EFFECT OF CLIMATE CHANGE TO PASTORAL COMMUNITIES IN MVOMERO DISTRICT, TANZANIA

SUZAN YUSUFU MAGITA

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ABSTRACT

Climate change is among the great challenges facing pastoralistse specially milk producing pastoralists in Tanzania. The main objective of this study was to assess the climate change effect on grazing land and quantity of milk produced by pastoralist in Mvomero District. Specifically, the study aimed at determining rainfall and temperature trends of Mvomero District over the past 30 years and their consequence on pasture resources and the quantity of milk produced by pastoralists. A total of 90 pastoralists were randomly selected for interview. Primary data were collected through structured questionnaire for individual interview, while focus group discussions and key informant interviews were done using a designed checklist. Climate and other secondary data were from Tanzania Meteorological Agency (TMA), United States Geographical Satellite (USGS), internet and other reports. The climatic data were analyzed using Microsoft Excel, Statistical Package of Social Science was used to analyze the quantitative and qualitative data, while Arc GIS and Q-GIS were used to analyze the satellite images. Analysis of climate data over 30 years revealed a linear increment of temperature by 0.02% and decline of precipitation by 3%. These findings were comparable to how pastoralists perceived trends of climate in the District. Most of the pastoralists (about 90%) agreed that there has been an increase of temperature and unpredictable rainfall. Analysis of satellite images showed that pasture resources decreased tremendously from 82.1% in 1985 to 5% in 2015. It is concluded that drought is a major challenge and has negatively affected grazing resources and pastoralist’s livelihoods in various ways. The pastoralist’s livelihoods have in turn become more vulnerable as they are dependent on livestock products to obtain their basic needs. To reduce effects, adaptation and mitigation technologies like awareness creation of other sources of income other than milk production should be encouraged.

DECLARATION

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

______________________________ ____________________

Suzan Yusufu Magita Date
(MSc. Candidate)

The above declaration is confirmed;

______________________________ ____________________

Dr. Anthony Zozimus Sangeda Date
(Supervisor)

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DEDICATION

This work is dedicated to my parents Yusufu Magita and Peninah Gibayi who laid the foundation for my studies and to my siblings Ellen, Ester, Tamari and Winnie.

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LIST OF ABBREVIATIONS

CCIAM	Climate Change, Impacts, Adaptation and Mitigation in Tanzania
FAO	Food and Agriculture Organization
IFAD	International Fund for Agriculture Development
IPCC	Intergovernmental Panel for Climate Change
I-CAN	Institutional of Canopy for Conservation
ILRI	International Livestock Research Institute
KM	Kilometers
MEA	Millennium Ecosystem Assessment
MLFD	Ministry of Livestock and Fisheries Development
NBS	National Bureau of Statistics
NCCS	National Climate Change Strategy
NRPH	National Range and Pasture book
TAMPA	Tanzania Milk Processors Association
TCAR	Tanzania Climate Action Report
TMA	Tanzania Metrological Agency
SUA	Sokoine University of Agriculture
SPSS	Statistical Package of Social Science
SQ	Square
URT	United Republic of Tanzania
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VPO	Vice President Office
USAID	United States Agency for International Development

CHAPTER ONE

1.0 INTRODUCTION

1.1Background information

The current most serious threat in the global community is the change of the world's climate that has been affirmed by scientists as changing at an unprecedented rate. The Fourth Assessment Report of the IPCC (2007) pointed out the main reasons for an increase of global average air and ocean temperatures that lead to wide spread melting of snow and ice, precipitation imbalance leading to flood while decreasing causes drought as well as the rising global average sea level. Many countries including Tanzania are undertaking numerous studies to understand more on the existing changes and associated local impacts.

According to Hope (2009) climate change is described as a result of temperature variability due to emissions of greenhouse gases produced by human activities. Human development, especially industrialization which led to an increase in greenhouse gases (GHGs) into the atmosphere that has resulted to weather changes (IPCC, 2007). The impacts of climate change have been reported in several studies. Mendelsohn and Dinah (2005) and UNFCCC (2007) explained the impacts as the changes in cloud cover and precipitation, melting of polar ice caps and glaciers, reduced snow cover, rising of sea waters, extinction of species, and worsening drought. However, Mubaya *et al.* (2010) stated them to fall into two-folds; bio-physical and socio-economic impacts; whereby bio-physical impact include rising sea waters, more frequent and intense storms, extinction of species, worsening drought, crop failure. In spite of uncertainties in climate variability, the IPCC Fifth Assessment Report identified the ‘‘likely range” of increase in global average surface temperature by the year 2100 as between 0.3^0C and 4.8 ^{0}C (IPCC, 2013).

Over the course of last century, Africa has experienced a 0.5^0C rise in temperature with some areas warming faster than others (Eriksen *et al.*, 2008). Africa has been claimed to be one of the most vulnerable continent to climate change due to its dependence on climate activities (IPCC, 2007). The impacts of climate change like rising of temperatures decreases wet periods resulting into longer dry periods that increase pressure on grazing lands; this leads to a significant rise in destitution among pastoral groups depending on livestock production on getting milk and meat products in Africa, including Tanzania (Ced and Lorenzo, 2006). The overall effect of future climate changes on pasture production in grazing lands is uncertain and likely to vary regionally, depending on the combination of changes to temperature and rainfall, as well as plant responses to elevated atmospheric CO_2 concentrations (Harle *et al*., 2007; Howden *et al*., 2008; McKeon *et al*., 2009).

In Tanzania, climate change has also been observed i.e. the mean annual temperature increase of 1.0^0C was recorded since 1960 with decreasing rainfall at an average rate of 2.8 mm per month and 3.3% per decade (TCAR, 2015). Conversely, a decrease in rainfall occurred more in southern part of Tanzania (Mashingo, 2010). Among the regions in Tanzania whereby the impacts of climate change are highly exhibited is Morogoro region, especially in Mvomero district where most pastoralists live.

Currently, Mvomero district is among the particularly vulnerable areas because of high dependence on climate sensitive livelihood activities and low adaptive capacity including livestock keeping. Furthermore, it is among the pastoral districts found in Tanzania contributing into pastoral economy estimated as the basis of the livelihood of almost four million people, which is ten per cent of its population (World Bank, 2006). According to Shayo (2006), pastoralists are forced to relocate to places where pasture and water are available. Temperature increase causes the outbreak of new born diseases and scarcity of fodder which lead to changes in livestock pattern (Digambar, 2011). Although many studies on climate change have been done worldwide, specific studies on the effects to grazing land and milk production by pastoralists are missing. The proposed study would therefore investigate these effects at district level to build a case that can inform policy in the country.

1.2 Problem statement and justification

Climate change affects the amount, patterns and distribution of rainfall and the rise in temperature in Tanzania (USAID, 2012). This causes longer dry period and floods in the country including Mvomero District that leads to not only the failure and damaging of crop but also affected livestock through chronic food shortage (Liwenga *et al.*, 2007; Kangalawe and Liwenga, 2005). Moreover, it affects livestock production indirectly by decreasing grazing land through decline of pasture resources and changes on species composition due to precipitation variation (Herrero *et al.*, 2009). The domestic ruminants under pastoral systems mainly depend on natural forages that are cheap and plenteous during rain seasons but scarce in dry seasons (Mwilawa *et al*., 2008). The study done by Ayers (2009) confirms that, climate change increases the vulnerability of poor people by adversely affecting their health and livelihoods, thus undermining economic growth opportunities and livelihood assets.

Mvomero district is the one of the districts affected by climate change, this cause the impact on grazing land and water sources used for livestock production including milk. For example in 2012 it was reported that, pastoralists from Mvomero district shifted to other places like the Coastal Region in search for water and pasture due to long periods of drought which caused conflict with farmers. People in Mvomero have lived with uncertainty for long and are likely to face increased climate changing in the future (Paavola and Jouni, 2004). Livestock resources are central to the livelihoods of pastoralists in Mvomero district who rely on them for income from sales of animal products including milk (Sangeda and Malole, 2013). Pastoral societies in Tanzania namely, Maasai, Barabaig and Nyaturu have their livelihood largely dependent on livestock husbandry (URT, 2003). If mitigation measures are not taken, livelihood of such societies in Mvomero and other pastoral communities in Tanzania will be jeopardized.

Research findings from this study will help to inform policy and practitioners to take appropriate mitigation and adaptation measures to cope with the effects of climate change in order to improve livelihoods. The results from this study also will inform rangeland managers, pastoralists, policy makers and other practitioners to be able to make decision and plans for the adaptation strategies undertaken to address climate change on grazing land and quantity of milk produced by pastoral households.

1.3 Objectives of the study

1.3.1 Overall objective

To assess the effects of climate change on grazing land and milk produced by pastoral households in Mvomero District.

1.3.2 Specific objectives

i. To determine climate pattern (temperature and rainfall) of the study area over the past 30 years.
ii. To assess the effect of climate change on pasture resources in the study area.
iii. To investigate the effect of climate change on the quantity of milk produced by pastoral households in the study area.

1.4 Research questions

i. What is the rainfall and temperature trend in the study area over the past 30 years?

ii. What are the effects of climate change on pasture resources in the study area?

iii. What are the effects of climate change on the quantity of milk produced by pastoral households in the study area?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definitions of key terms

2.1.1 Climate change

The Inter-governmental Panel on Climate Change IPCC (2007) defines climate change as a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

2.1.2 Pasture

Grazing lands comprised of introduced or domesticated native forage species that are used primarily for the production of livestock. They receive periodic renovation and/or cultural treatments such as tillage, fertilization, mowing, weed control, and may be irrigated. They are not in rotation with crops (NRPH, 1997).

2.1.3 Pastoralists

Pastoralists are people who live mostly in dry, remote areas. Their livelihoods depend on their intimate knowledge of the surrounding ecosystem and on the well-being of their livestock. Pastoral systems take many forms and are adapted to particular natural, political and economic environments (IFAD, 2009).

2.2 Climate change concept

Global climate change is primarily caused by greenhouse gas (GHG) emissions that result in warming of the atmosphere (IPCC, 2013). Carbon dioxide (CO2) emissions from fossil-fuel use, and from other sources, can be offset by removal of CO2 from the atmosphere via a net increase in the carbon stocks of the biosphere (West and Marland, 2002). The greenhouse gases resulted from both natural and human causes. Natural causes include continental drift, volcanoes the earth's tilt and ocean currents (Adger, 1999). According to the IPCC report (2007) about 90% of the greenhouse gases are caused by human activities including industrialization, deforestation and degradation of forests. Human development, especially industrialization has led to an increase in greenhouse gases (GHGs) into the atmosphere that has resulted to weather changes (IPCC, 2007). According to Hope (2009) human activities such as ‘burning of fossil fuels, industrial production, cutting down of rainforests change the atmosphere’s composition by increasing the amount of greenhouse gases, which, in turn, traps heat in the atmosphere and thereby facilitate climatic changes.

2.2.1 Global climate change

Evidence from the Intergovernmental Panel on Climate Change is overwhelmingly convincing that climate change is real, that it will become worse, and that the poorest and most vulnerable people will be the worst affected (IPCC, 2007). The best estimate of global surface temperature change is a 0.6°C increase since the late 19th century with a 95% confidence interval of 0.4 to 0.8°C (Folland and Karl, 2000). Climate change will have serious implications, impacting on ecosystems goods and services upon which poor people and livestock keepers depend, thus exacerbating current development challenges (IPCC, 2007).

The IPCC report also projects a further increase of mean temperatures to approximately 0.74°C and sea level increase at approximately 17cm; whereby greenhouse gas emission could be raised globally by 25–90% by the year 2030 and temperatures could be increased by 3% by the year 2050 (ibid). Africa has been identified as one of the parts of the world that are most vulnerable to the impacts of climate change (IPCC 2014; Niang *et al.*, 2014). In many rural communities, livestock is the only asset of the poor, but it is highly vulnerable to climate variability and extremes (Easterling *et al.*, 2007; FAO, 2007; Thornton *et al.*, 2007; IFAD, 2010). According to Rust and Rust (2013), the predicted effects on dairy and beef production include: decrease in fodder production from dry land and irrigated pastures, with a resulting rise in feed costs, decreased milk production, reduced animal weight gain, decrease in reproduction rate, lower feed conversion efficiencies, increase in the prevalence of vector-borne diseases as well as increase in the prevalence of internal parasite infestation.

2.2.2 Climate change in Tanzania

Studies done in Tanzania, indicate that climate change is expected to raise mean annual temperatures by 3-5°C, and average daily temperatures by 2-4°C by the year 2075 (Ehrhart and Twena, 2006). Rise in temperature will be greater during cooler months (June to August) than warmer ones (December to February) (Agrawala *et al.*, 2003). The research also points out that increases in temperature will be most marked in central and western regions, where temperatures may rise by up to 4°C and less striking in north-eastern areas, where there may be a warming of up to 2.1°C (Ndelolia, 2013). Decreases in observed rainfall have been significant with observations showing annual rainfall decreasing by 2.8mm per month per decade since 1960 (TCRA, 2015). The greatest annual decrease has occurred in the southernmost parts of Tanzania (McSweeney *et al.*, 2010).

According to Tanzania historical data, droughts are experienced after every four years, affecting 3 629 239 people (ibid). The most frequently hit areas are central areas of Dodoma, Singida and some parts of Coast, Shinyanga, Mwanza and Mara. These regions receive 200–600mm of annual rainfall (Senga, 2007). Slowly changing climatic conditions and more frequent extreme events (i.e. drought, floods and sea level rise) are likely to pose threat to water supply to local communities and hence affect livelihood security (Ehrhart and Twena, 2006). Experience of the past twenty years 1980-2000 has shown that floods occurred 15 times, killing 54 people and affecting 800271 others. Flood prone regions include Tanga, Mbeya, Coast, Morogoro, Arusha, Rukwa, Iringa, Kigoma and Lindi (Senga, 2007).

The Fifth National Report of Tanzania to the UN Convention on Biological Diversity reported that severe droughts have exerted pressure on biodiversity and ecosystems (VPO, 2014). Climate change is expected to further shrink the rangelands which are important for livestock keeping communities in Tanzania (NAPA, 2007; URT, 2009). Shrinkage of rangelands is likely to exacerbate conflicts between livestock keepers and farmers in many areas resulting from human and livestock population migration (ibid). According to FAO (2008), some of the indirect effects will be brought about by changes in feed resources linked to the carrying capacity of rangelands. According to Chauhan and Ghosh (2014), climate change is seen as a major threat to the survival of many species, ecosystems and the sustainability of livestock production systems in many parts of the world.

2.3 Climate change effects

2.3.1 Effects on grazing lands

Out of the total 94 million hectares (ha) of land resource in Tanzania, 24 million ha are used for grazing MLFD (2010). Tanzania’s rangelands are dominated by extensive livestock production systems and securing these assets particularly for poorer households in the face of climate change is a major challenge (Sangeda and Malole, 2013). Climate change affects livestock production by altering the quantity and quality of feed available for animals (Chauhan and Ghosh, 2014). It has been confirmed that livestock system centred on grazing land will be more affected by global warming than industrialized livestock system (Nardone, 2010). The rising of temperature and uncertainties in rainfall associated with global warming have also resulted in ecological shifts where changes in plant and pasture species have been evident in many parts of the country which affects livestock production (Sangeda, 2013). Climate change may also affect grazing systems by altering species composition; for example, warming will favour tropical (C_4) species over temperate (C_3) species (Barbehenn *et al*., 2004). In most cases, C_3 species are of higher forage quality than C4 species, and are expected to remain so under elevated atmospheric CO_2 conditions (ibid). Thus, the effect of climatic change on the balance between C_3 and C_4 species could have important implications for animal production (Howden *et al.*, 2008).

Climate change is also expected to alter the species composition (hence biodiversity and genetic resources) of grasslands as well as affect the digestibility and nutritional quality of forage (Thornton *et al.*, 2009). Estimates suggest that one third of the people in Africa live in drought-prone areas and extreme events, including floods and droughts, are becoming increasingly frequent and severe (UNFCC, 2007). Between 1973 and 2002 climatic events constituted 53% of all reported natural and technological disasters in Africa. In some regions, both droughts and floods have been experienced in one year (CCIAM, 2014).

Droughts and extreme rainfall variability can trigger periods of severe feed scarcity, especially in dry land areas, with devastating effects on livestock populations (Chauhan and Ghosh, 2014). Also in many previous studies in East Africa, drought is reported as one of the major natural threats to sustainable livelihood (Bruins and Ros-Tonen, 2003; Huho *et al*., 2011; Campbell, 2013). Droughts reduce pastures, causing high mortality rates in livestock and reduction in milk yield due to inadequate feeding and increased incidence of diseases (Swai, 2012). An extended drought has resulted into increased mortalities of perennial plants and the tendency of switching to an annual-dominated flora such as *Bracharia spp* (Hein, 2006). Reductions in the quantity and quality of feed (leading to less feed intake and higher mortality could make the impacts of climate change on livestock systems severe in certain places (Chauhan and Ghosh, 2014).

Climate with high temperatures causes rapid maturation of grass and therefore tropical pastures are often of low quality, with low protein content and low digestibility, which in turn decreases feed intake (Minson, 1990).

Climate change can adversely affect productivity, species composition and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands (Giridhar and Samireddypalle, 2015). In addition, changes due to rainfall patterns may influence natural resource degradation processes such as erosion and salinity through changes in runoff and drainage patterns (van Ittersum *et al*., 2003; Howden *et al.*, 2008).

Climate change has also seriously affected the availability of grazing pasture, as most of it has dried up or is infested with weeds (Mwakaje, 2013). Many water sources are drying up, especially during the dry season (ibid). Currently, pastoralists move long distances to obtain water for their livestock and for domestic use (ibid). The findings are consistent with those reported by other researchers that the death of large numbers of livestock due to lack of water and pasture has been a repeated occurrence (Shemsanga *et al.*, 2010).

However, some households may afford long distance travel with their livestock to unaffected regions (Fazey *et al.,* 2009; Kuhn *et al.,* 2010). Further research suggests that changes in climate would affect the quality and quantity of forage produced (Baker, 1998). Other changes include a greater frequency of loss of livestock assets particularly through drought and through an expansion of vector-borne diseases (e.g. ticks) into cooler areas (Thornton *et al.*, 2006a).

2.3.2 Effects on rangeland and rangeland productivity

Africa's rangelands, covering 43% or nearly 13 million km^2 of the continents land surface, are comprised mostly of woodlands or shrubs and grasslands (Thornton *et al.*, 2006). According to Tanzania National Census of Agriculture (2012), rangeland resource is estimated to be 61 million hectares of which about 44 million hectares are grazing land while the remaining 17 million hectares are fallow and forestland. More importantly, the composition and productivity of rangelands are influenced primarily by rainfall, fire and grazing and are associated with changes in temperature and the concentration of atmospheric CO_2 over longer time (Fischlin *et al.,* 2007). Increased temperature increases drought stress and tissue lignification in plants and, consequently, affects their digestibility and decomposition rates (Sangeda and Malole, 2013). Shrinkage of rangelands is likely to exacerbate conflicts between livestock keepers and farmers in many areas resulting to human and livestock population migration (NAPA, 2007; URT, 2009).

Rainfall and temperature are key determinants of rangeland productivity (Hoffman and Vogel, 2008). The effect of future climate change projections on the length of the growing period (LGP), which integrates the influence of temperature and rainfall on productivity, results in a number of potential impacts, including changes in the length of the growing season for certain agricultural activities (Thornton *et al.*, 2006). In general, Fischlin *et al.* (2007) suggests a far more, future for Africa's rangelands with considerable portions of the subtropics showing an increase in forest, woodland and herbaceous cover. The amount and timing of rainfall on its own, also has an important influence on rangeland species composition in both short and long-terms, primarily through its differential effect on the growth and reproduction of key forage species (Hoffman and Vogel. 2008). An extended drought can result in the mortality of perennial plants and the switch to an annual-dominated flora (Hein, 2006).

Bush encroachment occurs as a result of the invasion of shrubs and trees into previously grassy rangeland (Hoffman and Vogel, 2008). It is a common phenomenon in Africa and usually results in an increase in biomass but a decrease in rangeland productivity (Hoffman and Vogel, 2008). The projected increase in the concentration of atmospheric CO_2 could enhance the process of bush encroachment in two important ways (Hoffman and Vogel, 2008). Firstly, less transpiration could result in more plant available water, particularly at depth, where deeper-rooted trees and shrubs have their roots (ibid). Greater access to water could increase the length of their growing season and increase their competitive dominance to the exclusion of shorter growth forms such as grasses and perennial herbs. Another mechanism for the increase in bush encroachment suggests that an increase in CO_2 results in faster growth rates of saplings (Bond and Midgley, 2000).

2.3.3 Effects on livestock resources

Tanzania is endowed with abundant natural resources, which include land, water, forage and a large livestock resource base.Livestock sector is among the critical sectors of the economy and Tanzania has the third largest cattle population in Africa and it is estimated that Tanzania has over 22 million cattle (TAMPA, 2016). Morogoro region has total of

455 985 cattle whereas Mvomero district alone has 236 685 cattle (MLFD, 2013). More than 80 per cent of livestock in the country are highly vulnerable to climate extremes (URT, 2012). For instance, in 2009 some areas in northern Tanzania were hit by drought and resulted to death of 735 929 livestock, due to shortage of pasture and water (ibid).

Livestock are faced with weather extremes difficulties, for example intense heat waves, floods and droughts; which in addition to production losses, also results into livestock death (Gaughan and Cawsell-Smith, 2015). Livestock are adversely affected by the detrimental effects of extreme weather where by climatic extremes and seasonal fluctuations in herbage quantity and quality will affect the well-being of livestock, and will lead to a decline in their production and reproduction efficiency (Sejian, 2013).

Climate change affects quantity and quality of feed and fodders resource like pasture, forage, grain and crop residues which subsequently affect distribution of livestock diseases and parasites have indirect but significant bearing on livestock productivity (Sere *et al.*, 2008). The most significant direct impact of climate change on livestock production comes from heat stress; resulting into a significant financial burden to livestock producers through the decrease in milk component and milk production, meat production, reproductive efficiency as well as animal health (Sejian *et al.,* 2016).

Animals exposed to heat stress reduce feed intake and increase water intake, which changes the endocrine status by increasing the maintenance requirements leading to reduced performance (Gaughan and Cawsell-Smith, 2015). It is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance and adversely affecting livestock production by aggravating the feed and fodder shortages (Chauhan and Ghosh, 2014). A case study reported by Upadhyay *et al*. (2009) indicated that increased heat stress was associated with global climate change, causing distress to dairy cows and possibly affecting milk production. A loss of 25% of animal production by global warming is predicted in developing countries (Seguin, 2008).

2.3.4 Effects on pastoralists

In the planet there are 1.3 billion poor people of whom 90% of them are located in Asia and sub-Saharan Africa. Climate change will have major impacts on the more than 600 million poor people who depend on livestock for their livelihoods (Thornton *et al.,* 2002). Around 40% of the households in Tanzania own livestock rely on them for major part of their income (TAMPA, 2016). Pastoralists are concentrated in the northern plains and in the central and some western parts of Tanzania, where climatic and soil conditions do not favour crop production (FAO, 2005).

The single largest cause of poverty in pastoral communities is climate variability (Bagamba *et al.,* 2012; Morton, 2007). Pastoralists depend on livestock for a number of uses, including the direct consumption of meat, milk and blood (Mwakaje, 2013). With the current changes in climate, livestock productivity, survival and distribution will be affected through reduced grazing lands and the prevalence of vector-born livestock diseases (IPCC, 2001). The impacts of climate change are posing a direct threat to pastoralists and agro-pastoralists’ livelihoods in the arid and semi-arid lands of Tanzania (Mwakaje, 2013).

Droughts not only endanger income, for example from milk products, but also the assets providing income (Scoones, 1995; McPeak, 2004). However, nomadic pastoralists perceive droughts as primary cause for the loss of livestock and therewith livelihood

(Breuer, 2007). Drought was often seen as a trigger for the collapse of pastoral households (Breuer, 2007). Pastoralists have in turn migrated to the area from the north in search of grazing land and water (Paavola and Jouni, 2004). There is a reduction in income, increased income inequalities and a general reduction in livelihood security for people who derive their livelihoods primarily, or even in part, from Africa's rangelands (Easterling *et al.*, 2007). Deaths of large numbers of livestock due to lack of water and pasture has been of repeated occurrence in Tanzania in recent years hence threatening livelihood of pastoralists in the country (Ceven *et al*., 2010).

2.3.5 Effects on quantity of milk produced

The success of the African pastoral family is determined by the amount of milk their animals produce. It is estimated that Tanzania has over 22 million cattle, whereby 720,000 are dairy cattle with the capacity to produce a total of 2 billion litres annually (TAMPA, 2016). Milk in rural areas is mostly consumed within the producing households, and less produced in surplus marketed during the rainy season compared to very low supply during dry seasons (ILRI 2005; Schooman and Swai, 2011). Dhakal *et al.* (2013) observed that climate change had negative impact on milk production; with one of the direct impacts of climate change on livestock being milk yield. A thermal environment is another factor that can negatively affect milk production in dairy cows, especially in animals of high genetic merit (Chauhan and Ghosh, 2014).

Studies show that milk and meat production will be reduced following the stress on grazing lands (IPCC, 2001). During the dry season, the decline in milk production per household is likely due to shortage of water and pasture as shown by low rainfall and decline in quantity and quality of the available feeds, which are among the major constraints on increased milk production in Tanzania (Mdoe and Wiggins, 1996;

Mtengeti *et al.*, 2008; Njombe *et al*., 2011). According to Kurwijila *et al.* (2012), seasonality of rainfall (and access to water) is extreme and reflected in producers' management of their animals in dairy systems, resulting in severe seasonality in milk volume produce. During dry seasons, animals lose weight (Pagot, 1993) and reduction in milk yield is been observed (Matthewman *et al*., 1993) in animals walking long distances in search of food and water. Animals walk long distance in search of feed and it is presumed that at least the animals walk twice a day to the pasture and back to the barn (Sejian *et al*., 2012). This means that the animals at distant pastures have higher energy requirement for walking. Most part of the year under tropical environment, animals have to walk long distances in search of water, and are usually replenished once in two to three days (*ibid*).

2.4 Conceptual framework

A theoretical framework is a sketch description or diagrammatic presentation of variables to be studied and theoretical relationships between and among study variables (Kajembe, 1994). Climate change, being a global phenomenon, has its impacts felt in various diverse areas of Tanzania, Mvomero District inclusive. Over the past 30 years, climate change has affected the agriculture sector including livestock resources in the district. Major effects have been shown to be on rainfall and temperature; whereby the District has experienced a drastic increase in temperature accompanied with fallout in the amount rainfall received. The climate change impacts have affected the status of livestock keepers. The pastoralists have experienced a decline in the quantity of water and pasture resources due to lack of sufficient rains and declining grazing lands. That has led to reduced amount of milk produced in the District. Several areas had little pasture, unfortunately, due to lack of moisture; such pastures were of poor quality to support milk production. The outcome of the decline in the quantity and quality of pasture has caused decline in vigour and health of the cows and eventually massive death. The effect of the outcomes has led to negative consequences upon the pastoralists whose livelihoods are dependent on livestock products.

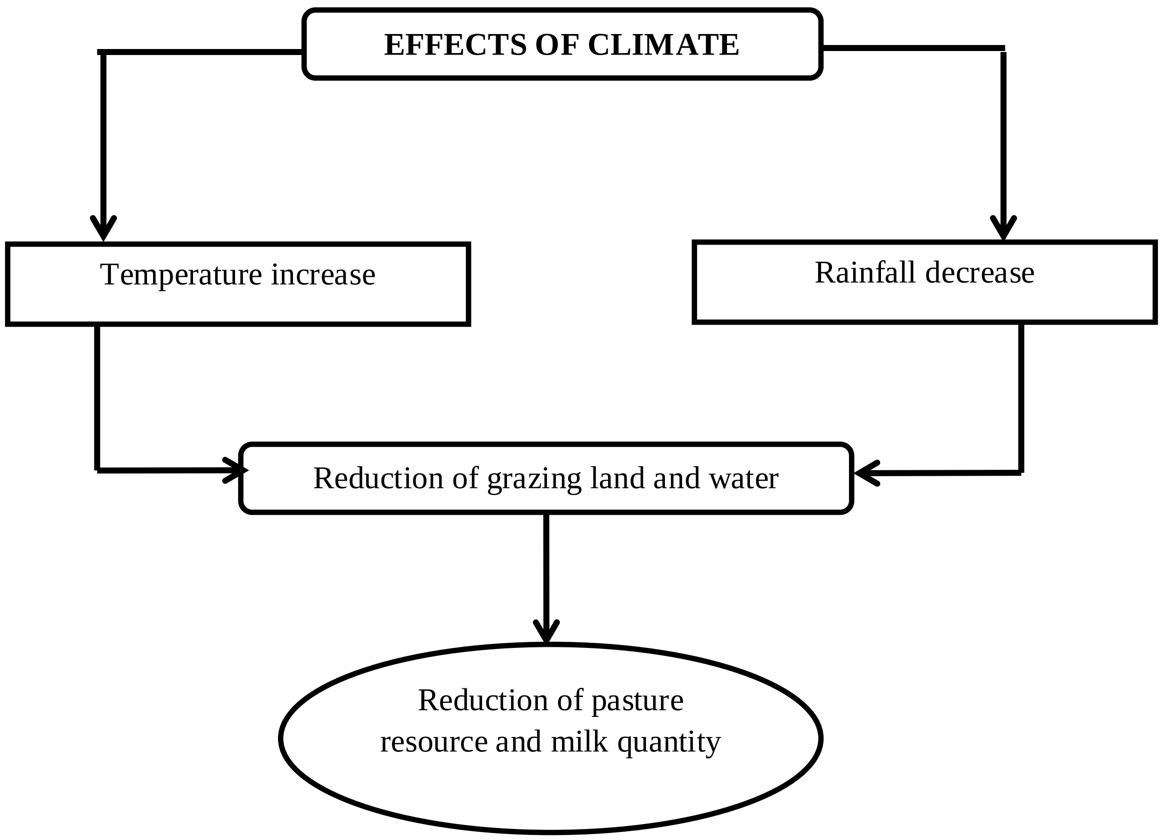

Figure 1: Conceptual Framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Geographical location

The study was conducted in Mvomero District, Morogoro region. The district is located between latitudes 05° 80' and 07° 40' S and between longitudes 37°20' and 38° 05' E. The District has a total area of 7 325 km. Sq., where potential grazing land covers 6 635 km. Sq. , arable land 2 664 km. Sq. , Forestry 328 km. Sq., and National Park 702 km. Sq. The district is bordered by Handeni District to the North, Bagamoyo District to the East, Morogoro Municipal and Morogoro District to the South, and Kilosa District to the West (Mvomero District Council, 2012).

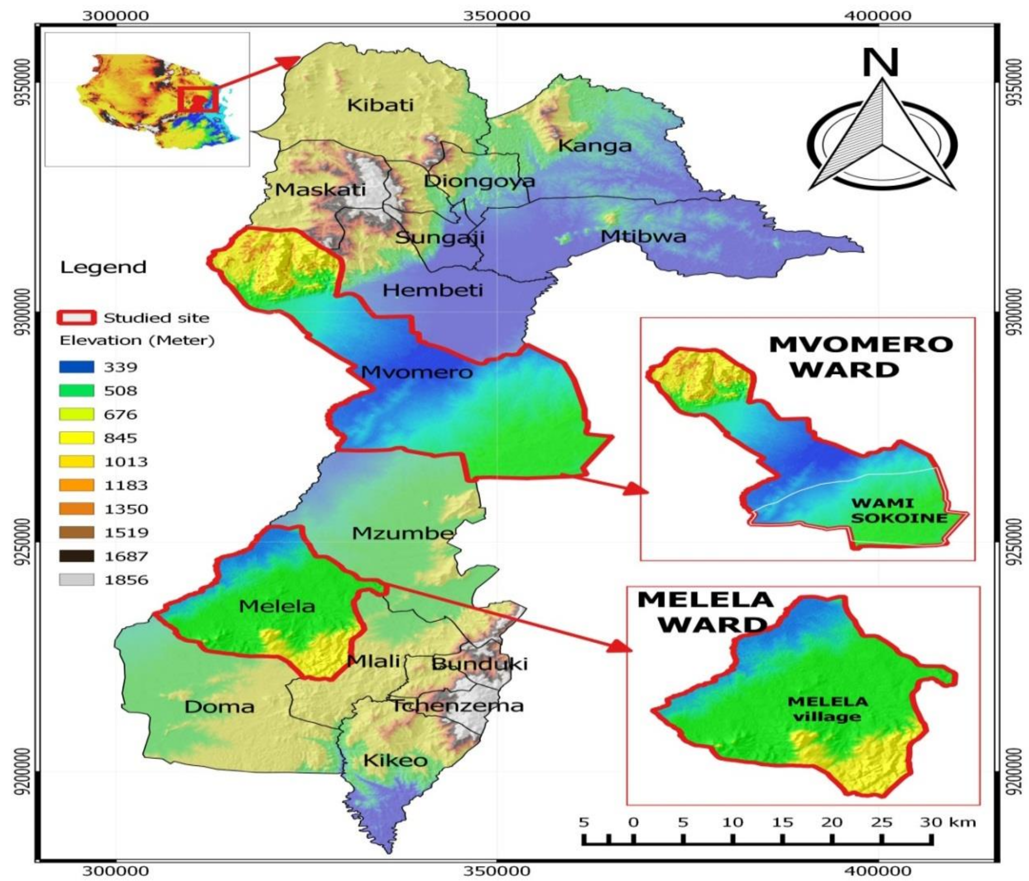

Figure 2: Map of Mvomero District showing the studied villages

3.2 Population

According to the Tanzanian Population Census of 2012, Mvomero District has total population of 312 109 people of whom 154 843 are male and 157 266 are female (URT, 2013). The main tribes are the Luguru, Kutu, Kwere, Maasai, Zigua, Gogo and Sukuma.

3.3 Climatic conditions and relief features

The district has temperature ranging from 19.9°C to 30.9°C with mean annual rainfall from 662.9 mm (NBS, 2016). The area experiences bi-modal rainfall pattern where long rains are from March to the end of May while short rains (*vuli*) occur from October to December. The dry seasons are from June to August and January to March (ibid).

3.4 Socio-economic activities

The district economy depends mainly on agriculture. The natives engage in economic activities including crop production whereby maize, beans, cassava, rice, fruits and sunflower are produced; whereas other inhabitants engage themselves in livestock husbandry (URT, 2005).

3.5 Research design

A cross-sectional research design was employed in this study where by data is collected in a particular place at once and enables descriptive study for the determination of relationship between the independent and dependent variables. The preferable design was most efficient on data collection for the periods of time and financial resource constraints (Saunders *et al.*, 2007).

3.6 Sampling unit and sample size

The sampling procedure was probability sampling using multistage cluster technique to select wards to village level. Two wards were selected in Mvomero District, based on firstly; the extent of pastoralist depending on milk production, and secondly; the adverse effects of climate change on the areas. In each ward one village was selected followed by selection of pastoralists' households from each of them. A simple random sampling was used to select a total of 45 households in each village, making sample size of 90 households. The village registers/books were used as sampling frame during selection of individual household. A sample size which requires 5% of the total population was taken, considering the recommendation of Boyd *et al.* (1981). The sample was 5% of the 943 households in Melela village and 5.4% of the 826 households in Wami Sokoine village, which summed up to 90 households (Table 1).

Table 1: The number of households sampled and interviewed

Name of the village	No of households	Sample size	Percent (%)
Melela	943	45	5
Wami Sokoine	826	45	5.4
Total	1 769	90	10.4

3.7 Data collection methods

3.7.1 Primary data

Both qualitative and quantitative data were collected. The quantitative data were collected using questionnaire (Appendix 1). For qualitative data collection and supplement information, focus group discussions (included elders who have lived in the villages for at least 30 years) and key informant interviews were conducted using a designed checklist.

3.7.1.1 Village level household survey

The two villages selected for household survey includes Wami Sokoine and Melela. Through the use of questionnaire (close-ended), details on climate change pattern, indicators of climate change, perceptions of climate change and the climate change effects on quantity of milk were recorded in all villages.

3.7.1.2 Focus group discussion (FGD's)

FGD's discussions were organized in order to provide detailed information. In this study, the elders who have lived in the area for more than 30 years were involved. The FGD's were comprised of 6 to 10 men and women in each group of different age groups (over 45 years) with knowledge on the change of rainfall and temperature of the village for at least 30 years. These were used to provide information on the trend of rainfall and temperature in the village and the effect of climate change on pasture resources and quantity of milk produced between the timeline (1985-2013).

3.7.1.3 Key informant interviews

The key informants in this study were the District Livestock and Fisheries Development Officer (DLFO) from Mvomero District, Ward Livestock Field Officers (WLFO) from Dakawa and Melela Wards; and the Village Field Officers from Melela and Wami Sokoine Villages. These were used to triangulate information on effects of climate change to pasture resources and milk production in the studied villages. According to Katani (1999), the interviews provide details on broad context for local circumstances and practises, through individuals who have more knowledge on the subject matter. Msalilwa (2013) further contends that what set such respondents apart as key informant is that they are recognized by others in the community as being particularly knowledgeable about the area.

3.7.2 Secondary data

Information was collected from books, published research papers, technical reports, internet and other relevant sources related to climate change effects to pastoral communities.

3.7.2.1 Meteorological data

Data on rainfall and temperature were obtained from Tanzania Meteorological Agency (TMA), Morogoro station (Appendix 4 and 5). The amounts of rainfall in mm covered from 1985 to 2013 and the maximum and minimum temperatures in ^{0}C covered from 1985 to 2013. This is line with Burn and Elnur (2002) who stated that a minimum length of 25 years ensures statistical validity of the climate trend in climate change research. The data were therefore significant to assess the effects of climate change on pasture and milk produced by the pastoralists.

3.7.2.2 Satellite data

Landsat imageries of 1985/1995/2005/2015 were downloaded from USGS website; the images were used to assess the effect of climate change on pasture resources through checking the changes on grazing land in an interval of ten years. Figure 3, shows the Landsat satellite series and Table 2 show the characteristics of remote sensed data acquired.

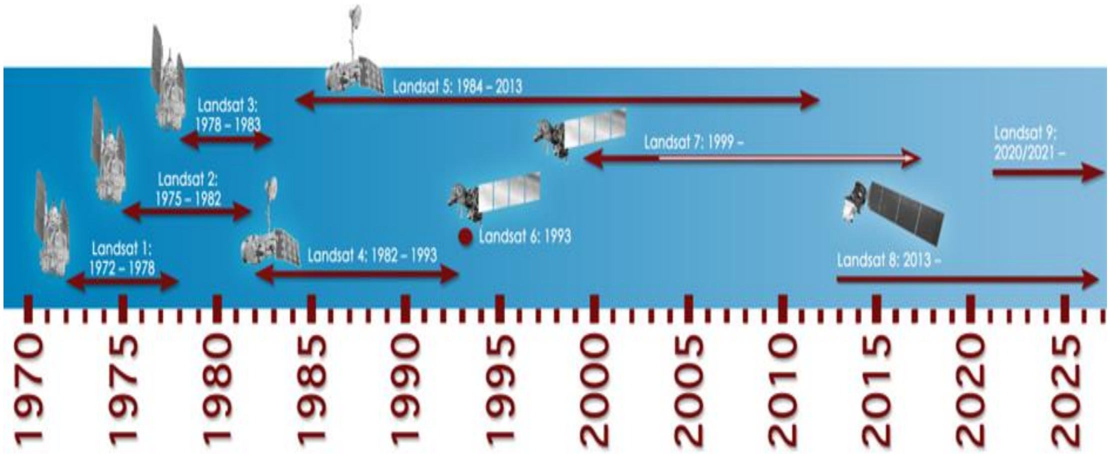

Figure 3: Landsat satellite series
Source: USGS, 2016

The imagery of 1985/1995/2005/2015 years was used and compared with the impacts analysed from field survey data through interviews and focus group discussions.

Table 2: Characteristics of acquired remote sensed data

Satellite	Sensor	Spatial resolution	Season	Period
Landsat4	TM	30 m	Dry	1985
Landsat5	TM	30 m	Dry	1995
Landsat5	TM	30 m	Dry	2005

3.8 Data processing and analysis

Data collected from the field survey were coded, summarized and analysed by using Statistical Package of Social Science (SPSS) software version 20. Descriptive statistics were computed such as frequencies and percentage. Meteorological data were analysed by Microsoft excel while Q-GIS and Arc GIS were used to analyse pasture resource data from satellite images.

3.8.1 Analysis of meteorological data

Temperature data was for 1985-2013.The trends were computed on annual average maximum, minimum temperature in °C and rainfall in mm from 1985 to 2013 (Figure 7 and 8) by using Microsoft Excel.

3.8.2 Analysis of satellite data

Remote sensing data were extracted from satellite images that were acquired from the USGS. The images were acquired and analysed under supervised image classification using Arc GIS and Q- GIS. The remote sensing and GIS has emerged as important tools in assessing natural resource degradation by providing timely, accurate and up to date information obtained from remotely sensed data on a cost effective basis (Javed *et al*., 2012). The imagery of 1985/1995/2005/2015 years was used, while the impacts were analysed from field survey data through interviews and focus group discussions.

3.9 Study limitation

Unfortunately, data collection coincided with government livestock branding activity in Mvomero district. Since most pastoralists were not happy with the branding activity, there was lack of cooperation with the researcher which resulted to acquiring limited information from the milk producing pastoralists. Most of the pastoralists were suspicious upon seeing any newcomer or researcher in their vicinities. This limitation was minimized through proper introduction that was done by sub village chairperson who accompanied with the researcher to respondents, Furthermore; there was a limitation of missing temperature data for two years in the span of 30 years. This was due to inefficiency of the weather data collection tools in the meteorological stations. Therefore the analysis was done using 28 years which is equally good to determine the trend of climate in climate change research.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results are built on temperature and rainfall data trend for 28 years, climate change effects on grazing land and investigation of climate change effects on milk produced by pastoralists.

4.1 Climate Pattern (Temperature and Rainfall)

Result on maximum and minimum temperature and rainfall amount were computed. Linear line was used to indicate the trend of the rainfall and temperature data (see Figure 4, 5 and 6).

4.1.1 Trend for minimum temperature

Results for minimum temperature for 28 years from 1985-2013showed positive trend which implies that there was increase in temperature (Figure 4). The increase in the minimum temperature; indicated an increase in temperature especially in January, the month where by the recorded temperature was always high.

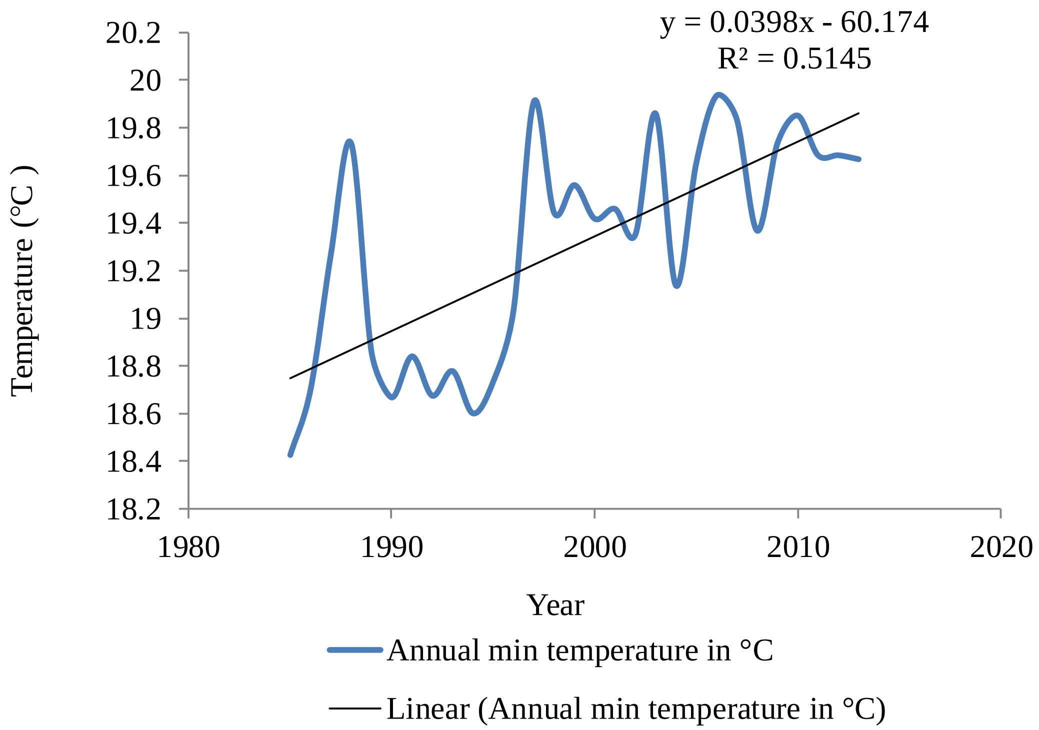

Figure 4: Minimum temperature trend (1985-2013)

The increase of temperature has probably a great impact on pasture resource whereby during periods of high temperature, reduction of pasture was common which has been associated with the reduction in the quantity of milk produced. This is in line with other studies which show that, during the dry season the decline in milk production per household is likely due to shortage of water and pasture as shown by low rainfall and the decline in quantity and quality of available feeds (Mdoe and Wiggins, 1996; Mtengeti *et al*., 2008; Njombe *et al*., 2011).

4.1.2 Average maximum temperature

Annual result of surface temperature showed that the temperature increased by 0.02% (Figure 5). Also, the linear trend indicates that there is increase in temperature by showing a positive slope.

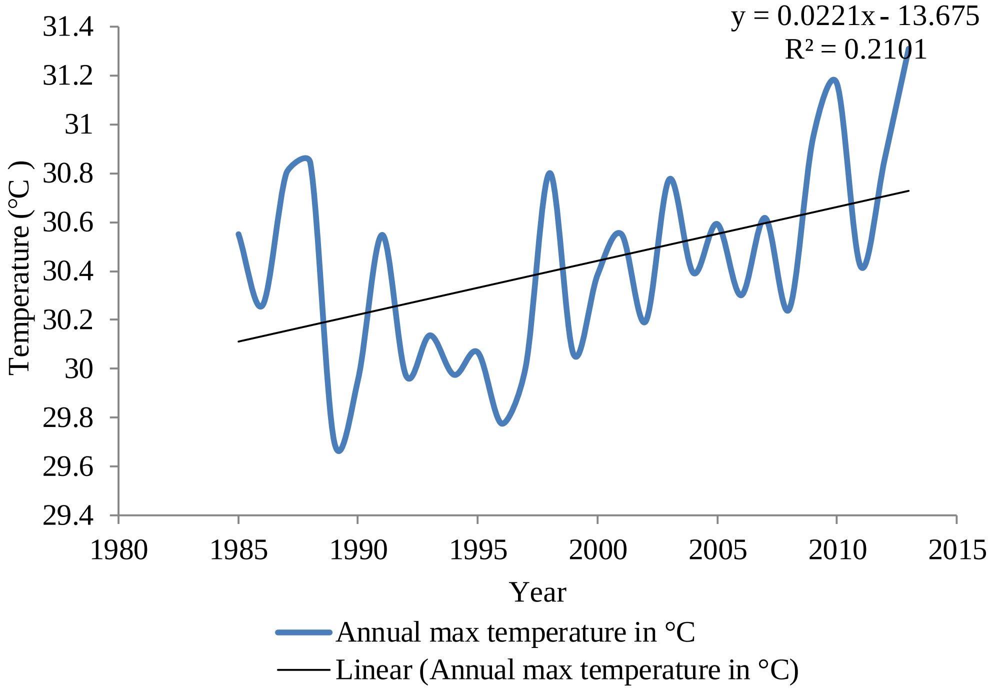

Figure 5: Maximum temperature trend (1985-2013)

The higher peak above 30°C (Figure 5) in the years 1988/1998/2003/2010, most likely led to long drought which steered drying out of pastures that make unavailability of pasture and water resources to livestock. This further was supported by pastoralists' response in household survey who claimed that temperature increased with time and led to increase in drought. Some key informants also claimed that they would not forget the drought stress of 1999 and 2016. According to Mr Mumba Ngare (A Maasai pastoralist from Mvomero), 1999 and 2016 were the years that he lost the largest herd of cattle due to drought. He was quoted saying "*I personally lost 38 large cows in 1999 and 51 in 2016; I can't forget these years.....this means a lot to myself and my family livelihoods*."

When Ngare was more interrogated, it was discovered that in their *Boma* (Maasai household) where they live three brothers with their spouses and kids, they lost a total of 209 cows worth 8 360 000 Tanzania shillings equivalent to US$ 38 000 in the drought stress of 2016. In a very sorrowful face, Mr Ngare claimed that the main reason to this massive death was lack of forage caused by drought stress.

The findings goes in line with the pastoralists' response to the survey questionnaire where most of them claimed that temperature increases as the years goes on, whereby the temperature became more intensive since 2005. The current findings were in line with IPCC (2007) projects a further increase in the mean temperatures to approximately 0.74^0C; a sea level increase at approximately 17cm; a greenhouse gas emission rising globally by 25–90% by the year 2030 and a possible temperatures increase by 3% by the year 2050.

Moreover, Mashingo (2010) narrated that in Tanzania, climate change has also been observed; whereby in 1960 it was recorded that there has been a mean annual temperature increase of 1.0^0C. These changes have serious impact on pasture production as its depends much on soil moisture content; whereby when there are higher temperatures, the moisture content of the soil decreases through high evaporation hence reduction of pasture in terms of quality and quantity (Mdoe and Wiggins 1996; Mtengeti *et al.*, 2008; Njombe *et al.*, 2011).

It was also revealed that minority of respondents 1.1% (Table 3) were not aware that climate has changed, while most of the respondents 98% (Table 3) claimed that there has been a change but they did not know if it was climate change as they were only reporting on the increase in temperature that they were experiencing.

Table 3: Awareness that climate is changing

Response	Frequency (n=90)	Percent
Climate is change	89	98.9
Climate do not change	1	1.1

Source: Field survey, 2016.

This shows that the households did not have knowledge that climate has been changing. Therefore, they could not adapt easily to climate change effects; whose adverse outcomes would catch them unprepared.

4.1.3 Trend for average temperature

The data generally showed that the average temperature has increased and probably affecting pasture growth in terms of increasing evaporation and decreasing moisture content, which has great impact on pasture productivity. The analysed data showed that temperature was increasing with time. This is also explored by Minson (1990) that climate with high temperatures causes rapid maturation of grass and therefore tropical pastures are often of low quality, with low protein content and low digestibility, which in turn decreases feed intake.

The increasing of temperature is also reported by TCAR (2015), that in 1960 the climate in Tanzania had also changed; by a mean annual temperature increase of 1.0^0C. Also Anderson *et al.* (2008) agreed that high temperatures during the rainy seasons resulted to a lot of water loss through evaporation, and intense downpours ensured that water runs off in floods.Most of the respondents declared that there is great difference between the temperature in current years and past years. They claimed that the changes in temperature causes great impacts especially on livestock production, whereby pasture becomes unavailable as well as the increase in diseases like East Coast fever (*ndigana*).

4.1.4 Trend for rainfall (1985-2013)

The results showed that rainfall decreases with time, as implied by the negative slope which showed that rainfall decreased especially in 2003 and 2005 years as shown in Figure 6.

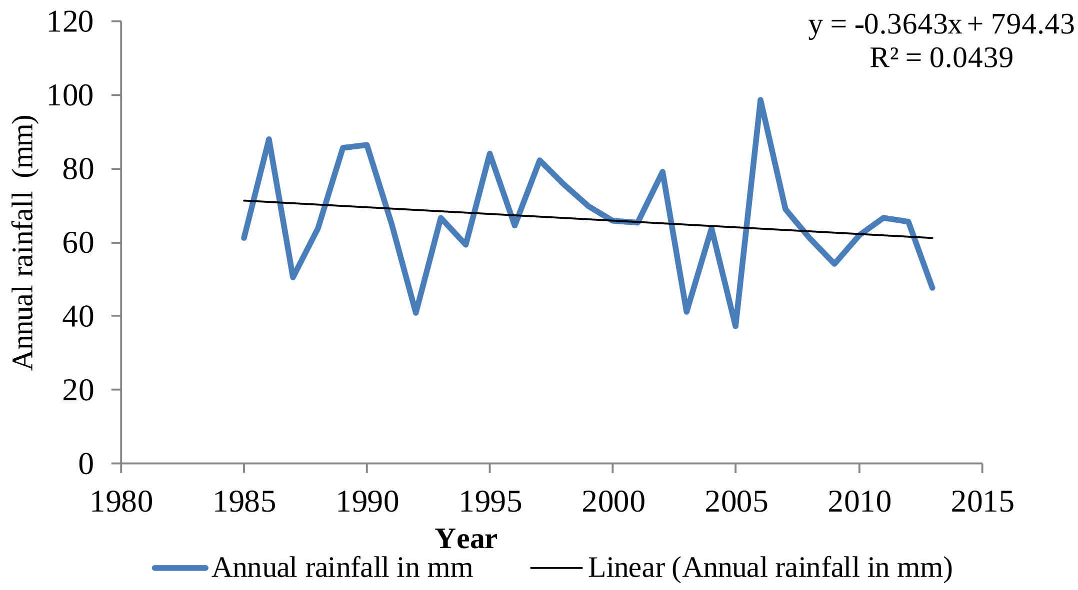

Figure 6: Trend of rainfall amount (1985-2013)

It was shown that there has been a decrease in rainfall by about 3% especially in the present years. Water is very crucial for vegetation growth as it increases the amount of moisture in the soil. Insufficient rainfall results to the death of plants as well as negatively affecting pasture growth. In Tanzania, the fluctuation in rainfall can be dated back to 1960 where there was observed a decline in rainfall at an average rate of 2.8 mm per month and 3.3% per decade (TCAR, 2015).

Regarding the amount of rainfall and its pattern, majority of the respondents 77% (Figure6) agreed that rainfall has decreased in terms of amount and timing. During focus group discussion, it was noted that currently Mvomero District rarely receives short rains commonly known as *Vuli*. This was confirmed by a Maasai elder Mr Lekule that "*We have not received the Vuli rains since 2010....we are depending on single rain per year like our neighbours in Gairo District"*. Mr Lekule added by saying "*Rainfall is very crucial for pasture growth as it increases the amount of moisture in the soil. Insufficient rainfall results to the drying up and retardation of vegetation*".

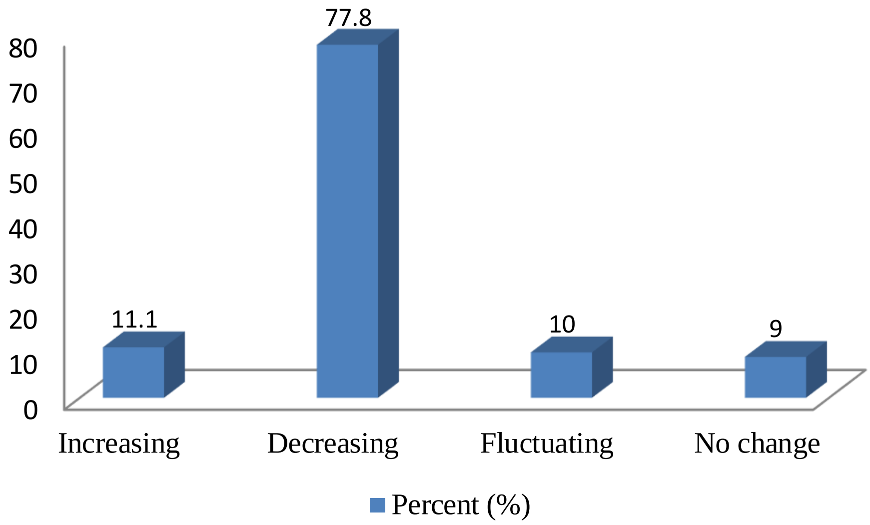

Figure 7: Perceived trend of rainfall during 30 years

Severe drought in Mvomero district was more prominent in 2016; Magita and Sangeda (2017) found that, the number of animals died due to long drought that led to inadequate pastures. Plate 1 shows some of Mr Lekule's cows feeding on sisal plants in his *Boma* during 2016 drought in Mvomero district. Majority of respondents 77.8% (Figure 7) agreed that rainfall has decreased over time, indicating that the amount of rainfall was insufficient for their uses; which makes pastoralist to be more vulnerable due to their dependence on rainfall. Ceven *et al.* (2010) agreed that in 2005, the *Vuli*, short rains were very poor in many regions including areas where the rains are usually plenty, like Kilimanjaro region. Also Thornton *et al.* (2006) supported that African countries are vulnerable to the impact of climate change due to overdependence on rainfall for crop and livestock production.

Plate 1: Pastoralist household in bare grounds (Left) and cow feeding on sisal during critical pasture loss in drought stress of 2016 (Right), Mvomero Tanzania.

Key informants further argued that rainfall was not only scarce but rather erratic. They reported that, for some decades, rainfall has been starting from November to March, but since 2010, the rainfall season has changed. It comes very late and one cannot tell exactly when it may commence. This variability affected several planning schedules and consequently growth of natural pastures. Reduced amount and scarcity of rainfall in Mvomero District has been said to cause shortage of feed for livestock and consequently reduction of milk production and its products.

Minority of the respondents 11% (Figure 7), claimed that there was an increase in rainfall, whereby 10% responded that rainfall has been fluctuating. This is in line with a study by Anderson *et al.* (2008) and Sangeda *et al.* (2013) who explained that semi-arid areas are also characterised by unpredictable differences in total rainfall between and within years.

Pasture is very crucial to livestock especially in pastoralists' areas, as the only resource used to feed their livestock. The decreased amount of rainfall most likely may leads to reduction of pasture resource, which directly affects livestock production, whereby most of the livestock died due to absence of the pasture on both villages. Pastoralists depend on livestock production to sustain their life, especially milk products. Normally, they sell milk to get money in order to obtain the basic needs. Hence, if livestock are affected by the absence of pasture, it means the pastoral life is also affected.

4.1.5 Frequency of drought

Most of the respondents (95%) Table 4**,** agreed that there has been a high drought rate due to poor amount of rainfall. Rainfalls are usually late, making the drought periods even much longer. Very few respondents (5%) agreed that drought has not increased. This implies that the area has become very dry due to lack of rainfall; with the associated negative impacts including water scarcity, poor pasture/vegetation growth and death of livestock due to hunger, thirst and sickness.

Table 4: Frequency of drought

Response	Frequency	Percentage
Agree	85	94.5
Disagree	5	5.5

Respondents during field survey claimed that Mvomero District is prone to climate change, mostly adverse effect during long drought period which is common in their area. Increase in periodic drought length and frequencies resulted to changes in plant communities (Shilla, 2015). According to Shayo (2013) the livestock sector is affected by various climate change impacts, drought being the most serious. There have been severe and recurrent droughts, particularly in the northern parts of the country, reducing water and pastures availability for livestock. For instance, the drought which occurred in 1996 in 14 regions affected about 3.9 million people, while the one which occurred between 2009 and 2010 killed a total of 316 437 cattle, 236 359 goats and 92 640 sheep in Arusha region alone (Shayo, 2013). In recent years, the country has experienced increasing incidences of recurrent and prolonged droughts with severe implications in the livelihood activities of the communities particularly those dependent on livestock.

4.2 Effect of climate change on pasture resources

Results on effects of climate change on pasture resources were built on Landsat classification. Land was classified in terms of Cultivated land, Grasses, Shrubland, Forest and Woodland.It was revealed that there was substantial pasture resource change in all classes. The Landsat image in spatial temporal land covers change from 1985 to 2015is presented in Figure 8.

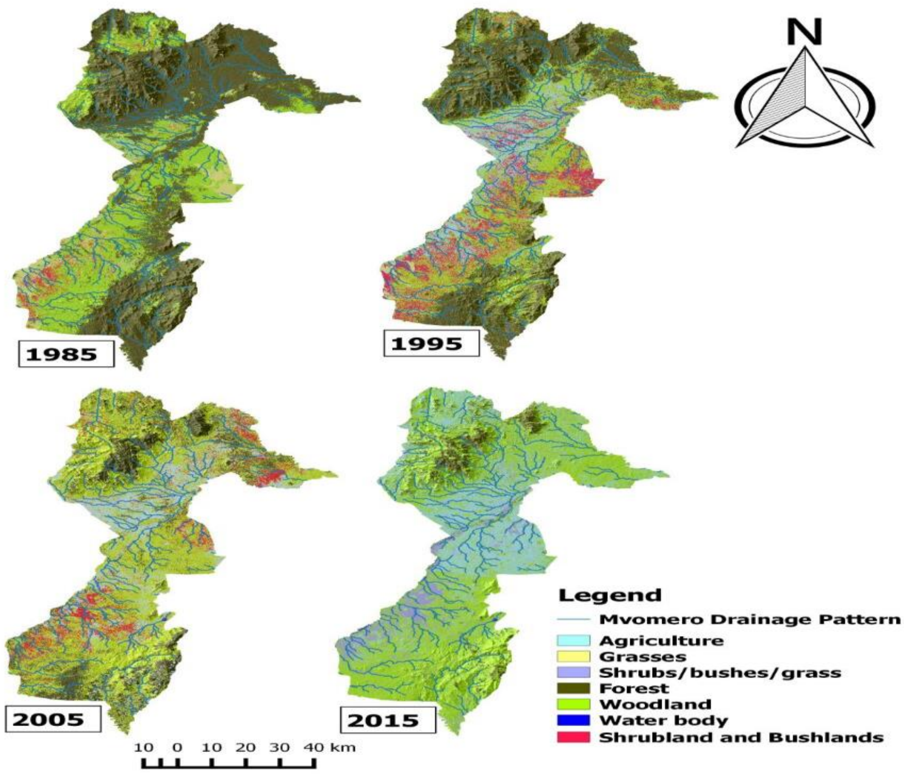

Figure 8: Spatial temporal land cover change from 1985 to 2015

The results revealed that the grazing land has been reduced in size over times, for the past 30 years. There is strong spatial correlation between land cover and climatic data (temperature and rainfall). This is supported by the data from TMA that the temperature increased for about 0.02%. Observation for temperature increase could have caused the land cover change noted in Figure 8. Critical observation on land cover changes in Figure 7 shows significant variation with time. The area which had grass cover in 1995 has changed to become shrubland in 2015. This could be due to the nature of grass rooting structure failing to reach the water in the ground, hence causing secondary succession.

Results revealed a general increase in cultivated land, shrublands and woodland (Figure 9) while the grassland and forest declined (Table 5). The decline of grasses may be replaced by shrublands and woodland (Figure 9). According to Britz and Ward (2007) this phenomenon is called bush encroachment whereby it changes the herbaceous cover and natural vegetation as the woodland increase. This is due to the competition of resources like nutrients and water between grasses and tree as according to resource allocation model (Ward, 2005). This is further supported by Hoffman and Vogel (2008) who reported that an increase in the concentration of atmospheric CO_2 could enhance the process of bush encroachment in less transpiration could result in more plant available water, particularly at depth, where deeper-rooted trees and shrubs have their roots (ibid).

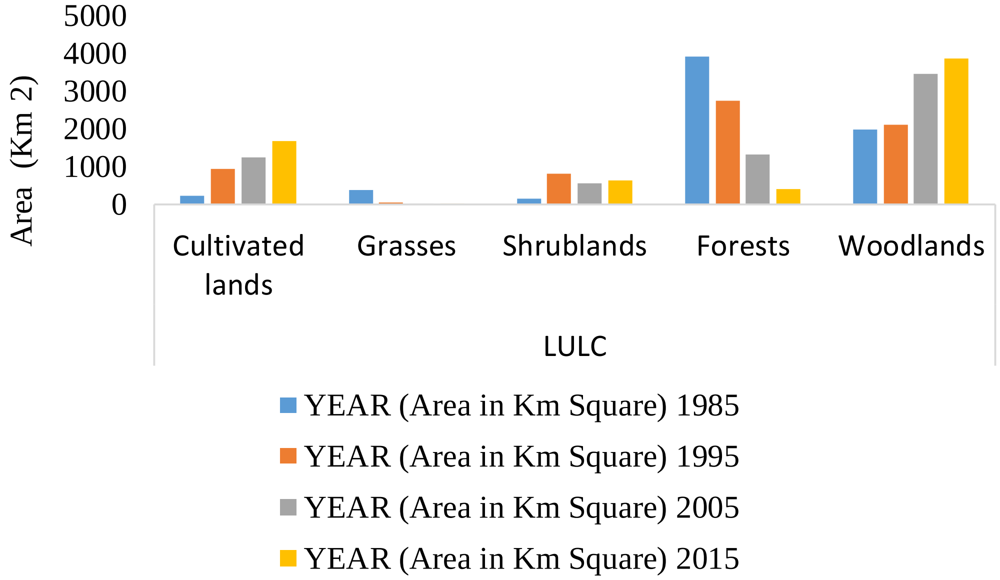

Figure 9: Land cover change

Greater access to water could increase the length of their growing season and increase their competitive dominance to the exclusion of shorter growth forms such as grasses and perennial herbs. In two-layer hypothesis trees and grasses compete for water in the upper soil profiles, and although grasses are superior competitors for water in the upper horizons, trees are able to persist in the system because of exclusive access to deeper water (Walter, 1971). For a given set of environmental conditions, the ratio of trees to grasses is then a function of the vertical distribution of water in the soil profile, with tree biomass increasing as the amount of subsoil water increases.

Overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing sun light that should reach to the grass layer due to high canopy cover (Thurow, 2000).The study done by Maleko and Sangeda (2015) in northern part of Tanzania also found that canopy cover for woody plants limits the grasses development.

Table 5: Land cover change

	Year (Area in Percentage)			
Land cover types	1985	1995	2005	2015
Cultivated land	5.5	22.8	30.5	40.2
Grasses	82.1	7.9	4.9	5
Shrublands	7	7.9	26.1	29
Forests	46.8	32.8	15.6	4.7
Woodlands	17.3	18.5	30.3	33.9

(Source: USGS, 2016)

Climate change associated with other factors like poor grazing practises probably lead to land cover changes, this is supported by Ward (2005) that global climate change may also create bush encroachment. Angassa *et al.* (2012) reported that the local climate and long-term climate change in compounded with grazing effects have been identified as possible causes of bush encroachment. This has resulted in reduced grass cover, poor range condition, and subsequently poor livestock productivity (Gifford and Howden, 2001; Oba *et al.,* 2000). Hence climate change may destruct the intensity and timing of precipitation and increase of temperature that leads to changes on plant composition. Precipitation is the primary control of moisture in the soil hence the unpredictability of it may affect plant's production.

Grasses reduction can also be due to conversion to crop production as the area for agriculture increased over time (Table 5).This is associated with increase in human population and privatization of land (UN, 2013) predicted that human population is expected to increase from 7.2 to 9.6 billion by 2050. This represents a population increase of 33%, but as the global standard of living increases, demand for agricultural products will increase by about 70% in the same period (FAO, 2009a). The reduction of grasses cover can lead to less functional capacity of grazing land which can affect livestock production.The expansion of crop cultivation to the rangeland decimating the grazing land.

The observed decline of forest might be due its conversion to woodland which can be associated with mostly anthropogenic activities like logging and wildfire. As also supported by Maliondo *et al.* (2001), climate change is a threat to forests, since as climate gets hotter and drier, it increases frequency and intensity of forest fires. Wildfire is associated with the vegetational change as the increase of frequent and severe drought. NCCS (2012) noted that in some parts of the country, climate change, particularly increase in temperature, increased frequency and intensity of wildfires inducing shifts in geographical distribution of biodiversity.

Generally, the study associated major changes in land cover with changes in climate pattern, whereby the reduction in rainfall turns grassland areas to shrubland areas and then finally to woodland. Increases in temperature also lead to higher evaporation which diminish the growth of herbaceous vegetation and support other vegetation types such as wood species and weeds. The main feed resources of pastoral areas include natural pastures like grasses, forbs, herbs, shrubs, trees leaves and pods. Despite the decline of pasture in the study area, there were found different pasture species like *Cencrus ciliaris* (African fox-tail) and *Chloris spp.* (Horse tail) which are dominant in the grazing land, besides trees like *Acacia spp*. and *Commiphora spp*. which are browsed by goat (Plate 2).

Plate 2: Goats searching for browsing resources
(Photo by Mtengeti)

It has been observed that in the dry season most grazers like cattle ended up feeding on sisal or became browsers when the under storey herbaceous vegetation was exhausted. This field observation was also confirmed during group discussion session whereby elders argued that, it was their first time to see cattle feeding on tree twigs and branches like goats or giraffes. It was also their first time to observe cattle feeding on poisonous weedy plants and rice bran due to scarcity of pasture. According to IPCC (2007), the projected global increase of temperature to 2.5 °C will result to major losses; one of them being a high risk of extinction of 20-30% of all plant and animal species.

4.2.1 Decline of pasture and drought

Due to extremely high temperature, majority of the respondents (99%) Table 6, claimed that there has occurred a scarcity in pasture. The respondents also agreed that they cover long distances, about 40 km searching for water and pasture.

Table 6: Awareness on decline of pasture

Pasture declining	Frequency	Percentage
Agree	89	99.9
Neither agree nor disagree	1	1.1

This is supported by Degen (2007) that in order to feed their livestock, herders move to places where there is pasture availability. Maleko and Sangeda (2015) also observed the walking over long distances over 25km in search for water and pasture in Simanjiro District. This resulted to poor livestock health, animals losing weight as most energy is used in walking. Maurya *et al*. (2010b) found that, the long-distance walking in search of water and feed creates negative energy balance in the animals which also affects body condition score of animals. One projection, from the Intergovernmental Panel for Climate Change (IPCC) suggests that, for every 1^0C rise in global mean temperature approximately 10% of species will be exposed to extinction risks (IPCC, 2007).

Climate change coupled with the decrease in pasture resources is driving unprecedented forage scarcity which limiting the livestock production. This is due to the fact that pasture growth, just like any other type of vegetation, depends on favourable temperature and moisture availability on the soil. IPCC (2001) and URT (2003) narrate that with the current climate variability; livestock productivity, survival and distribution will be affected through reduced quantity and quality of grazing land and prevalence of vector-born livestock diseases.

According to focus group discussions, respondents claimed that due to high temperature, drought has been common in their area, implying that there has been a huge problem of pasture and water unavailability; adversely impacting their livelihoods which are dependent on livestock. Ceven *et al.* (2010) maintains that the livestock sector is among the sectors in the country that are worst hit by climate variability through repeated droughts**.** History shows that droughts occur after every four years and this affects a large number of people especially pastoralists who have also been reported to experience recurring droughts; in the years 1983/1984, 1993/1994 and 2005/2006 (Senga, 2007). Giridhar and Samireddypalle (2015) narrated that climate change can adversely affect productivity, species composition and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands.

4.2.2 Herd mortality

Majority of respondents about 97%in Table 7, pointed out that there is an increased rate of animal collapsing and death (Plate 3) attributed to the lack of enough pasture and water. The impact included a high rate of decrease in livestock number, propagating the poverty cycle among the livestock keepers as they depend on livestock keeping especially milk production to sustain their lives.

Table 7: Awareness of herd mortality

Herd mortality	Frequency	Percentage
Agree	87	96.7
Neither agree nor disagree	2	2.2
Disagree	1	1.1

This finding is in line with Chauhan and Ghosh (2014) who explained that reductions in the quantity and quality of feed (leading to less feed intake and higher mortality) could make the impacts of climate change on livestock systems more severe in certain places.

According to key informants, it was reported that the area had been frequently impacted by the long drought period as shown in Plate 3. Pasture has dried out due to high temperature; the area has ecologically changed from grasses replaced by the shrubs and woods which are not palatable to livestock, thus leading to lowered production rate of livestock and high loss of large numbers of livestock.

Plate 3: Cows collapsing due to insufficient pasture (Left) and pasture dried out due to drought in Mvomero district in 2016 (Right).

Ceven *et al.* (2010) reported that in recent years, deaths of large numbers of livestock due to lack of water and pasture has been of repeated occurrence in Tanzania; threatening the livelihood of pastoralists. Pastoralists explained that sometime they choose a hard decision of slaughtering animals that collapses and seems to be on the verge of death; others admitted that they also slaughtered dead animals for their own consumption and for sale, a fact that was also supported by one of the key informants. They do so believing that it is a way of minimising losses due to animal mortality; that at least they should benefit from their dying animals.

4.3 Climate change effect on milk produced by pastoral households

Pastoralists reported that there has been a decrease in the amount of milk produced (Table 8) due to climate change especially from the year 2005. This is due to lack of water, pasture and the associated long walking distances covered in search for the resources; making the livestock very weak. Walking over long distances makes the livestock exhausted and therefore unable to graze comfortably.

Table 8: Amount of milk produced

Change in milk production (per day/cow)	Mean	Std. Deviation
Amount of milk for last 20 years	5.9434	2.47616
Amount of milk produced in current years	1.1622	0.79977

Results revealed a significant difference between amounts of milk produced 20years ago and the current production. This implies that there is reduction of milk produced by the pastoralists between the last 20 years and current years, as also supported by the respondents during survey. It was pointed out that in previous years, an indigenous cow (short horned Zebu), produced up to 5 litres of milk per day, contrary to the time of data collection (November, 2016) where it was difficult to obtain a litre of milk from lactating Zebu. The implication was that, livestock feeds were not enough to provide the cow with energy for sufficient milk production, and as a result of walking over the long distances for pasture and water as observed by Mtengeti *et al.* 2008 and Njombe *et al.* 2011. Other studies showed that milk and meat production could be reduced following stress on the grazing lands (URT, 2003, 2007; IPCC, 2001).

4.3.2 Impact of milk reduction on pastoralists livelihoods

Majority of the pastoralists (99%) Table 9, agreed that climate change has destabilized their life. They claimed to depend on milk production to sustain their life; in terms of food and selling the milk. They also claimed that the reduction of milk on their cows was due to lack of enough water and pasture.

Table 9: Reduction of milk produced by pastoralists

Response	Frequency	Percentage
Reduction of milk production over years	89	98.8
Normal milk production over years	1	1.1

It was noted that, the income earned from milk contributed to attain their basic needs like social and economic services such as sending the children to school. The reduction or lack of milk makes their lives miserable, because it is the only way through which they ensure their economic well-being. They usually sell 1 litre of milk at 500 Tshs during rainy season and up to 1000 Tshs during drought season. There is no permanent selling unit because of the seasonality. Long droughts destruct the opportunity to get income from milk, something that retards livelihood chances.

Most of the pastoralists also depend on milk as the source of food. Due to decline of milk some family underwent malnutrition due to lack of balanced diet. Moreover, in 2003, Tanzania was described by FAO as having a very high level of undernourishment, with 43% of the population being under nourished directly because of drought related food shortages. Thereforereduction of milk production would lead to chronic food insecurity and poverty.

CHAPTER FIVE

5.0 CONCLUSION AND RECCOMENDATIONS

5.1 Conclusion

The climate has changed in Mvomero district as the evidence of increase in temperature and precipitation variation proved in the study. An assessment on the effects of climate change on pasture resources and quantity of milk produced has been successfully done. Generally, both temperature and rainfall trends in Mvomero District are unstable for the last 30 years. While temperature is increasing for 0.02% and rainfall trend is declining for 3%.Pasture resources decreased tremendously from 82.1% in 1985 to 5% in 2015. The study revealed that there is climate change that negatively affects livestock resources in Mvomero district that will continue to affect availability of pasture and well-being of livestock and automatically milk quantities will continue to decline if remedial measures are not taken. Due to the decrease in the quantity of pasture on grazing land accompanied with an increased walking over long distances in search for water and pasture; there has been a marked reduction of the quantity of milk produced. The pastoralists' livelihood has in turn become more vulnerable as they are dependent on livestock products especially milk to obtain their basic needs.

5.2 Recommendations

i. Climate foresight and relevant meteological information on weather should be provided to pastoralists on time to reduce livestock losses caused by climate change.

ii. Adaptations and mitigation technologies should be encouraged in Mvomero District to regulate the changing pattern of climate parameters (Temperature and precipitation).

iii. Awareness creation on alternative sources of protein and income out of milk need to be done to reduce dependence of milk which are already very low in quantity.

iv. Effective public information campaigns should be conducted to pastoralists as most of them are unaware of climate change phenomenon to help them understand and respond to its effects as occurring in their areas

v. Further research should be conducted to build and share knowledge on climate change adaptation plans. The findings should be disseminated to the pastoralists for enlightenment and implementation.

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APPENDICES

Appendix 1: Individual Questionnaire

Section A: General Information:

Date of Interview..

Name of the village...

Name of Respondent...

A. Characteristics of Pastoralist.

1. What is your age...?

1=18-35, 2=36-45, 3=45-65, 4=Above 66

2. Gender of respondent

1=Female, 2=Male

3. What is your marital status?

1=Single, 2= Married, 3=Divorced, 4=Widowed/widower, 5=Separate

4. What Education level you have achieved?

1=No formal education, 2=Adult education, 3=Primary education, 4=Secondary education, 5= Higher education

Section B: Perception of Climate Change, Patterns and Indicators of Change.

1. Have you heard about climate change?

1=Yes, 2=No

2. Are you aware that climate has changed or is changing?

1=Yes, 2=No

3. What do you think about the level of awareness of climate change in the village?

1=None, 2=High, 3=Low

4. What is the trend of rainfall during the last 30 years?

1=Increasing, 2= Decreasing, 3=Fluctuating, 4= No change, 5= Do not know

5. Have you observed any changes in temperatures during the last 30 years?

1=Yes, 2=No

6. If yes, what kind of changes: 1=Increasing, 2=Decreasing

A. Indication that weather has been changing over time

Kindly use the options below to answer the following questions according to your level of agreement and disagreement:

1=strongly disagree, 2=Disagree, 3=neither agree nor disagree, 4=Agree, 5=strongly agree

(1)………………………….rainfall has decreased

(2)………………………….water and air temperature has increased

(3)…………………………frequency of flood has increased

(4)…………………………..frequency of drought has increased

B. Perceived effect of climate change

Kindly use the options below to answer the following questions according to your level of agreement and disagreement:

1=strongly disagree, 2=Disagree, 3=neither agree nor disagree, 4=Agree, 5=strongly agree

1. Irregular pattern of recent time affected pasture availability…………………

2. Prevailing temperature has no effect on milk production…………………….

3. Flood occurrences hinder pasture growth hence decrease milk production……

4. Drought is not a common occurrence in your location…………………………

5. Milk product is obtainable throughout the year…………………………………

6. Pasture is readily available throughout the year…………………………………

7. You cover long distance to graze animals……………………………………….

8. Herd mortality is on the increase………………………………………………..

1. How many cows used for milk production?

1= 3cows, 2= 5cows, 3=10 cows, 4= More than 10cows

2. Have you noticed any changes on milk production?

1=Yes 2=No

If yes what kind of changes…………………………

3. How long have you noticed this?

1=2years, 2=5 years, 3=10 years, 4=More than 10 years

4. Milk production has reduced tremendously due to noticeable change

1=Yes, 2=No

5. How many litres do you get per day compares to previous years?

…………………………………….

C. Perceived effect of climate change on performance of herd on milk production.

Kindly use the options below to answer the following questions according to your level of agreement and disagreement:

1=strongly disagree, 2= Disagree, 3=neither agree nor disagree, 4=Agree, 5=strongly agree

1. Climate change has led to decrease of milk product………………………

2. The cost of milk product is increase because of climate change…………..

3. The livestock suffers due to climate change………………………………

4. Changing in timing of rains has resulted into having low production of milk…….

5. Climate change has led to decline of pastures…………………………

6. Climate change has led to decline of water…………………………..

7. Variation of climate change have destabilized milk produce pastoralist………..

D. Information and Communication

1. How do you access to information on weather?

   1=Radio, 2=Newspaper, 3=Television, 4=Village leaders, 5=Family members/friends, 6=None.

2. Have you received any information on climate change in your village?

   1=Yes, 2=No

3. Have you received any information on drought or flood before they occur? If yes who

   1=Radio,2=Newspaper,3=Television,4=Villageleaders,5=Family members/friends,6=None.

Appendix 2: Checklist for Focus Group Discussion

Elderly people who have lived in the village for at least 30 years

B. Quantity of Milk production

1. What is the livestock type found in the area?

2. How much litres produced per day compared to previous years?

3. What are the reasons of reduction of milk product?

4. Is there any change on quantity of milk produce?

5. What might be the reason for any change?

C. Rainfall and Drought

1. What is the trend of rainfall during the last 30 years?

2. When did you have unusual rainfall/drought events?

3. What coping Strategies in place in case of drought or excessive rainfall?

D. External Support

1. Is there any local or International external Support in your village?
2. How important is such support to addressing issues of drought and floods? provided that information?

Appendix 3: Checklist for key informants

Name of Officer……………………………….

Designation/Title……………………………..

1. When did the effect of climate change start in Mvomero district?
2. What is the trend of climate change for past 30 years?
3. What is the average rainfall and temperature in every year?
4. Do you think the climate change has a significant contribution to milk produce and which is the cause the impact to pastoralist?
5. What kind of assistance do you provide to the pastoralist in help them in managing their grazing areas?
6. How does climate change affect pastoral community as they are mostly depend on livestock products like milk?
7. What adaptation strategies are applied to deal with climate change and its effects on milk production?
8. How effective are these strategies?
9. Are there laws and by-laws concerning grazing areas and their management?
10. What are these laws and by-laws?
11. Are these laws and by laws being implemented?
12. What are the challenges facing the pastoral milk produce households in Mvomero district?

Appendix 4: Monthly total rainfall (mm) 1985-2015

	STATION:MOROGORO																
	MONTHLY TOTAL RAINFALL (mm) 1985-2015																
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	JF	**MAM**	**JJA**	**SOND**	**ANN**
1985	9.8	158.7	107.1	135.1	181.3	1.3	16.7	6.9	0.8	13.7	58.3	43.3	84.3	141.2	8.3	29.0	61.1
1986	134.6	70.1	156.5	142.7	157.7	11.4	2.3	6.9	1.2	37.6	176.5	157.1	102.4	152.3	6.9	93.1	87.9
1987	108.7	74.9	65.7	108.2	132.7	0.0	4.0	8.5	0.0	43.8	36.0	24.9	91.8	102.2	4.2	26.2	50.6
1988	93.7	33.7	191.9	87.1	12.7	44.8	0.0	17.6	33.3	27.5	51.7	170.1	63.7	97.2	20.8	70.7	63.7
1989	229.0	7.2	145.8	250.4	112.7	11.7	3.9	6.8	0.4	71.8	85.5	102.5	118.1	169.6	7.5	65.1	85.6
1990	83.6	187.3	229.1	193.6	56.8	10.2	8.2	7.0	30.5	6.8	154.8	67.8	135.5	159.8	8.5	65.0	86.3
1991	142.9	3.5	88.5	233.8	59.4	2.9	2.9	26.6	9.6	6.7	17.5	183.8	73.2	127.2	10.8	54.4	64.8
1992	13.4	45.5	85.0	24.3	86.9	21.1	4.7	0.1	1.7	0.0	85.8	122.4	29.5	65.4	8.6	52.5	40.9
1993	32.1	157.3	117.8	296.4	89.7	12.7	4.4	3.0	2.2	45.8	37.4	0.8	94.7	168.0	6.7	21.6	66.6
1994	54.0	134.6	77.4	168.8	88.2	8.2	37.1	18.7	6.4	26.0	43.5	49.2	94.3	111.5	21.3	31.3	59.3
1995	148.2	98.5	185.8	246.7	134.2	0.0	1.3	29.1	13.1	78.7	0.6	73.4	123.4	188.9	10.1	41.5	84.1
1996	105.0	151.5	127.9	208.5	132.0	2.0	2.1	0.0	0.0	13.6	25.9	7.6	128.3	156.1	1.4	11.8	64.7
1997	18.8	55.6	152.2	240.5	37.3	39.3	9.8	2.0	0.9	83.6	103.9	242.3	37.2	143.3	17.0	107.7	82.2
1998	226.8	233.1	114.8	216.8	47.9	26.8	4.4	9.9	7.6	8.2	9.9	2.0	230.0	126.5	13.7	6.9	75.7
1999	116.1	29.0	186.3	200.7	95.3	26.8	38.7	21.3	16.1	11.5	35.7	60.9	72.6	160.8	28.9	31.1	69.9
2000	68.8	37.9	207.4	110.6	32.5	47.8	5.2	17.2	4.1	0.0	49.4	208.4	53.4	116.8	23.4	65.5	65.8
2001	104.3	99.0	172.5	224.6	90.4	4.6	5.8	0.0	0.0	11.1	0.0	71.7	101.7	162.5	3.5	20.7	65.3
2002	35.6	116.8	187.4	264.6	24.6	1.1	4.9	8.7	13.6	75.9	60.5	157.1	76.2	158.9	4.9	76.8	79.2
2003	63.0	25.9	162.3	54.5	51.2	13.2	11.4	0.0	0.0	55.2	5.2	52.1	44.5	89.3	8.2	28.1	41.2
2004	164.1	18.5	131.6	219.4	0.6	13.2	4.2	2.6	2.5	40.9	58.7	109.0	91.3	117.2	6.7	52.8	63.8
2005	89.2	18.5	131.6	102.5	55.7	3.6	0.2	1.9	1.3	6.9	23.3	12.5	53.9	96.6	1.9	11.0	37.3
2006	33.5	72.9	188.1	257.1	71.0	47.2	13.1	21.9	15.6	87.3	165.2	210.0	53.2	172.1	27.4	119.5	98.6
2007	87.6	114.9	150.4	151.4	93.8	18.1	9.3	23.8	5.6	30.6	101.9	39.0	101.3	131.9	17.1	44.3	68.9
2008	15.4	77.5	138.7	298.1	27.7	14.9	2.9	3.5	8.9	23.6	82.6	40.6	46.5	154.8	7.1	38.9	61.2
2009	15.4	157.4	95.3	135.9	68.0	15.3	1.8	2.5	0.0	34.9	29.1	93.1	86.4	99.7	6.5	39.3	54.1
2010	97.3	80.6	87.3	201.2	83.8	6.4	0.0	0.0	1.3	0.0	4.2	181.6	89.0	124.1	2.1	46.8	62.0
2011	52.8	73.7	111.2	194.2	58.8	5.3	0.4	5.8	45.0	23.2	37.0	191.1	63.3	121.4	3.8	74.1	66.5
2012	52.8	73.7	111.2	181.7	58.9	5.3	0.4	5.8	45.1	23.2	37.0	191.1	63.3	117.3	3.8	74.1	65.5
2013	136.9	38.0	99.4	126.3	22.8	0.9	1.7	4.1	0.8	70.5	47.3	22.0	87.4	82.8	2.2	35.2	47.6
2014	56.0	69.4	182.7	231.0	113.0	24.0	13.0	4.0	9.1	188.6	43.6	155.5	62.7	175.6	13.7	99.2	90.8
2015	86.8	32.7	144.3	131.4	72.2	0.0	17.3	5.6	0.6	11.8	73.1	73.9	59.8	116.0	7.6	39.9	54.1

Appendix 5: Maximum temperature

	Monthly Mean Max.T																
Year	J	F	M	A	M	J	J	A	S	O	N	D	JAN\FEB	MAM	JJA	SOND	ANN
1985	33.0	30.9	32.7	29.6	28.8	28.1	27.7	28.5	30.3	31.3	32.9	32.8	32.0	30.4	28.1	31.8	30.6
1986	31.3	33.7	31.4	30.1	28.3	27.8	27.4	28.6	29.8	32.4	31.5	30.8	32.5	29.9	27.9	31.1	30.4
1987	30.3	32.1	32.4	30.9	29.2	28.5	28.2	28.8	30.5	31.5	33.4	33.8	31.2	30.8	28.5	32.3	30.7
1988	33.6	33.1	32.4	30.4	29.7	27.7	28.7	28.0	29.7	32.2	33.1	31.5	33.4	30.8	28.1	31.6	31.0
1989	29.2	32.6	31.4	29.1	28.3	27.3	27.2	27.4	29.9	30.3	31.8	31.9	30.9	29.6	27.3	31.0	29.7
1990	31.7	32.5	30.8	29.7	29.3	28.7	27.5	27.5	29.0	30.6	30.7	31.5	32.1	29.9	27.9	30.5	30.1
1991	31.3	33.6	33.0	30.1	28.6	27.8	27.5	28.5	30.0	31.9	32.9	31.6	32.4	30.5	27.9	31.6	30.6
1992	32.2	32.7	31.9	29.3	28.7	27.3	26.6	28.0	29.9	31.6	31.1	30.4	32.4	30.0	27.3	30.7	30.1
1993	31.4	31.7	31.2	29.9	28.8	27.3	26.6	28.7	29.4	30.7	32.0	33.9	31.6	30.0	27.5	31.5	30.1
1994	32.9	32.0	31.0	29.0	27.6	27.6	27.5	28.1	30.1	30.6	31.3	32.0	32.5	29.2	27.7	31.0	30.1
1995	31.6	31.7	30.8	29.1	27.6	27.1	27.9	28.6	29.9	30.7	32.3	33.5	31.7	29.2	27.9	31.6	30.1
1996	32.0	31.0	31.0	28.4	28.0	27.3	26.7	27.9	29.3	30.0	32.0	33.7	31.5	29.1	27.3	31.3	29.8
1997	34.2	33.9	31.5	28.7	27.9	26.3	27.3	28.8	30.7	30.2	30.8	29.8	34.1	29.4	27.5	30.4	30.3
1998	30.7	32.0	31.7	30.3	29.8	28.8	28.0	29.0	30.5	31.5	32.5	34.5	31.4	30.6	28.6	32.3	30.7
1999	33.4	33.8	30.3	28.6	28.9	27.6	26.5	26.7	29.6	30.9	32.8	31.6	33.6	29.3	26.9	31.2	30.3
2000	33.1	31.7	31.0	30.8	28.5	27.9	27.1	28.4	29.8	32.4	33.0	30.9	32.4	30.1	27.8	31.5	30.5
2001	34.1	31.5	31.3	29.7	28.7	27.7	26.4	28.5	29.3	32.5	33.7	33.2	32.8	29.9	27.5	32.2	30.6
2002	32.0	30.9	30.9	28.5	29.1	27.8	28.2	28.4	30.0	33.3	30.7	32.5	31.5	29.5	28.1	31.6	30.2
2003	31.0	34.0	32.6	29.9	28.5	28.7	28.6	28.6	29.3	31.5	32.2	34.4	32.5	30.3	28.6	31.9	30.8
2004	32.9	31.2	31.2	29.7	29.1	27.3	28.4	29.3	30.7	30.7	32.5	31.7	32.1	30.0	28.3	31.4	30.4
2005	33.0	33.1	32.0	30.3	28.9	27.7	27.8	27.0	30.0	31.2	32.9	33.2	33.1	30.4	27.5	31.8	30.7
2006	34.1	34.4	31.2	29.3	28.6	27.7	27.5	28.3	29.7	31.2	30.5	31.1	34.3	29.7	27.8	30.6	30.6
2007	31.6	33.2	32.1	30.8	29.2	28.2	27.9	28.8	30.4	31.8	31.1	32.3	32.4	30.7	28.3	31.4	30.7
2008	33.2	30.7	31.1	28.5	28.7	27.2	27.2	28.7	30.7	31.9	32.3	32.7	32.0	29.4	27.7	31.9	30.2
2009	33.9	31.6	32.1	29.7	29.0	29.2	28.3	28.8	30.7	32.0	32.8	33.2	32.8	30.3	28.8	32.2	31.0
2010	31.4	31.4	32.8	30.7	29.6	29.0	28.7	28.9	31.7	33.3	**33.8**	**32.7**	31.4	31.0	28.9	32.9	31.0
2011	31.7	32.0	31.6	29.8	28.7	28.3	28.2	28.8	30.4	31.6	32.4	31.5	31.9	30.0	28.4	31.5	30.4
2012	31.3	33.8	33.1	31.6	29.9	28.7	28.0	28.2	29.4	31.2	32.0	33.1	32.6	31.5	28.3	31.4	31.0
2013	33.5	33.3	32.1	30.0	29.6	29.2	29.4	29.2	31.4	31.5	33.5	33.0	33.4	30.6	29.3	32.4	31.4
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
2015	0.0	0	0	30.7	28.8	28.7	28.3	29.2	31.1	32.7	30.7	33.2					

Appendix 6: Minimum temperature

Monthly Mean Min.T																
YEAR	JAN.	FEB	MAR	APR	MAY	JN	JULY	AUG	SEPT	OCT	NOV	DEC	JF	MAM	JJA	SOND
1985	21.0	20.8	19.6	20.3	18.1	15.2	15.1	15.7	16.6	17.7	19.7	21.3	20.9	19.3	15.3	18.8
1986	20.8	20.7	20.7	20.2	19.7	15.3	14.2	15.4	16.5	18.9	20.5	21.5	20.8	20.2	15.0	19.4
1987	20.9	21.1	21.6	21.0	19.2	15.3	15.7	17.2	17.7	19.1	20.4	22.0	21.0	20.6	16.1	19.8
1988	22.3	22.2	21.8	21.3	18.5	18.6	16.6	17.5	17.6	18.7	20.6	21.1	22.3	20.5	17.6	19.5
1989	20.7	21.3	20.8	20.5	19.3	16.4	15.3	16.1	16.9	18.2	19.3	21.5	21.0	20.2	15.9	19.0
1990	20.7	21.6	20.4	20.8	18.7	16.3	14.7	16.0	16.6	17.8	20.0	20.4	21.2	20.0	15.7	18.7
1991	20.6	20.3	21.0	20.4	19.8	15.9	15.5	16.0	16.5	18.7	20.1	21.1	20.5	20.4	15.8	19.1
1992	21.4	21.7	21.3	21.0	19.1	16.6	15.1	15.4	16.6	17.8	18.7	19.3	21.5	20.5	15.7	18.1
1993	21.3	21.2	20.7	20.7	19.6	16.2	14.6	16.6	16.2	17.6	19.5	21.2	21.3	20.3	15.8	18.6
1994	21.7	20.2	20.5	19.5	18.6	16.4	15.2	15.8	16.8	18.5	19.5	20.5	21.0	19.5	15.8	18.8
1995	21.0	20.6	20.5	20.3	18.9	16.1	14.9	16.0	17.0	18.8	19.3	21.4	20.8	19.9	15.7	19.1
1996	21.9	21.6	21.9	20.5	19.9	14.3	15.5	15.8	17.2	18.1	19.4	22.3	21.8	20.8	15.2	19.3
1997	22.2	21.8	22.4	22.5	19.4	18.1	16.3	16.4	17.5	19.9	21.0	21.4	22.0	21.4	16.9	20.0
1998	21.8	21.5	21.8	20.9	18.3	17.3	16.1	17.1	18.2	17.8	20.2	22.3	21.7	20.3	16.8	19.6
1999	22.3	19.4	21.4	20.6	19.4	16.4	18.2	17.5	22.3	18.8	19.8	18.6	20.9	20.5	17.4	19.9
2000	21.6	21.3	22.1	19.9	19.0	17.4	15.9	17.0	17.2	18.6	21.4	21.6	21.5	20.3	16.8	19.7
2001	21.7	21.2	21.8	21.7	19.8	17.0	15.7	16.2	17.1	18.5	20.2	22.6	21.5	21.1	16.3	19.6
2002	22.6	22.0	22.8	21.1	18.6	17.3	16.9	16.4	15.1	19.3	20.6	19.5	22.3	20.8	16.9	18.6
2003	21.4	21.9	21.7	21.8	20.7	17.7	16.7	16.6	18.0	19.1	20.9	21.8	21.7	21.4	17.0	20.0
2004	22.2	21.6	22.0	20.9	17.4	16.2	15.4	16.5	17.7	19.6	20.9	22.1	21.9	20.1	16.0	20.1
2005	20.0	22.1	22.0	19.3	19.3	18.6	16.2	17.7	17.9	19.4	20.6	22.7	21.1	20.2	17.5	20.2
2006	22.7	22.6	21.8	21.2	20.2	17.4	15.5	17.5	17.9	19.3	21.3	21.8	22.7	21.1	16.8	20.1
2007	21.9	21.7	21.6	21.6	20.4	16.7	16.9	17.7	17.8	18.7	20.9	22.1	21.8	21.2	17.1	19.9
2008	22.4	20.3	21.5	20.8	18.4	15.7	15.8	16.6	17.0	19.6	22.2	22.1	21.4	20.2	16.0	20.2
2009	22.5	21.4	21.5	21.1	19.1	18.4	15.9	17.3	17.2	19.1	21.1	22.2	22.0	20.6	17.2	19.9
2010	22.4	22.4	23.0	21.5	20.3	17.9	16.3	16.9	17.2	19.1	19.5	21.7	22.4	21.6	17.0	19.4
2011	21.4	21.8	21.3	21.1	20.2	17.8	15.4	16.6	18.1	19.7	21.3	21.5	21.6	20.9	16.6	20.2
2012	21.5	21.5	21.3	20.5	19.3	17.0	15.8	19.9	17.6	19.1	21.5	21.2	21.5	20.4	17.6	19.9
2013	22.4	21.8	22.1	21.4	19.6	16.2	15.4	17.2	17.6	19.4	20.8	22.1	22.1	21.0	16.3	20.0
2014	22.9	22.2	21.8	21.3	19.8	17.8	16.4	17.4	m	m	m	m				
2015	21.8	22.1	21.7	21.5	20.0	16.5	17.0	17.0	17.6	19.9	22.9	22.4				

JF: January and February, MAM: March, April and May, JJA: June, July and August, SOND: September, October, November, December.