the decade 1996 – 2005 was 0.554 t/ha. Overall average maize yields declined by 33% from 1975/1976 to 2004/2005.

4.3 Trends in Rainfall

Analysis of rainfall data over 30 years revealed great variation in rainfall (Fig. 4). Though there were great inter-annual variations in the mean rainfall the general trend has been declining over the years.

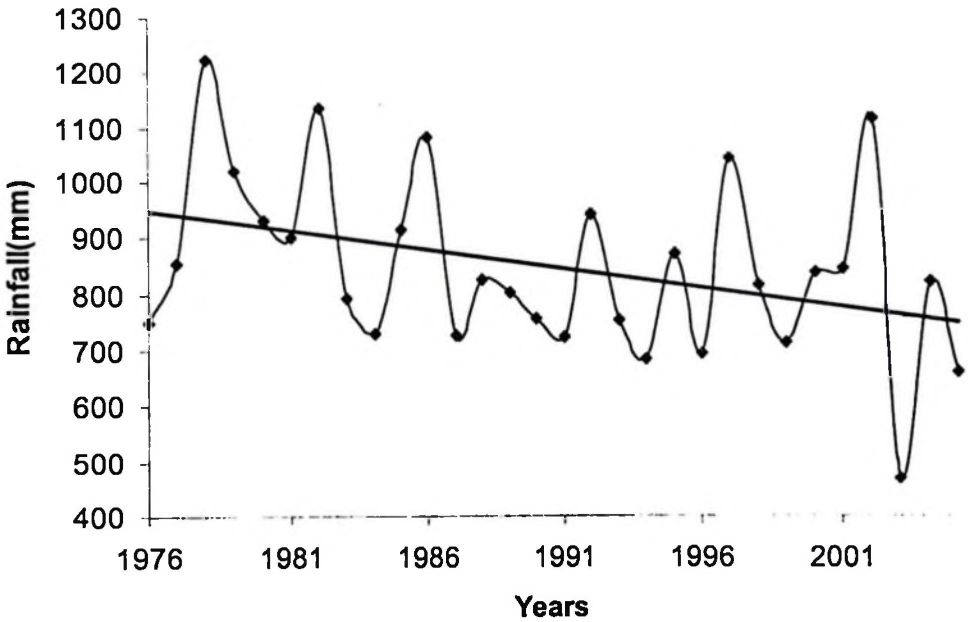

Figure 4: Annual rainfall trend in Handeni and Kilindi districts (1976-2005)

The onset of the long rains (*Masika*) changed slightly. The average rainfall recorded over 7 days period at the onset of the rain season (February) decreased dramatically from 101.5 mm in 1976-1985 to 63.9 mm in the 1995-2005. The mean monthly rainfall (10 days records) recorded in March in the decade (97.4 mm) was not significantly different from that of the 1995-2005 decade (130.4 mm). The amount of rainfall at the onset of short rains (*Vuli*) recorded in October in the decade 1976 – 1985 was 60.9 mm (9 rainy days) while in 1995 – 2005 it was 80.0 mm. According to the data, possibly the onset of rainfall had shift from February to March and November to October in *Masika* and *Vuli* rains respectively. This means that the long rains start late while the short rains start earlier today than it used to be in the past.

The numbers of rainy days showed a decreasing trend year to year and have high variation (Fig. 5). The total number of rainy days for the decade 1976 – 1985 was 1127 days while in the decade 1986 – 1995 were 891 days. The total number of rainy days for the last decade 1996 – 2005 was 917 days. Despite such variations there was generally a decreasing trend in the number of rain days over that period. Generally the number of rainy days decreases by 19% between the decade 1976 – 1985 and the last decade 1996 – 2005. This is also reflected in the local people perceptions. They indicated some of the extreme event of drought to be 1979, 1982, 1983, 1992, 1993, 1996, 1999, 2003, and 2005. They further ascertained that they were of the opinion that droughts have been intensifying during the same period .This was a clear shift in weather patterns that can be attributed to climate variability.

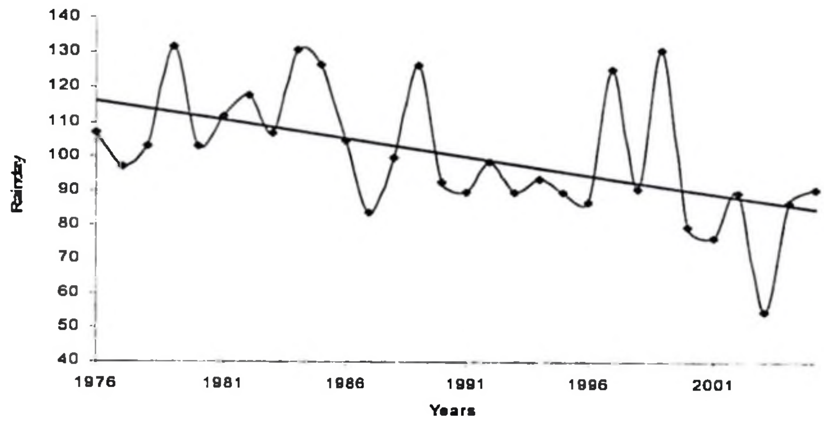

Figure 5: Trends in the number of rain days in Handeni and Kilindi (1975 to 2005)

4.4 Relationship between Rainfall and Maize Production

Long-term maize production and rainfall data for the period 1976 to 2005 were analyzed for trend and correlation. Statistical analysis shows a positive correlation between maize production and annual rainfall. Trend lines for both maize production and annual rainfall are both negative (Fig. 6). The relation between rainfall and maize production data has high correlation coefficient. Table 2 shows that adjusted R^2 is 0.736 ($P \leq 0.001$) this implying that there is a high correlation between the maize production and rainfall. Adjusted R^2 is the explanatory power of the selected variable of the linear regression analysis (Cohen *et al.*, 1983). Multiple R show the correlation of independent variable and in this case the independent variable was correlated by 86% (multiple R = 0.86). The standard error of the regression analysis was 14.47. The standard error (SE) is an estimate of the magnitude of error that can be expected in estimating future values of dependent variable (Cohen *et al.*, 1983).

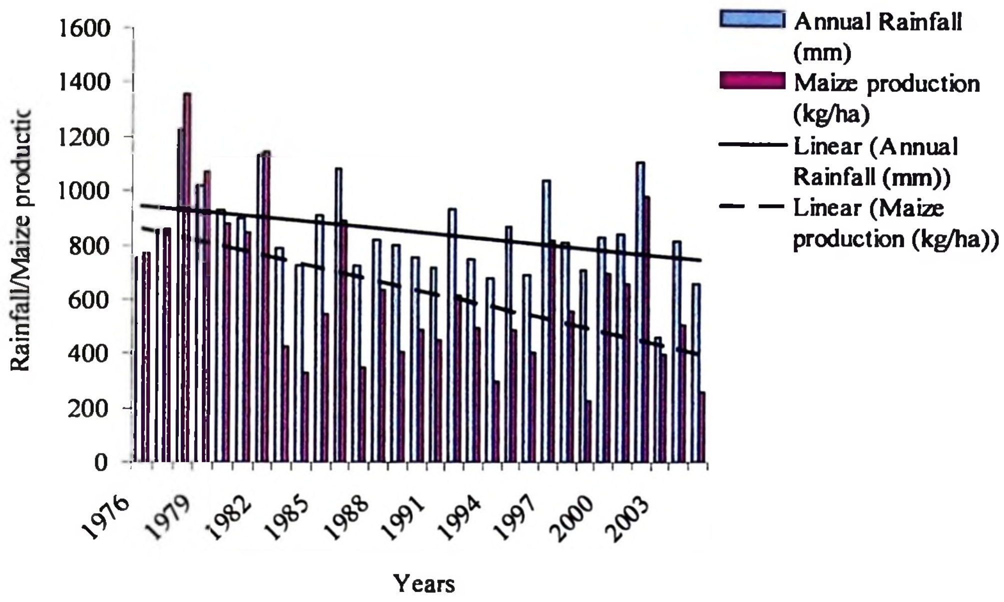

Figure 6: Relationship between rainfall and maize production in Handeni and Kilindi districts (1976-2005).

The relation between temperature and maize production was not significant which may indicate that maize production was not much influenced by temperatures in isolation (Table 2).

Table 2: Relationship between climate variability and maize production in Handeni and Kilindi districts

Independent variable	Regression equation	Coefficient of determination (R^2)	Correlation coefficient R(X,Y)	Number of observation (Years)
Rainfall	Y = -63.34 + 0.149X	0.745	0.863	30
Temperature	Y = 23.93 – 0.601X	0.00248	0.0498	30

Dependent variable = Maize production

The big variation in rainfall occurs in the February to April and October to November months during which the rainfall intensity and the number of rain days changes year to year (Fig. 5). This period is the beginning of the growing season for most crops in the district. Farmers used to have rainfall in the early days of October for (*Vuli*) and February for (*Masika*) rains. According to the Tanzania Meteorological Agency data, mean temperature over Handeni and Kilindi ranged from 21°C to 25 °C (Fig. 7). The annual mean temperature of the area is characterized by warm periods in October and November and the coldest months are June and July.

The mean annual temperature trend fluctuates but in general the trend line shows an increase of about 0.1 °C from 1981 to 2005. Fig. 7 shows the rises of about 0.1 °C from 23.8 °C in the early 1980s to 23.9 °C in 2005. According to Yanda *et al.* (2006) the mean annual temperature have risen for about 0.6 °C from 1978 to 1999 in Kampala and Kisumu but it shows a declining trend in Mwanza for the same period.

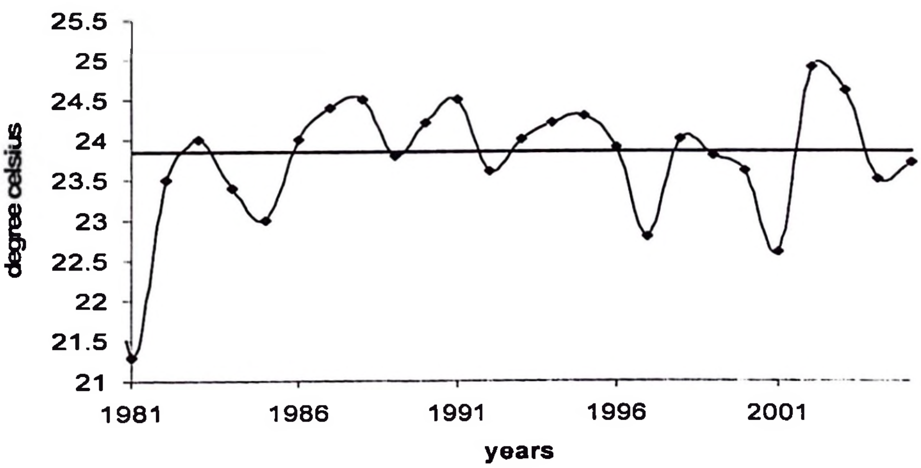

Figure 7: Annual mean temperature trend Handeni and Kilindi districts (1976-2005)

Although the maximum temperature recorded varied from year to year the trend has been on increase from 1980 to 2005 (Fig. 8). On the other hand the minimum temperature declined from 1980 to 2005 (Fig. 9). This is an indication of a relatively warmer climate.

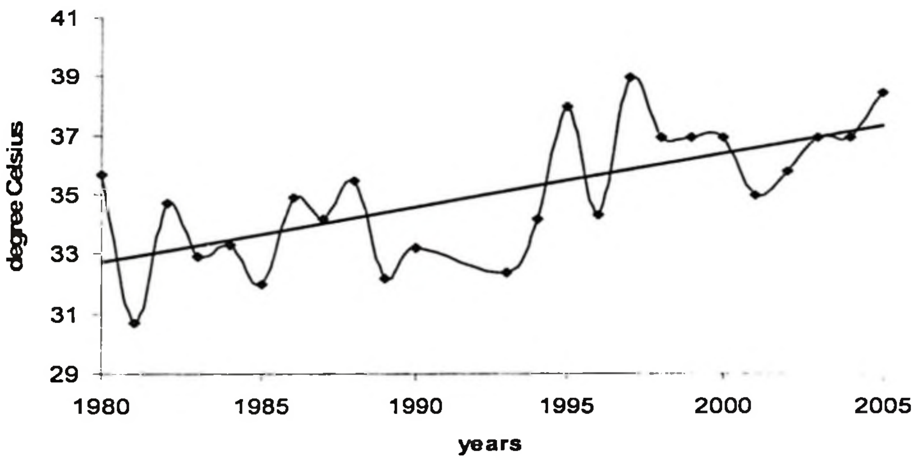

Figure 8: Maximum temperature recorded in Handeni and Kilindi districts (1976-2005)

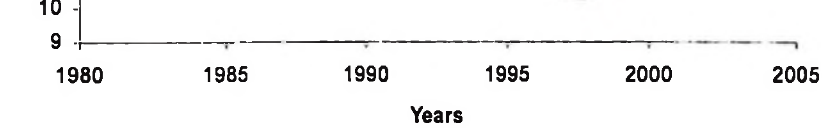

Figure 9: Minimum temperature recorded in Handeni and Kilindi districts (1976-2005)

Source: Handeni Meteorological station

4.5 Farmer's perception on Climate Change/Variability

Majority of the farmers have a better understanding of the impacts of climate variability. Most farmers who were interviewed knew about climate variability though some of them focused on day-to-day weather events. About 126 (30%) of respondents defined climate variability as decreases in rainfall while 189 (45%) defined climate variability as the extended dry season and 105 (25%) were not able to define climate variability, but understood about seasonal and inter-annual climate variations.

When asked about the causes of climate variability, majority of the respondents (98%) mentioned deforestation as main factor. Other factors included overgrazing (57%), shifting cultivation (24%), uncontrolled fire (18%) and cultivation in water sources (11%).

Some of the extreme climatic event remembered by most farmers are the droughts of 1930, 1931, 1932, 1933, 1945, 1962, 1963, 1974, 1979, 1982, 1983, 1992, 1993, 1996, 1999, 2003 and 2005 and the heavy rainfall of 1997, and 1998 (Appendix 4). PRA showed that there are some consistencies between farmers' memory on years with extremely precipitation and available meteorological data. Since 1975, farmers identified climatic extremes (primarily drought) as the data indicate, with a subset identifying every year since 1995-2005 as extreme years. About 99.8 percent of the respondents mention the increases in temperature since 1975 to 2005. Roughly two-thirds of the farmers saw some periodic pattern in climate variability, with drought occurring after two years. Half of the respondents mentioned a heavy rainfall occurring after ten years, while three quarters mentioned severe drought occurring after nine to ten years.

From the local meteorological data there is variability the number of rain days that affects the growing seasons. The drought to most farmers is when it does not rain on time. In February, for example, rainfall is expected to start falling any day between 15^{th} and 20^{th} days but these are not consistent. Some times the onset of rainfall delays to late March or in more extreme cases to April as was in 1984 (MAFS, 2005).

According to the respondents, the presence or absence of natural springs and floods on flat landscapes during or shortly after a rainy season indicates variability in rainfall and consequently variability of moisture contents in the soils and water levels in natural water sources, such as streams for a particular rain season. When the occurrence of natural springs is temporary, that is, occurs only during the rain season and disappears shortly thereafter, then there is less amount of rainfall with great variations between seasons in a year. On the other hand, when natural springs become permanent over years, it indicates high rainfall with less variations of rainfall between seasons over years. When the existing natural spring dry-up and no new natural spring appear during the rain season, then it indicates less amount of rainfall with extremely high variations of rainfall in the respective period of time. Only two villages on the study area (Kideleko and Kwediboma) have permanent natural springs while other villages' springs have dried up. The presence or absence of certain fruits was an indicator of high or low rainfall in a specific rain season. For instance, majority of respondents claimed that, when there are plenty of mango fruits locally it indicates low rainfall in the particular rain season.

Local people in Handeni and Kilindi understand and describe drought as both agricultural and hydrological droughts. They describe agricultural drought as "a state whereby water (soil moisture) is insufficient for crop growing" and hydrological drought as "a state whereby rainfall as the main source of water is extremely low, to the extent of causing water scarcity to meet different demands for water". Local people in the study area revealed that both agricultural and hydrological droughts have been adversely affecting their livelihoods. Local people therefore were able to describe the low amount of rainfall in the comparable time periods in their area, which is then remembered based on socio-economic and hydrological events which occurred in their areas in different time periods (Appendix 5). Extreme events of climate especially those that were associated with low crop production were explained by the local people in terms of "hunger" periods which literally indicate insufficient crop production to food requirements. The following events described in this case:

(a) Hunger of *Kidyakingo*

This is the worst period of food shortage in history in the study area, which was caused by both hydrological and agricultural droughts. Many *Zigua* (residents of Handeni) know the legends of this incident famine called *Kidyakingo* when the people are said to have eaten cattle hides. Besides the legend of *Kidyakingo* other famine before the 1880s consists of two famines which led to some people moved to Somalia.

(b) Hunger of *Lugala*

This was the last major pre-colonial famine before 1900 and the very different early colonial famines; the famine seems to mark the onset of new conditions in *Uzigua*. It caused by drought which destroyed planted grain crops. Many people lacking food stocks sought to buy from the missionaries. *Nguu* (residents of Kilindi) was visited by many *Zigua* from the lowlands who sought food in the mountains. Throughout May people were leaving residence in larger number to look for food; other people were stealing from the mission fields while many *Zigua* of the lowland were subsisting on wild roots. According to respondents other people from Nguu went to Pangani town or to Kwamgwe village near Pangani falls to purchase "*Karachi*"sorghum which was imported from India.

(c) Hunger of *Mdudu*

In 1910-1911 there again was widespread dearth in the Handeni area and throughout Kilindi due to shortage of food. Many people survived by gathering fruits, wild roots, and wild growing leafy plants. An important food during that faminc for people who lacked grain was *mdudu*, a tuber root of the shrub *Thylachium africunum*. According to respondents, *Mdudu* is poisons, however unless it is repeatedly boiled. In 1911 an epidemic of dysentery-like intestinal disorder occurred in Handeni and Magamba villages. It was diagnosed by German doctors as poisoning caused by consumption of inadequately prepared *mdudu*. At Magamba alone there were at least forty cases of poisoning and five deaths.

(d) Hunger of *Locust*

Drought and locust plagues occurred in 1925 and 1932-1934, chronic shortage of food turned into devastating famine as short rains of 1932 failed. When the drought extended through the long rain season of 1933, shortage turned into killing famine. Once again the *vuli* were sparse. In many places, *vuli* crop were destroyed by locust in January 1934. Early in 1934 was the most desperate period of the famine; thereafter conditions improved as the drought broke in April. According to (TIRDEP, 1977 in Giblin, 1986) Handeni received only 511 mm of rainfall in 1933 and 940 mm and 813 mm in 1932 and 1934 respectively. In 1937 and 1939 there was famine again, local shortage of food was reported in Handeni district (Mandela Journal, 1939 in Giblin, 1986).

(c) Hunger of *Yanga*

Due to persistent droughts in the 1970s and early 1980s local people in the study area received yellow maize flour as food aid from the government donated by the United States of America. Local people therefore named the maize flour *'yanga'*. That hunger is therefore referred to as '*hunger of yanga*'.

4.6 Coping/Adaptation Strategies

Most of the respondents reported that climate variability affects crop growing season and productivity, increases diseases, pests and insect problem. Also it decreases water quantity, reduces vegetation due to drought and spoils crops due to high rainfall in harvesting period. Other effects include food shortage, death of animals, environmental degradation and washes out crops. However, climate variability has some positive effects. Increase in temperature causes early crop germination and fast maturation but this depends on the crop type/variety.

In dealing with climate variability farmers respond in the short run or immediately, designated as "coping strategies and in long run/long term designated as "adaptation strategies". Coping and adaptation strategies mentioned by respondents are summarized in (Table 3). The coping strategies are those used for short term and during the extreme events while the adaptation is used before; during and after the events and is a long-term strategy.

Table 3: Local people's coping and adaptation strategies in Handeni and Kilindi Districts

Coping strategies	Adaptation strategies
Selling livestock	Garden irrigation
Selling forest products (fire woods, Charcoal, pole, and timber)	Cultivating in wet areas/bottomland wetland
Engage in casual labour	Growing drought resistance crops such, sweet potatoes, and cassava
Government aid	Waiting the grace (take no action)
Hunting	Storage of food
Eating/selling honey	Tree planting
Gathering wild roots/fruits/leaves	Contouring
Buying food	Change crops and or diversify the type of crops
Decrease meals (e.g. supper)	Growing root crops
Stop selling food	
Receiving remittances from relatives	
Given food by relatives	
Mortgage growing crops	

4.6.1 Coping strategies

Farmers in Handeni and Kilindi engage in a diversity of activities during the extreme weather events as depicted in Table 3 includes receiving remittances from migrant household members, collecting wild fruits, switching to non-farming activities or in extreme cases, selling assets. Coping mechanisms during drought and other climate extremes also includes casual labour, brick making, handicraft, collecting honey and charcoal burning. Other strategies for coping with seasonal food shortages include petty business, changes in diet, fewer meals and loans from traders. In recent years, migration to urban areas in search of paid employment has become increasingly popular even though urban unemployment is high.

The main strategy during severe food shortage in Handeni and Kilindi districts is switching to non-farm activities (Table 4). Few livestock keepers participate in non-farm activities compared to crop producers because they sell their animals and buy foods from urban area.

Many people worked as casual labourers for payment of either cash or food. Charcoal making, carpentry, and brick making were performed more in Handeni because they were in high demand than in Kilindi.

Table 4: Distribution of non-farm activities during food shortage (n = 420) in Handeni and Kilindi districts

	Total (%)	Crop production (%)
Casual labour	28.6	12.9
Charcoal making	10.0	5.7
Carpentry	2.1	0.7
Small business	19.2	7.1
Brick making	2.1	1.4

According to respondents dry cassava is the main source of food during severe food shortage. Some dry cassava brought from Bogolwa village in Handeni but most of it bought from Muheza district. Majority of the people used to eat wild roots, wild fruits and wild leaves. Wild roots eaten during food shortage includes; *Mdudu, Sampu and Ndiga.* Wild fruit eaten includes; *Siga, Mbujembuje, Maviru , Sezi, Matomokwe, Matonga and Kwamba.* Wild leaves eaten were *Mchunga, Mnangu, Mhombo, Mchole, Kilumbu, Msufi, Mpwimbiji, Hangatu, Nderema and Kisamvu* (cassava or rubber leaves).

4.6.2 Adaptation strategies

Local people in Handeni and Kilindi districts have developed different long-term strategies to cope with both expected and unexpected variability of rainfall and water resources. The strategies are mainly related to the local production systems and the adaptation of local people to the surrounding environment. The strategies to cope with changes and variations of rainfall are geographically dispersed depending on the location and time in relation to nature of landscape such as slope, lowland and hills and nature of rain seasons. The strategies include rainwater harvesting, change of cultivation seasons, cultivation patterns, cultivation techniques and type of crops grown. These strategies are mostly intended to reduce the expected risk of rainfall variability on the production systems and life in general.

All respondents indicated that rainwater harvesting is effective and widely used as one of the coping mechanisms to rainfall and water resources variability in the study villages. The techniques for rainwater harvesting include the construction of water tanks and excavating shallow basins for collecting run-off water.

As rainfall changes over relatively long periods, the cultivation patterns of food crops tend also to change. When there is relatively low rainfall over a long period mainly over ten years, food crops, which are commonly grown in the uplands, can be grown in the lowlands and when there is relatively high rainfall food crops, which are commonly grown on lowlands can be grown on uplands. This strategy ensures sustainability of food sufficiency at the household levels in the Kilindi district throughout the year. About 75 percent of the respondents indicated that cultivation patterns are the common and effective coping mechanisms to rainfall and water resources variability particularly in sustaining food production.

When there is a persistent decrease of rainfall over long period of time, local people develop the cultivation techniques, which conserve moisture. For instance, by constructing and growing crops on ridges implies taping of surface run-off hence moisture storage increase moisture availability for plant growth. Similarly, during heavy rainfall, ridges reduce surface run-off and therefore minimise its impacts on the land, such as soil erosion. Employing different cultivation techniques as coping strategy to rainfall and water resources variability however is not common in the study villages. Only 30 percent of the respondents indicated that they have been cultivating on ridges as a cultivation technique to reduce the negative impact of rainfall variability. Majority of the farmers grow their food crops in wetlands/bottomland during the seasons with less rainfall. Most of them grow sweet potatoes, cowpeas or cassava as coping strategy.

Planting drought-tolerant crops is the common and effective strategy to dealing with rainfall and water resources changes and variations employed by local people in the study area. About 80 percent of the respondents revealed that they had been planting drought-tolerant crops, such as cassava, pigeon pea and sweet potatoes, as a strategy to changes and variations in rainfall and water resources in the study villages. All respondents said they have been growing drought tolerant maize seed called *Katumaini,* and *Mzigua*. Eighty five percent said they have used improved drought tolerant seeds like *Sc 403, Taxpeno* and/or *St uca.*

The study found out that when there was enough rainfall in Kilindi district, cultivators used to have only one season, that is, long rains season. The decrease of rainfall necessitated the introduction of second cultivation season, that is, short season, to supplement food deficits due to unreliable rainfall. Though other factors, such as population increase at household level, may have caused the shift from one cultivation season to having two cultivation seasons in the year it was revealed that the cultivation during the short rain season is a result of decrease in rainfall over time. Sixty percent (60%) of the respondents revealed that cultivation during the short rain was introduced as a coping strategy to decrease in rainfall.

The occurrences of hydrological disasters have necessitated local people to develop different strategies to minimise related impacts. The strategies include directing or diverting running water to maize fields, the use of plots, which are not prone to floods and plant drought-tolerant maize seeds. The cultivation of maize is either on flat lands or valleys depending on the expected weather conditions, that is, when heavy rainfall is expected cultivation is on the flat lands while when drought is expected cultivation is on the valleys/valleybottoms. Likewise, planting of drought tolerant crops depend on the expected weather conditions (dry or wet conditions). When long dry season is expected local people plant drought tolerant maize seeds such as *Taxpeno* and *Katumaini* in order to minimise the problem of food insecurity.

Table 5: Adaptation strategies to climate variability in Handeni and Kilindi districts

Adaptation strategies	Percentage of farmers
Planting drought resistant crops	80
Changing cultivation pattern	75
Cultivating during short rain	60
Cultivating on ridges	30

CHAPTER FIVE

5.0 DISCUSSION

5.1 Maize Production Trend

According to the respondents in the study area and maize production data from District Agricultural and Livestock Development, production of maize decreases by 33% from 1976 to 2005. National Sample Census of Agriculture 2002/2003 survey report (URT, 2006) show a rapid decline in maize yield from around 1.25 tones per hectare to 0.25 tones per hectare in 2003 with the main period of yield reduction occurring over the period 1994 to 1998. Also the effect of climate change on maize yields through simulations by Crop Environment Resources Synthesis Model (CERES-Maize) showed that maize yield will be lower as a result of higher temperatures and, where applicable, decreased rainfall and the average decreases over the entire country will be 33% (Munishi *et al.*, 2006).

5.2 Rainfall Trend

Analysis of rainfall data from Handeni Meteorological Station for trends shows the mean annual rainfall decreased by 11.4% from the decade 1976 – 1985 to the decade 1996 – 2005. Analysis of climate change scenarios across multiple general circulation models show that areas in Tanzania with a bimodal rainfall pattern will experience decreased rainfall of 5% - 45% and those with unimodal rainfall pattern will experience decreased rainfall of 5% to 15%, (CEEST, 1999, Munishi *et al.*, 2006).

The number of raining days in Handeni and Kilindi showed a decreasing trend with high inter annual variations. The number of rain day decreased by 19% between 1976/ 1985 and 1996/2005 decades. Hatibu *et al.* (2000) articulated that, the rainfall in semi-arid areas is described as relatively adequate; highly variable with greater uncertainty and nearly throughout the country potential evaporation exceeds rainfall for more than nine months in a year. The decrease of rain days can lead to the failure of seasonal rainfall to sustain maize growth to reach maturity stage.

5.3 Relationship between Rainfall and Maize Production

Data from Handeni Meteorological Station shows the minimum amount of rainfall recorded was 468 mm of rainfall recorded in 2003, which was the least amount since 1975. The percentage of maize production per area in the same year was 40% which was the second from the bottom of the list of all thirty years. According to Rapid Vulnerability Assessment Report 2003 crop failure due to poor 2002/03 rainfall season has rendered 1 939 026 people in 320 026 households adversely food insecure in Tanzania. The number of food unsecured population in Handeni and Kilindi was 35 255 (14%) and 31 174 (22%) of total population respectively. Alexandrov and Hoogenboom (2000) observed that decreases in annual precipitation during 20^{th} century in Bulgaria during critical period of maize development limited growth development and final yields of maize.

People in Handeni and Kilindi districts are mainly agro pastoralists and their economic activities depend to a large extent on rainfall. Local people have been developed some adaptations to climate variability from their experiences while interacting with the environment in the production systems. Rainfall varied in terms of "amount", "intensity", "onset" and "offset". Nature of outputs from agricultural production, which are rain-fed oriented give, signals of the nature of rainfall, that is, whether low, moderate or high. Based on plant-water relationship, variations of crop harvests either between seasons or between years indicate variations of moisture contents in the soils in respective time period. Good harvests of different food and cash crops with high water requirements indicate high rainfall, hence low moisture contents with poor harvests normally indicate low moisture for crop production and hence, low rainfall. Average harvests indicate average rainfall and considerably moderate moisture contents in the soils. Majority of respondents said the decrease of maize production year to year was due to decreases of rainfall. Data from Tanzania Meteorological Agency and from Ministry of Agriculture and Food Security, Annual rainfall and maize production data for thirty years from 1976 to 2005 show decreasing of mean annual rainfall and annual maize production. Most of the years with high annual rainfall (Fig. 4) were the one with maximum maize production (Fig. 3) indicating that, maize production depends on the amount of rainfall in Handeni and Kilindi districts.

5.4 Local people Coping Strategies and Adaptation to Climate Variability

Respondents mentioned the main coping strategies to climate variability as; switching to non farming activities, offering causal labour, selling livestock, selling forest products, and collecting of wild roots/fruits and adaptation strategies as; Rainwater harvesting, change of cultivation seasons, change of cultivation patterns, improve cultivation techniques, cultivating along valley bottom wetlands and growing of drought tolerant crops/seeds. In literatures, (Orind and Murray, 2005) suggests some coping mechanism during drought and other climate extremes as: switching to non farm activities, offering causal labour and collecting wild fruits. Also one of the literature (Orindi and Murray, 2005) articulated that; coping mechanisms during drought and other climate extremes can includes brick making, handicraft, collecting honey and charcoal burning.

Low (2005) explain some adaptation to climate variability as; seasonal rainwater harvesting, growing of drought tolerant and fast maturity crops, control overgrazing and promotion of the use of alternative sources of energy such as solar cooker instead inefficient woodstove and charcoal stove.

Coping and adaptation strategies to climate variability should be sustainable and environmentally friendly. The survey indicated that most small farmers in rural areas use temporary solution that some time result into habitat changes and affects the natural ecosystem. Most of these adaptation strategies were used during drought and sometimes in extreme rainfall. The following authors are the ones who revealed that coping strategies helps farmers only for short-terms (Feenstra *et al.,* 1998; Low, 2005; Orindi and Murray, 2005).

The survey indicated that; remittances from migrant family members and relatives play an important role in household well being during difficult periods. People who receive remittances tend to be less affected by shocks in terms of access to food, health services and school attendance (Eriksen *et al.*, 2002 in Orindi and Murray, 2005). The sale of household goods is another strategy, albeit only for the short-term (Low, 2005). Household goods and assets such as land and livestock can be sold to pay off debts incurred during extreme events. This erodes the asset base and, ultimately, a household's chances of long-term survival. Such short-term coping strategies need to be managed to ensure that households do not descend into a state of helplessness.

Other strategies for coping with seasonal food shortages include petty business, changes in diet, fewer meals and loans from traders. In recent years, migration to urban areas in search of paid employment has become increasingly popular even though urban unemployment is high (Orindi and Murray, 2005).

From the survey, some adaptation measures for climate variability focus on increasing drought resistance crops that perceived in policies as a principal means of addressing problems related to climate variability and drought (Eriksen, 2001) found the same thing. Also, these measures have been integrated into national and district development policies, multi-sectoral policies, and sectoral policies.

Field observation revealed the negative and positive implication of coping and adaptation strategies in all surveyed villages, negative effects includes deforestation done by the farmers during famine by selling fuel wood for getting money to buy food. Fondazion, (1990) articulated the same implication of coping and adaptation mechanism as both negative and positive they have effect on soils, water, land, and livelihood systems. Also (Feenstra *et al.,* 1998) cited that human activities are always adapted to climate variability in negatively to land management.

Majority of respondent in group discussions mentioned the food shortage from great natural disasters partly associated with extreme atmospheric events. The famine becoming severe by lack of appropriate human adaptation/ adjustment and that shortage are being increased due to decreased rainfall. Ning *et al.*, 2003 articulated that any development of any set of response; coping or adaptation options needs to include present stress and strategies as well as future complications from human activities.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Rainfall trend shows the declined rainfall from 1976 to 2005 by 11.4% and rain day trend shows they decreased by 19%.The onset of rainfall had shifted from February to March during long rain and November to October during short rain. Mean annual temperature trends show the increase of about 0.1^{0}C from 1980 to 2005. Overall climate has become warmer after the 30 years. Maximum temperature trends shows increased while minimum temperature decreased. There has been a big influence on maize production by rainfall variability in Handeni and Kilindi districts. Maize production trend shows a decreasing in productivity. The overall maize yields declined by 33% from 1976 to 2005.

The mean annual rainfall decline by 11.4% and the number of rain days declines by 19%. Because of the high correlation between rainfall and maize production trends decreasing rainfall is likely to be the cause of decline in maize production in those districts.

Major coping strategies to climate variability are switching to non farming activities, offering causal labour, selling livestock, selling forest products, and collecting of wild roots/fruits and major adaptation strategies are cultivation in valley bottom, rainwater harvesting, change of cultivation seasons, change of cultivation patterns, improve cultivation techniques, cultivating along valley bottom wetlands and growing of drought tolerant crops/seeds. Local communities have copped and adapted with these trends in various ways, among which is cultivation in valley bottoms wetlands.

6.2 General Recommendations

There must be a tangible effort on the improvement of peasant agriculture so as to achieve the sustainable agriculture for their development and reduce the climate variability effects to farmers. These need to include the diversification of agricultural production, improving agricultural inputs and implements, rising standard of lives of peasant farmers and provision of environmental management education.

Adaptation strategies in rural areas must be improved so as to achieve sustainable land resource management and community development. These should involve the increase local communities' awareness on climate variability and their roles in land resources management and the institutions responsibility on land resources management. Communities and government agencies must enhance sustainable coping and adaptive capacity for reducing vulnerability, particularly for the most vulnerable region and social groups. Any future management plan of the adaptation strategies needs to be developed with the active participation of local communities. The collaborative management strategy would probably be the best approach in the future land resources management.

There is a need for adaptation to rely largely on projections of future impacts; this might argue for more immediate adaptation measures in case of such impacts as opposes to a "wait and see" strategy. For all the above reasons, there might be a need to differentiated adaptation strategy across various sectors and regions depending upon the certainty of projections, the mix of beneficial and adverse impacts, and the urgency and timing of such impacts.

6.3 Recommendations for Further Studies

The studies on climate variability and land resources management are diverse and have many perspectives that cannot be covered at a time. There is a need of further research that will give a more reliable picture of natural resources management, climate variability and community attitudes on resources management. The detailed research on the following field is needed:

Specific studies on food security can also be done to determine how land resource is affected by climate variability and the effects from coping and adaptation strategies. Similar studies can also be done in other parts of the country and even out of the country for comparison purpose and experience sharing especially on how coping and adaptation strategies can be improved to sustain land management for food security and attain sustainable environmental resources so as to eradicate poverty.

It is important for the community to be involved in forest management so as to allow access to forest resources in a sustainable manner and improve local livelihood options. However, Control of alien and invasive species and restoration of degraded areas are other options that may be carried out jointly with local communities.

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APPENDICES

Appendix 1: Household questionnaire

Household questionnaire

Dear household head,

Your household has been randomly been selected so as to provide data that could be used to asses the effect of climate variability in maize. All the information you will provide will be for academic purposes and be treated confidentially.

Therefore, you are kindly requested to respond truthfully and faithfully to the following questions. I thank you in advance.

I think you in advance.

A: General information

1. Name of interviewer...
2. Date of interview..
3. Questionnaire number...
4. Village number...
5. Ward...
6. Division...
7. District...

B: Household characteristic

8. Household number...9. Name of household head................................

10. Age (in year)...............11. Sex..........Male= (1) or Female= (2)

12. Marital status................Married= (1) or Single= (2) or Divorce= (3) or Widow= (4)

13. Level of education of household head (in year of attendance)...........................

14. Main activities of household.........Crop production= (1) Livestock production= (2) Both crop and livestock production= (4). Others, mention................................

C: Farm activities

15. How many acres did the household cultivate in 2005/2006 seasons?

16. When did you start cultivate your farm.....................year?

17 Did the rainfall enough...........Yes= (1), No= (2)

18. Which year between 1975 to 2005 on which the rainfall not enough, List them...

19. List the crop acreage and harvest for each crop for 2005/2006 seasons.

Type of crop	Acreage	Harvest bags	Average
Others			

20. Which year between 1975 to 2005 on which the crop production not enough, List them..

21. Which year from 1975 to 2005 on which the crop production was more than enough. List them..

22 Which year "between 1975 to 2005"on which the rainfall was average. List them...

23. Which year" between 1975 to 2005" on which the crop production was average List them...

24. What is your view on the amount of rainfall in 2005/2006 seasons................ Enough= (1), Moderate = (2) Adequate= (3)

25. Which year from 1975 to 2005 on which the drought causes hunger to your family. List them.............................

26 What are the coping strategies during famine; List them.............................

27 What are the causes of drought in your village ....

28 What are possible mitigation measures to drought; List them........................

29 What are the current solutions to drought in your village: List them................

Appendix 2: Linear regression model

A linear regression model will be used to show the relationship between maize production (dependent variable) and independent variable will be Rainfall, Temperature pest and diseases, wind, natural disasters and Trend of production factors

Statistical Model for regression will be

$Yi = a + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + bjXj + e$

Where;

Yi = maize production (tons)

X_1-Xj=independent variable

X_1= Rainfall

X_2= Temperature

X_3= Loss of yield due to outbreak of pest and diseases

X_4= Loss of yield due to natural disaster like floods

X_5=Fertilizer application

X_6= Farm size

X_7= Loss of yield due to all other factors

a = Intercept

b_1 and bj= Independent variable coefficient

e_i= Random error

i = 1, 2, 3...

Appendix 3: Crop harvest estimates

Expected minimum crop productivity per hectare in tones

Crop	Productivity per hectare
Maize	1.2
Cassava	0.4
Beans	3.0
Pigeon peas	0.6
Peas	0.3
Mangoes	10.0
Bananas	10.0
Coconut	2.0
Sugarcane	60.0
Cotton	0.3
Tobacco	0.5

Source: (URT) (2006). National Sample Census of Agriculture 2002/2003: Small holder Agriculture (Questionnaire for Small Farmers), pp. 22

Crop productivity per hectare in tones in Handeni and Kilindi districts

Crop	Productivity per hectare
Maize	1.5
Cassava	1.7
Beans	1.0
Cotton	1.5
Cashew	0.5
Pigeon peas	0.5

Source: DADP Handeni (2005); DADP Kilindi (2005)

Appendix 4: Climate extreme events, their effects and community responses

Village	Year	Extreme event	Impacts	Coping and adaptation
Kideleko	1977,1982, 1983,1996, 2003	Drought	***Hunger and diseases***	Causal labour, Selling livestock. Selling forest products, eating wild roots/vegetables/sugarcane Government food aids
	1997	Excessive rainfall	Destroy some crops, houses and infrastructures	Repair
Misima	1976,1977, 1979, 1983,1996, 1998, 1999, 2003,2005,	Drought	Hunger, dry of grasses	Buying food from other place, selling livestock and forest products, Government aids.
	1997	Excessive rainfall	Destroy crops,	There was no responses
Kabuku ndani	1976,1977, 1979, 1982, 1984,1996, 2003, 2005,	Drought	Hanger Crop diseases Pest destroy crop	Wait rainfall, buying food, Receiving help from relatives, growing new crop Government aids
	1997, 1998	Excessive rainfall	Some crops swept by water	No respond
Msente	1976,1977 1978, 1979, 1981, 1983, 1984, 1993, 1996, 1999, 2003, 2005,	Drought	Food shortage, Cause pest and diseases, water dried, crop dry out and increase hanger	Selling part of livestock, exchange crops, growing drought resistance crops, Use of chemicals, Government aids
	1997	Excessive rainfall	Some crops swept by water	No respond
Kwedibo ma	1977,1983, 1994 ,2003	Drought	Diseases and destruction of crops Food shortage	Selling forest products, eating wild roots/fruits/vegetable, Mortigation of crops in their farms, government aids.
	1997	Excessive rainfall	Some crops swept by water	Cleaning the surroundings and planting new crops
Songe	,1977, 1979, 1981, 1983, 1984, 1993, 1996, 1999, 2003, 2005	Drought	Cleaning the surroundings and planting new crops	Selling forest products, eating wild roots/fruits/vegetable, Mortigation of crops in their farms, government aids.
	1986,1997	Excessive rainfall	Severe soil erosion	Cleaning the surroundings and planting new crops

Source: Field survey

Appendix 5: Major events in the study area over time

Year	Socio-economic Events	Political Events	Hydrological Events
1880's	♦ Hunger of *Kidyankingo* and *Lugala*		♦ Drought
1911	♦ Expansion of rubber plantation ♦ Five people die in Magamba because of eating *Mdudu*	♦ Execution of a man named Mtunte by German government ♦ Sub-district headquarters of Handeni opened.	♦ drought
1912	♦ Good crop harvest	♦	♦ Heavy rainfall
1925	♦ Locust plagues occurred, short rain of November and December fail	♦ Vigorous tax –gathering campaign sells their grain and liver-stock. ♦ Famine occurred.	♦ Drought
1930	♦ Abundant harvest		♦ Heavy rainfall
Year	**Socio-economic Events**	**Political Events**	**Hydrological Events**
1933	♦ Plagues of red locusts	♦ Catastrophic famine, which was serious than all famines, happens in handeni and Kilindi. Some people die and other migrate to Muheza and other area.	♦ Drought throughout the year
1960s	-	♦ Independence for Tanganyika and Kenya	♦ Uhuru rainfall (heavy rainfall ever seen in the region)
1970s	♦ Hunger of *Yanga* ♦ Introduction of cassava as food crop	♦ Agricultural resolution lead to expansion of area under cultivation ♦ Ujamaa villagilisation policy ♦ Universal primary education	♦ Persistent drought ♦ Many livestock died due to water shortage
1980s	♦ Hunger of *Yanga*	-	-
1990s	-	-	♦ El Nino rainfall

Source: Field survey

Appendix 6: Production of a major crops in Tanzania, 1986/87 -2001/02 (in thousand tones)

Year	Maize production in tons	Other cereal production (tons)	Total cereal crop production	Non cereal crops	Total food production	Percent of maize production to other cereal crops
1986/87	2359	1445	3804	3088	6892	62
1987/88	2339	906	3497	3246	6742	67
1988/89	3125	1369	4494	3413	7907	70
1989/90	2445	1155	3600	3958	7558	68
1990/91	2332	1240	3572	3032	6604	65
1991/92	2226	1170	3396	3141	6537	66
1992/93	2282	1405	3687	3174	6861	62
1993/94	2159	1154	3313	3090	6403	65
1994/95	2567	1795	4362	2972	7334	59
1995/96	2663	1800	4463	3034	7497	60
1996/97	1831	1281	3112	2776	5888	59
1997/98	2685	1586	4271	3700	7972	63
1998/99	2452	1344	3796	3645	7440	65
1999/2000	2009	1359	3368	3955	7322	60
2000/01	2579	1565	4141	3553	7695	62
2001/02	2705	1757	4462	4111	8572	61

Source: MAFS, 2002

Recall food situation on 2000/01 and 2001/02

	Total cereal			Total non-cereals			Total Food		
	Production	Require-ment	Gap/ Surplus	Production	Require-ment	Gap/ Surplus	Production	Require-ment	Gap/ Surplus
2000/01	3 367 672	4 788 009	1 245 384	3 954 675	3 088 891	703 877	7 322 347	7 916 166	541 507
2001/02	4 461 782	5 109 460	647 677	4 110 506	3 274 172	836 334	8 572 288	8 383 631	188 657

Source: MAFS, 2002

Appendix 7: Maize production and Rainfall in Handeni and Kilindi districts from 1975 to 2005

Year	Annual rainfall (mm)	Production area (Ha)	Planted area (Ha)	Armyworm outbreak (Ha)	Production (Tons)	Production (T/Ha) in%
1976	750.9	47,866	40,010	0	36,756	77
1977	856	48,823	37,929	0	41,789	86
1978	1223	49,799	45,384	1,021	68,076	136
1979	1020	50,795	40,374	0	60,561	107
1980	931	51,811	37,858	325	45,430	88
1981	901	52,847	37,447	125	44,936	85
1982	1135	54,004	41,200	0	61,800	115
1983	793	63,821	30,731	0	27,658	43
1984	729	65,097	25,201	0	21,616	33
1985	913	66,399	30,691	0	36,829	55
1986	1081	67,727	40,146	0	60,219	89
1987	726	69,082	26,983	0	24,285	35
1988	825	70,464	41,165	0	45,282	64
1989	803	71,873	24,793	0	29,793	41
1990	756	73,310	40,289	0	36,260	49
1991	722	74,776	37,616	470	33,864	45
1992	940	76,272	39,310	160	47,172	62
1993	753	77,797	43,215	140	38,894	50
1994	682	79,353	29,550	1,115	23,640	30
1995	871	80,940	36,056	55	39,662	49
1996	693	82,559	42,536	100	34,029	41
1997	1044	84,210	51,166	27	69,319	82
1998	817	85,894	43,526	0	47,879	56
1999	712	87,612	20,726	460	20,311	23
2000	837	89,364	57,054	250	62,759	70
2001	845	91,059	75,061	4,185	60,049	66
2002	1116	107,565	89,139	5,900	106,967	99
2003	468	109,716	87,113	0	43,557	40
2004	823	119,910	102,801	1,588	51,681	51
2005	661	114,148	37,420	30	30,241	26

Source: Districts Agricultural and Livestock Development reports (March 2007).

Appendix 8: Food shortage associated with climate change at regional level over the recent 5 years (1998-2002) in Tanzania.

REGION	Deficit District (%)	Frequency in years	Percentage of Districts experiencing food shortage		
			≥50	≥75	100
Arusha	100	3	Arusha	Arusha	Arusha
Manyara	100	2	Manyara	Manyara	Manyara
Dar es Salaam	100	2	Dar es Salaam	Dar es Salaam	Dar es Salaam
Dodoma	100	3	Dodoma	Dodoma	Dodoma
Shinyanga	100	3	Shinyanga	Shinyanga	Shinyanga
Tanga	100	2	Tanga	Tanga	Tanga
Coast	83	3	Coast	Coast	
Lindi	83	2	Lindi	Lindi	
Mtwara	80	2	Mtwara	Mtwara	
Singida	75	3	Singida	Singida	
Morogoro	67	1	Morogoro		
Tabora	67	2	Tabora		
Mwanza	63	2	Mwanza		
Mara	60	2	Mara		
Kilimanjaro	50	3	Kilimanjaro		
Rukwa	50	1	Rukwa		
Iringa	43	2			
Ruvuma	40	1			
Mbeya	38	1			
Total			**16**	**10**	**6**

Source: MAFS (2005) AGSTATS for FOOD Security, Volume 1

Appendix 9: Mean annual temperature trend from 1981 to 2006

METEOROLOGICAL COMPUTATION FORM AND SUMMARY

(AVERAGE TEMPERATURE 'C')

HANDENI DISTSRICT COUNCIL

YEAR	JAN.	FEB	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.	AVER
1981	22.3	22.5	22.5	22.4	21.8	18.2	18	19	19	20.2	23	26	21.3
1982	25	27.0	26.8	24.5	22.3	22.0	22	22	20.0	23.7	24..2	22.6	23.5
1983	25	26.4	27.0	22.4	22.4	22.3	23	22	22.4	24	25.7	25	24
1984	25.5	26.4	26.5	24.5	23.2	20.7	20.6	20.7	22.2	23	23	25	23.4
1985	25.1	24	24.2	24.0	22	21.0	20.7	20.6	22.4	21.5	24.6	25.0	23
1986	25.3	27.1	26.8	24.4	23	24.3	20.2	21	22.3	24.6	25.3	25.3	24
1987	25.7	26.1	27.1	26	23.4	21.4	21.3	21.6	22.4	24.4	25.8	27.5	24.4
1988	27.1	27.2	26.0	25.1	24	22.4	22.3	22.2	22.2	24	26	25.6	24.5
1989	24.6	26	26.4	24.4	23	21.3	21.2	21.8	22.5	23.5	25	26.2	23.8
1990	26	26.5	25	26	24	22	21	22	23	24.1	25	26	24.2
1991	27.2	27	27.3	26	23.4	21.5	21.3	21.8	22.6	24.5	25.8	25.5	24.5
1992	26	26.7	26.7	25.1	23.3	21.	20.4	20.5	21.4	24.1	24.3	24.7	23.6
1993	24.9	25.7	26.3	25	24	21.9	20.8	21.0	22.4	23.5	25.4	26.3	24
1994	27.3	27.2	26.1	25.1	22.4	21.4	21.2	22.1	23.2	25.0	24.3	25.5	24.2
1995	26.3	25.3	26.2	25.2	23.3	21.9	21.7	22.2	23	24.1	25.1	26.4	24.3
1996	26.8	26.5	27.0	24.7	23	21.7	20.6	21.4	20.6	22.4	23.4	24.5	23.6
1997	25	27.3	25.7	23.5	22	21	20.4	21.6	23	23	24.3	24.4	23.4
1998	25.2	25	26.2	25	23.6	22.1	21.5	22.5	22.7	23.3	25.0	26.8	24
1999	26.6	27	26	24	22.9	21.3	20.6	21.0	22.5	23.2	25	25.4	23.7
2000	27.1	27.2	26.0	24.4	22.8	21.6	20.9	21.7	22.5	24.4	26.2	25.9	24.2
2001	26.2	25.7	25.9	24.4	23.3	21.3	20.6	21.3	22.8	23.9	25.8	27.1	24
2002	26.6	25.9	26.0	23.6	22.9	21.7	22.1	21.6	22.4	23.9	24.8	25.7	24
2003	26.0	27.3	27.0	24.8	23.0	21.4	20.9	21.3	22.5	23.3	25.5	26.2	24.1
2004	26.0	25.2	25.0	23.9	22.8	21.3	21.0	21.5	22.8	23.4	23.8	25.4	23.5
2005	25.7	26.2	23.9	24.4	22.3	21.6	20.9	21.1	23.1	24.6	26.3	25.8	23.9
2006	25.8	26.9	25.1	23.8	22.6	20.8	20.6	21.4	21.9	22.4	23.7	25.1	23.3

Source: Handeni Meteorological Station (March 2007)

Appendix 10: Total average monthly rainfall for ten years.

Decade	1976 -1985		1986 - 1995		1996 - 2005	
Monthly	**Rainfall (mm)**	**Rainy day**	**Rainfall (mm)**	**Rainy day**	**Rainfall (mm)**	**Rainy day**
January	507	65	795	86	736	63
February	1015	71	774	53	639	55
March	974	101	914	87	1304	99
April	1698	184	1763	165	1788	167
May	124	167	1381	159	935	118
June	335	64	207	62	321	58
July	230	67	147	42	83	39
August	182	64	216	53	417	56
September	266	66	177	41	148	43
October	609	86	406	72	80	78
November	1149	90	643	71	423	73
December	1291	112	79	93	636	67
Total	**8380**	**1137**	**7502**	**984**	**7510**	**916**

Source: Handeni Meteorological Station, 2006

CC