SFS CENTER FOR WILDLIFE, WATER AND CLIMATE RESILIENCE

P.O. BOX 27743-00506, NAIROBI-KENYA

Climate Change Perceptions and Impacts on Local Livelihoods in the Amboseli region of Kenya

By Gabriel Wilkins

wilkins5@umbc.edu

University of Maryland, Baltimore County

1000 Hilltop Circle Baltimore, MD 21250, United States

Supervisor: John W. Kiringe (Ph.D.)

December 3rd, 2019

Abstract – Climate change negatively impacts people across the globe, especially those in arid and semi-arid lands who are dependent on already infrequent rainfall. This study assessed community perceptions of climate change and its impacts in the Amboseli region of Kenya. Impacts to pastoralism and other livelihoods, as well as coping strategies being used, in the area were the focus of expert judgement interviews and a group discussion with community elders. The study found that community members were aware of significant changes in the local climate, including reduced levels of precipitation and longer, more frequent droughts. They were not, however, very aware of the global context of climate change. Respondents had noticed, and attributed to climate change, decreasing livestock production and crop yields, increasing prevalence of diseases and pests, reductions in water availability, and depressed health status and economic wellbeing. Coping strategies primarily included saving resources, like pasture, food, and crop leftovers, for use during the dry season. These strategies, however, were being seen as less effective than they had been in previous years. Respondents also reported a change in their daily activities, primarily by increasing agricultural activities, due to climate change. A shift of livelihood, either towards more agriculture or beginning a business, was commonly considered by respondents as their next step in adapting to climate change. This study emphasizes the need for outside assistance in order for communities to cope with impacts on their livelihoods, and the need for community awareness about climate change, its causes, and associated impacts.

Key Words: climate change, community, impacts, livelihoods, natural resources, arid and semi-arid lands

1.0: INTRODUCTION

1.1: Climate Change and Variability

Across the globe, people are experiencing the effects of climate change and variability. The term 'climate change' is used to describe changes in weather patterns that occur over a long period of time (Amwata, 2013). Climate variability, on the other hand, denotes annual fluctuations in aspects of climate such as precipitation and temperature; and unlike climate change, it indicates short-term changes in those aspects that happen each year (Amwata, 2013).

Climate change is largely caused by anthropogenic activities, including increased greenhouse gas (GHG) emissions (Australian Academy of Science, 2015). GHGs like Carbon dioxide (CO_2) trap heat in the atmosphere as their particles scatter thermal energy emitted by the earth, redirecting more radiation back to the planet rather than out to space (IPCC, 2007). Agricultural GHG emissions comprise more than 60% of anthropogenic radiative forcing (disturbance in the planet's radiative energy budget) (IPCC, 1995; Naqvi & Sejian, 2011). The concentration of methane (CH_4) in the atmosphere is rising faster than other GHGs, having doubled between the pre-industrial era and present day (mainly due to livestock farming) (Naqvi &

Sejian, 2011). Additionally, human actions are contributing to the depletion of the ozone layer. Chemicals like Chlorofluorocarbons (CFCs) and Nitrous oxide (N_2O), another greenhouse gas whose largest anthropogenic source is agriculture, destroy the ozone layer (Ravishankara et al., 2009). Thus, the increased concentration of N_2O is mostly due to an increase in cultivated land area and the use of fertilizers (Reay et al., 2012). Ozone depletion leads to more ultraviolet radiation (UV) entering the earth's atmosphere, which further contributes to increasing global temperatures. An increase in radiation from UV-B rays linked to the deteriorating ozone layer was detected in the 1980s and 1990s (McKenzie et al., 2011).

Changes in land use may also impact climate change. For example, Taylor et al. (2002) found that, due to land use changes, 1996 and 2015 simulations showed decreased rainfall in the Sahel region of Africa compared to the 1961 simulation. The Sahel is near northern Africa below the Sahara Desert comprised of different land types, including tiger bush, crop fields, and savanna (Nicholson, 2000). The researchers' model estimated that the percentage of land dedicated to cultivation grew from 5% to 14% between the 1960s and 1990s and experienced a 28% reduction in forest cover. Additionally, Mango et al. (2011) analyzed the potential impact of three different land use scenarios on the Mara River's hydrology: some deforestation and replacement with agriculture, total deforestation and replacement with grassland, and total deforestation and replacement with agriculture. The simulations of each scenario demonstrated a lower baseflow, and the two scenarios involving agriculture showed an increase in evapotranspiration and a decrease in water output from the river basin. All three scenarios showed a decline in groundwater discharge, which reveals that land use changes can have serious detrimental impacts on the environment.

The Intergovernmental Panel on Climate Change (IPCC, 2007) outlines several global climate projections using different models. The IPCC ran models on surface warming over the next century for three different emissions scenarios (high, medium, and low). The high emissions scenario shows the surface temperature will warm by more than 3°C by the year 2100 while the low emissions scenario shows warming by almost 2°C. Events like heat waves, cyclones, and heavy precipitation are expected to increase due to climate change. The whole of Africa will likely experience increasing temperatures (higher than the yearly average across the globe) during the 21st century (IPCC, 2007). Multiple models estimating change in rainfall between 1980 to 1999 and 2080 to 2099 show an increase in precipitation levels in East Africa and drying in northern and southern Africa (IPCC, 2007). Higher global temperatures will likely cause increased evaporation, which can be detrimental for arid and semi-arid areas.

Climate change manifests in many different forms, including natural disasters like droughts, hurricanes, and floods, as well as species extinctions, ice melt, sea level rise, and decreasing natural

resources (IPCC, 2007). IPCC (2007) states that droughts have become longer and more severe since the 1970s, a change attributed to increased temperatures and lower levels of precipitation. Other impacts include decreasing amounts of snow and glacier cover on mountains, which has led to significant sea level rise and slower groundwater recharge. The melting ice on Mt. Kilimanjaro has indicated climate change in East Africa. Thompson et al. (2009) show that the area of ice cover on the mountain has decreased by about 85% between 1912 and 2007, and Cullen et al. (2006) suggest that, since there has been no change in air temperature over a long period of time at the glacial elevation, the decrease in ice cover may be due to a change in humidity. A decrease in atmospheric moisture is associated with less cloud cover and precipitation, which would lead to increased solar radiation and a resulting lower albedo, which would compound the process of glacial melt. Human health can also serve as a proxy for climate change and variability, as death and illness are associated with a variety of climatic changes (Kovats et al., 2005). For example, heat waves may lead to death and diseases, hotter temperatures decrease the time it takes pathogens to fully develop, and droughts are linked to malnutrition (Kovats et al., 2005). Accordingly, experts estimate that since the 1970s, climate change has caused more than 150,000 deaths globally.

Currently, many countries are acting to mitigate the impacts of climate change. International agreements like the Copenhagen Accord, Kyoto Protocol, and Paris Agreement set emissions standards for participating countries. The Copenhagen Accord states that decreasing emissions worldwide is necessary and focuses on keeping global temperature increase below 2°C (according to the 2004 IPCC report) (UN, 2009). The Kyoto Protocol assigns each member state emissions amounts that they are not permitted to surpass (UN, 1998). Paris Agreement also focuses on emissions, with the goal of keeping global temperature increase to 1.5°C over pre-industrial levels, similar to the Copenhagen Accord (UN, 2015).

1.2: Climate Change Impacts in Kenya

Kenya has a diversity of climatic regions; some areas receive small amounts of rain, some high levels of precipitation, and others experience coastal climates and tropical weather (Bharwani, 2011). With such a wide range of ecosystems, climate change has different effects on each part of the country, but there is an overall expectation that temperatures across Kenya will rise. In Eastern Kenya, the temperature has already increased by 2.5°C in the past 50 years (GoK, 2018). Higher temperatures like these are occurring all over the country and disrupting weather patterns. For example, in 2007, the Rift Valley Province was inundated by heavy rains, which brought a flood that broke the Kainuk Bridge (GoK, 2010).

On average, these floods only occur every three to four years when El Niño conditions (not present in 2007) increase the rainfall for that season (GoK, 2010). In 2008, there were severe droughts that spread across much of Eastern Kenya, killing a majority of people's livestock and crops (GoK, 2010). Along the Kenyan coast, the situation does not look any better. People here will be among the predicted 267,000 people across the globe that, by 2023, will be at risk of floods from rising sea levels (GoK, 2018).

The natural disasters associated with climate in Kenya have significant implications for the environment and people's livelihoods. For instance, following the 2017 drought an estimated 500,000 people did not have access to water, with an additional 3.4 million people facing food insecurity (GoK, 2018). Many people became victims of food insecurity because 25% of the population relies on agriculture, and an even greater percentage relies on pastoralism as a key source of livelihood (GoK, 2010). Both economic activities depend heavily on water availability and are therefore very vulnerable to the impacts of climate change and variability. In the case of agriculture, whether rain-fed or irrigated, a sufficient abundance of water is required for crops to grow well. As for pastoralism, if there is little to no rainfall then production and availability of forage food resources to meet livestock needs will be significantly reduced. Kenya's Gross Domestic Product (GDP) declines an average of 0.6% during drought years (Gok, 2018), and from 2007 to 2017 the country lost an estimated $1.08 billion worth of livestock to severe droughts. Aside from reducing the national GDP, this loss also affects the economic income of communities that depend on livestock. Overall, with increasing climate change and climate variability, water insecurity across the country will increase and continue to harm many people whilst impending socio-economic development of communities.

Climate change and variability in Kenya has not only affected people's financial security but has also influenced their social lives. For instance, the Samburu people of Northern Kenya have different gender roles in their daily lives that have been influenced by climate change (Ongoro & Ogara, 2012). Men usually take care of the livestock, while the women manage the household and agricultural activities (Ongoro & Ogara, 2012). However, there has been an increase in drought frequency and duration across Samburu land that has killed most of the community's livestock (Ongoro & Ogara, 2012). As a result, the Samburu men feel discouraged that they cannot control these deaths and think that they have let down their society (Ongoro & Ogara, 2012). Livestock loss also influences who the men can marry, since cattle is used to pay dowries (Ongoro & Ogara, 2012).

Since the impacts of climate change and variability are widespread throughout Kenya, communities have come up with different short-term coping mechanisms. In Northwestern Kenya, the Turkana pastoralists have diversified the type of livestock they keep (Opiyo et al., 2015). Their herds include cows, sheep, goats, and camels, so that not all of their livestock will die if there is a severe drought in a given year. Regarding agriculture, preferred coping mechanisms include planting more trees, planting different types of crops, and changing the time of planting (Bryan et al., 2013). While these strategies may indeed assist communities adapt to climate change and variability, it is unclear how long these solutions will last (i.e. their sustainability) and whether they are effective. If they are only short-term solutions, then eventually communities will be faced with more severe problems and may be less able to find other workable coping mechanisms.

The Paris Climate Agreement is a global agreement to cut down on global emissions from major polluting countries and support developing countries in the process (GoK, 2018). Before this agreement was put in place, Kenya was already drafting a climate change plan of its own: the National Climate Change Action Plan (NCCAP) 2013 – 2017 (GoK, 2016) The goal of this plan was to set up actions that create a resilient, low-carbon pathway for the future of the nation (GoK, 2016), and this plan has continually been improved since 2013. In addition, the government has begun working with organizations such as REDD+ to help the country reduce its admissions (Dooley & Chapman, 2014). RED++ is a United Nations initiative that places a monetary value on forests across the world in an effort to prevent them from being cut down (Dooley & Chapman, 2014). Implementing REDD+ in Kenya would help preserve forests, with the hope that CO_2 emissions across the world would be slightly reduced through carbon sequestration. Other strategies can be incorporated into a REDD+ plan, such as allowing animals to graze in the forests during drought seasons (Dooley & Chapman, 2014). This would significantly help pastoralists who are not able to find enough pasture for livestock on their land, and thus reduce their food insecurity. With the help of organizations which aim to support local communities with additional resources and knowledge, as well as the implementation of policies that protect local communities and ecosystems, traditional coping strategies may not be the only option for communities working to combat climate change and variability.

1.3: Problem Statement

Eighty percent (80%) of Kenya's territory is classified as arid or semi-arid land (ASAL), in which one-third of the country's population resides (Huho et al., 2010). Most of these people make a living as agriculturalists or pastoralists, and often a combination of the two (Misra, 2014; Huho et al., 2011). These livelihood strategies are dependent on natural resources, especially water and grassy vegetation, and are thus extremely vulnerable to the effects of climate change and variability (Bobadoye et al., 2016). The arid and semi-arid landscape of Southern Kenya where this study was done is already characterized by high variability in rainfall throughout the year, with droughts causing significant damage to local livelihoods (Huho et al., 2010; Kimaro & Chibinga, 2013). Whether to small-scale subsistence farmers or Maasai pastoralists (who are themselves increasingly turning to agriculture), seasonal rains are of paramount importance in crop production, pasture regeneration and production, and growth of woody vegetation (trees and shrubs) which locals depend on for uses like herbal medicine and fuel.

The health and population size of Maasai livestock herds are dependent on natural resources like water and nutritious grasses as well as environmental conditions such as ambient temperature and precipitation levels (Kimaro & Chibinga, 2013; Taruvinga et al., 2013). As a result, the availability of these resources is integral to the livelihoods and food security of pastoralists in the study area. Climate change and variability will continue to decrease the amount of precipitation, thus reducing the quantity of water resources in the Amboseli region. The people, their livestock, and wildlife of the region which depend on this water will have to compete over less and less of it. Livestock mortality will increase due to dehydration (Bobadoye et al., 2016) and the risk of predation will increase as livestock need to travel further for water, increasing time spent unprotected from predators like leopards and hyenas (Patterson et al., 2004). People that rely on these animals will thus loose an important source of food and income. A decreased amount of water available to crops, whether as less rainfall or lower quantities with which to irrigate, will decrease how often crops are watered, leading to reduced crop yields (Huho et al., 2010). Reduced crop yields negatively impact farmers' ability to feed themselves and the community, as well as their monetary wealth. Fewer water resources will also increase the time spent by women and children to gather water, which will diminish caregiving time, reduce time spent on more economically gainful activities, and increase the risk of encountering dangerous wildlife (Huho et al., 2010). Longer trips and less abundant sources decrease the total amount of water households have to use for cleaning and cooking, negatively impacting sanitation, nutrition, and overall health.

Less rainfall and higher temperatures will reduce the abundance of grass forage and other vegetation food types that currently sustain large populations of livestock and wildlife on Kenyan ASALs. The same area of land will no longer be able to sustain the same population levels, especially during prolonged dry spells, as livestock will consume the lower amount of forage more quickly and many will starve, or become malnourished, while moving to more vegetated areas (Huho et al., 2011). Maasai pastoralists, who rely almost entirely on their livestock (Bobadoye et al., 2016) will have their livelihoods severely limited as their primary sources of food and income are lost at an increasing rate. As the quantity and quality of cattle each household has decreases, there will be fewer to milk, eat, and sell, and those that can be used will provide less milk and meat, and will fetch a lower sale price at market (Huho et al., 2011). With less money to buy food, needed more in order to supplement a reduced amount of milk and meat, Maasai pastoralist food security will be negatively impacted. Income and general socio-economic status will also be reduced by smaller herd sizes, as fewer can be sold or traded in return for money or other goods and services.

Climate change and variability threatens the Amboseli region in many ways, primarily by disrupting the availability of natural resources like water, grasses, and woody plants, through increasing the frequency and duration of droughts (Huho et al., 2010). These reductions in resource availability affect communities in the Amboseli ASAL in many ways, which will combine to increase poverty rates and the level to which livelihoods are depressed. Decreased household incomes may result in increased levels of school dropouts as well as crime or other conflicts over resources. Reduced food security will increase the rate of malnutrition, especially among children, which will combine with fewer school enrollments and less money to fund jobs to diminish economic opportunities for younger generations. This study therefore sought to investigate how communities view climate change and its impacts, as well as understand what they are doing to protect themselves and adapt to a different environment. It was guided by the following research questions –

1. What changes in the natural environment have communities noticed over the past 10-15 years?
2. What do local communities know about climate change and variability, and how dependent is this on the level of education and primary source of livelihood?
3. How has adaptation to environmental changes, especially climate change, modified how people use natural resources?
4. How does climate change directly and indirectly impact local communities and people' livelihoods?

5. What strategies do communities use to cope with impacts arising from climate change and variability, and how sustainable and effective are they?

This study took place in the Amboseli region in Southern Kenya. Previous droughts in this area and other ASALs have resulted in the drying up of water sources, stunted crop growth, diminished pasture area, and increased disease prevalence (Huho et al., 2010). Stunted plant development and less available water, which can result in crop failures, greatly reduce the quantity and quality of cultivated foods that families can sell or eat, thus diminishing their food security, nutritional health, and economic well-being. Lower levels of precipitation and higher ambient temperatures change the vegetation structures of ASALs to favor shrubs and other plants not palatable to livestock, which in turn decreases the health of individual animals and often results in significant herd population losses (Huho et al., 2010). This decreases the amount and quality of food available to households dependent on livestock, and because malnourished animals fetch much lower prices at market, and pastoralists have fewer to sell, those households also lose a key source of income (Huho et al., 2011).

Through increased ambient temperatures and decreased precipitation, both climate change and variability pose multiple threats to communities in ASALs. But most of the current literature on climate change in these regions focus on impacts to agriculture and only address pastoralism as a small part of this larger practice (Taruvinga et al., 2013). Given that, in Kenya, 95% of family income within ASALs comes mainly from pastoralism (Huho et al., 2011), this is a significant gap in research that could greatly reduce researchers' ability to help communities prepare for the effects of climate change and variability. This study aims to build off of previous research which analyzed pastoralism and other livelihoods in Kenyan ASALs (Huho et al., 2011; Bobadoye et al., 2016) to continue to bridge that gap and to achieve the overall goal of discerning how communities in the Amboseli region are managing a changing environment. This study will therefore address the following objectives –

1. Evaluate community views on climate change and variability.
2. Assess the impacts of climate change and variability on natural resources, pastoralism, and local livelihoods.
3. Determine actions or coping strategies used by locals to deal with the impacts of climate change and variability.
4. Understand how climate change is affecting livelihood choices and everyday activities.

2.0: METHODS

2.1: Study Area

This study took place in the former Kimana Group Ranch in Kajiado South sub-county of the Amboseli region, Kenya (Figure 1). South Kajiado sub-county, including the Kimana area, is a semi-arid landscape, characterized by a hot and dry climate (Cloudsley-Thompson, 1978). The rainfall pattern in this area is bimodal, consisting of long rains from March to May and short rains from October to December (Okello & D'Amour, 2008). The annual movements of the inter-tropical convergence zone largely drive the rainfall pattern in the Amboseli region, Kenya, and East Africa as a whole. Lack of regular, year-round rainfall in the region (averaging 300-500 mm/yr.) has forced local communities to rely on irrigation for their agricultural activities during the dry season (Aduma et al., 2018).

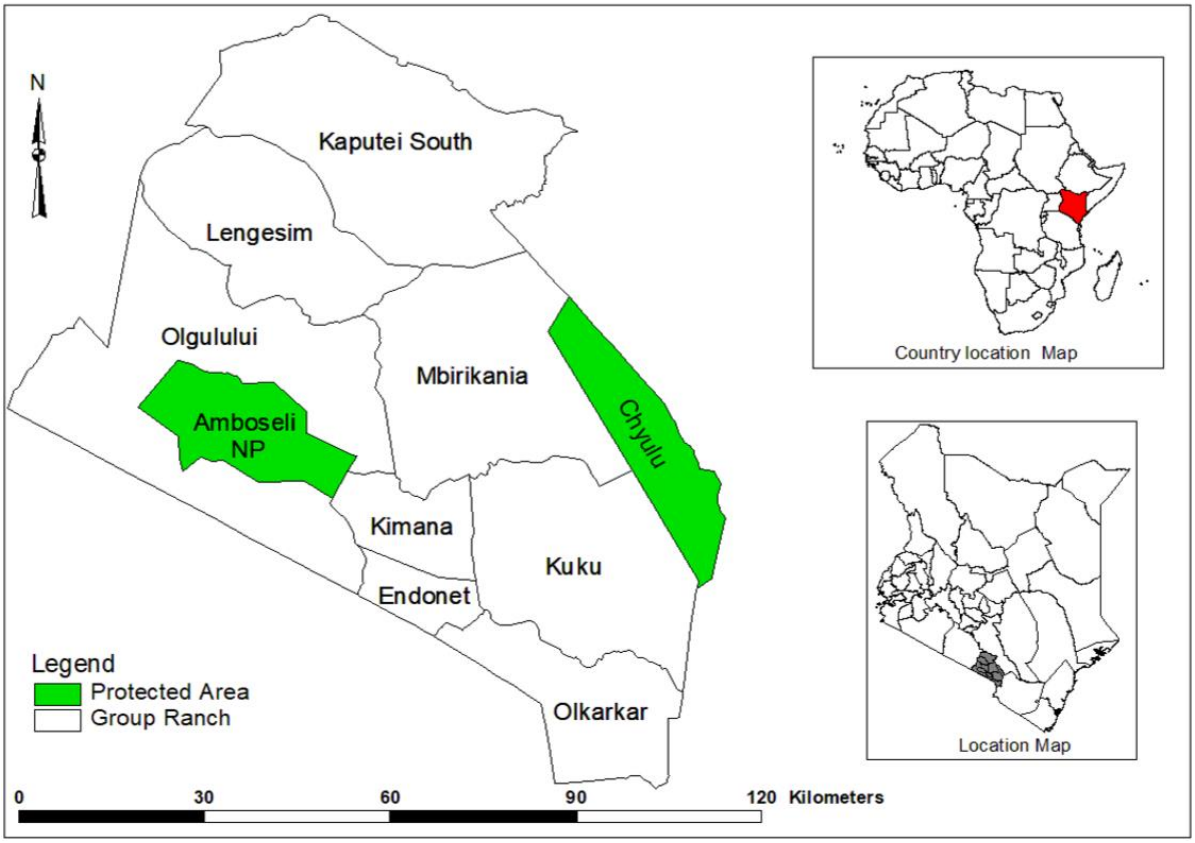

Figure 1. Spatial location of Kimana area in the Amboseli region. (Source: Aduma et al., 2018)

The soils of the Amboseli region are characterized by low porosity and permeability, and as a result they exhibit an extremely poor water holding capacity. Derived from volcanic activity associated with the formation of Mt. Kilimanjaro, these soils are observed to be highly saline and alkaline, as well as shallow, with a lot of rock debris and un-weathered parent rock material (Kiringe et al., 2009). These characteristics,

further compounded by frequent trampling from overabundant livestock, make much of the soil unsuitable for agricultural production. Additionally, soil erosion has become an issue in much of the study area, as community members have continuously cut down trees for firewood and timber resources (Ntiati, 2002; Kiringe et al., 2009). The removal of vegetation due to such activities, coupled with overgrazing by livestock herds, have contributed to increased homogenization of the plant community. With 37% of the Amboseli basin being comprised of grassland, an immense amount of land in the surrounding area may become devoid of vegetation (Ntiati, 2002). This trend has been seen in studies of the area between 1976 and 2007, showing a 3% decline in rangelands over the study period (Kioko & Okello, 2010).

Livelihoods within the Amboseli region largely revolve around livestock keeping, and this way of life has been entrenched in local communities through the traditions of groups like the Maasai (Ntiati, 2002; Huho et al., 2011). However, in recent decades there has been a growing diversification of livelihoods to include agriculture, with maize, tomatoes, and beans being the most popular (Kiringe et al, 2009). The continued usage of chemical fertilizers and pesticides to support this rapid growth of agricultural activity has contributed to increased contamination of water resources (Okello & D'Amour, 2008). In addition to agriculture, the presence of Amboseli National Park has created a viable tourism industry for local communities, allowing employment opportunities with tour companies, lodges, and the park itself.

Pastoralism and agriculture are the primary land uses within the Amboseli region, dominating the livelihoods of most local people (Ntiati, 2002; Okello & D'Amour; 2008 Kiringe et al., 2009). The resultant over-cultivation and overgrazing associated with them comprise the primary issues of land management found within this area (Kioko & Okello, 2010). These issues are exacerbated by increasing droughts, prolonged dry spells, and rainfall variability. With agriculture consuming over 400% of the water used by humans and animals combined, overcultivation has resulted in an aggravated mismanagement of the community's water resources (Okello & D'Amour, 2008). A popular transition towards farming has contributed to a large-scale invasion by farmers onto swampland and riverine vegetation. The thirty-year period between 1976 and 2007 showed that swampland in the Amboseli region declined by 89%, due almost exclusively to farming activities (Kioko & Okello, 2010). The diversification of local livelihoods from pastoralism to farming has not manifested as a complete lifestyle switch. Instead, responses to a survey regarding personal livelihoods showed that 31% of respondents in the Amboseli region claimed to be practicing both pastoralism and agriculture (Kioko & Okello, 2010). This percentage is suspected to have increased dramatically over recent years as community members strive for economic security in a setting of increased landlessness and poverty.

Extreme population growth has become increasingly evident through the uncontrolled expansion of human settlements observed in and around the Kimana area. An annual population growth rate of 5.5% has been observed in Kajiado County, and this number continues to rise every year (Kajiado County Govt., 2014). Poverty has also become a persistent problem among the people of the Amboseli region, with as many as 88% of the Kimana population being described as poor or very poor (Ntiati, 2002). The widespread poverty in the Kimana area is due to a combination of factors, including poor infrastructure and a lack of economic opportunities (Musoi et al., 2014).

2.2: Methodology

The expert judgement method was used to gather views of local people on climate change and variability. Household interviews and surveys were done in the Namelok, Lolmeuti, Noomayanat, Impiron, and Oloile areas of the former Kimana group ranch. A random sampling method was used to select households, and one person per household was interviewed. The questionnaire consisted of both closed and open questions, and each interviewer was accompanied by a local Maasai interpreter who translated questions into Maa or Swahili and responses into English.

The questionnaire aided researchers in assessing community views on climate change, at both local and global scales, as well as learn where people learned about climate change. Respondents were asked about their perceptions on how climate change was impacting various aspects of livelihood, such as livestock mortality, pasture abundance, water availability, and economic wellbeing. Researchers also inquired about the coping strategies the respondents were using to cope with these impacts, as well as how effective they seemed to respondents and where or from whom those strategies were learned. A large portion of the questionnaire also focused on how climate change had modified community members' daily activities, as well as whether it had made people consider changing their primary source of livelihood, and what changes were being considered.

Responses from the closed questions were entered into SPSS version 23 in order to perform statistical analyses. Chi-squared (X^2) goodness of fit tests were performed to examine whether there were significant variations in responses, and chi-squared (X^2) contingency tests were performed to determine if interviewees' responses were dependent on certain demographic characteristics, namely livelihood strategy and level of education. Responses for the open-ended questions were synthesized and collated to provide an overall summary of frequent responses and to understand the general themes expressed by the community respondents.

Furthermore, a focus group discussion was performed with ten community elders of 60 years and above. These individuals are knowledgeable of environmental changes occurring in the Amboseli region and have the important ability to compare current environmental and social conditions to those in the past. The discussion examined the elders' views on changes within the environment, what they have observed, key indicators (environmental and socioeconomic) of these changes, how climate change has affected local people, and the coping strategies utilized by communities. The responses were summarized in order to discern common themes or opinions among the group of elders.

3.0: Results

3.1: Demographic profiles of respondents

A total of 234 residents of the Former Kimana Group Ranch in the Amboseli region were interviewed. A significant (X^2 = 24.68, df = 1, $p < 0.001$) majority (66.2%) were female, with 32.8% of respondents being male. The age group distribution was uneven (X^2 = 17.73, df = 3, p = 0.001), with the 30-39 cohort being most represented (30.8%), followed by those above 49 years (28.2%), those between 20 and 29 years (27.8%) and the 40-49 cohort comprising 13.2%. There was a significant skew to the ethnic distributions as well (X^2 = 434.376, df = 4, $p < 0.001$), with Maasai comprising 73.9%, Kikuyu 12.8%, Kamba 8.1%, Tanzanian 1.3%, and a collection of others (Kisii, Lughya, Luo, Luya, and Talta) comprising the remaining 3.8%.

A significant (X^2 = 86.44, df = 3, $p < 0.001$) plurality (44.9%) of respondents reported having no formal education. Of the remaining respondents, 34.6% reported having a primary level, 11.1% a secondary level, and 9.4% said they had received a university degree. A significant (X^2 =84.68, df = 4, $p < 0.001$, n = 234)) plurality (38.5%) of respondents described their primary livelihood activity as agropastoralism. The second most common response (27.8%) were those who reported only doing agriculture; 18.8% were strictly pastoralists, 9.4% ran businesses as their primary source of income, and 5.6% received most of their livelihood from employment.

3.2: Perceptions of Climatic Changes and Impacts

A significant (X^2 = 169.96, df= 1, $p <0.001$) majority (92.7%) of respondents indicated that they had noticed a change in the local weather and climate patterns in the last 10-15 years. This response was independent of both level of education (X^2 = 1.51, df = 3, p = 0.679) and primary livelihood strategy (X^2 =

1.00, df = 4, p = 0.910) of the respondents. Respondents indicated that they had noted a decrease in the amount of precipitation and the consistency of wet seasons concurrent with an increase in drought duration and frequency. Higher average temperatures were also noted (Table 1).

Table 1. Observed changes in local climate characteristics

#	Local climate characteristics	Response	Frequency	Chi – square goodness of fit	n
1.	Amount of rainfall received per year (i.e. insufficient rain)	Increase	9 (4.1%)	X^2= 550.37	219
		Decrease	205 (93.5%)	df= 3	
		No Change	4 (1.8%)	p<.001	
		Don't Know	1 (.5%)		
2.	Consistency in wet seasons	Increase	16 (7.3%)	X^2= 481.11	219
		Decrease	195 (89.0%)	df= 3	
		No change	7 (3.0%)	p<.001	
		Don't Know	1 (.5%)		
3.	Frequency of droughts	Increase	211 (96.3%)	X^2=391.34	219
		Decrease	3 (1.4%)	df=2	
		No change	5 (2.3%)	p<.001	
4.	Duration of dry conditions or dry spells	Increase	209 (95.4%)	X^2=579.81	219
		Decrease	2 (.9%)	df=3	
		No change	7 (3.2%)	p<.001	
		Don't know	1 (.5%)		
5.	Average temperature	Increase	197 (90.0%)	X^2=292.15	219
		Decrease	6 (2.7%)	df=3	
		No change	14 (6.4%)	p<.001	
		Don't Know	2 (.9%)		

Climate change and variability was mentioned to have a multitude of impacts on the community. A significant (X^2 = 524.52, df = 9, p <0.001) majority (90.1%) of respondents indicated that they had noticed lower levels of livestock production, and this was independent the interviewees' level of education (X^2 = 8.26, df = 9, p = 0.509) and primary livelihood (X^2 = 17.50, df = 12, p = 0.132). Most respondents (87.0%, X^2 = 473.48, df = 3, p <0.001) also observed that households were becoming less dependent on livestock as a primary source of livelihood. These perceptions were dependent on the respondents' education level (X^2 = 17.37, df = 9, p = 0.043) and primary source of livelihood (X^2 = 48.45, df = 12, p < 0.001). The tendency was for those with a primary level of education or above to be more likely to note an increasing dependency than those with no education. However, the proportion of respondents who said they did not notice a change decreased as level of education increased. All respondents who noted that dependency had increased were agriculturalists, while those who practiced business had the highest likelihood to respond that there had been no change.

Significant majorities of respondents indicated that they had noticed an increase in the prevalence of livestock diseases (70.3%, X^2 = 256.35, df = 3, p < 0.001), and this view was dependent on both education level (X^2 = 20.48, df = 9, p = 0.015) and livelihood (X^2 = 40.47, df = 12, p < 0.001) of the respondents. Those with a secondary level of education were most likely to respond that they did not know about livestock disease prevalence, while those with no education were the least likely to respond that way. Respondents with no education or only a primary level were more likely than those with at least a secondary level to indicate no change in disease prevalence. A large proportion of agriculturalists and business owners responded that they did not know about livestock disease prevalence; and compared to pastoralists, both agriculturalists and agro-pastoralists were more likely to respond that there had been no change in disease prevalence.

An increase in overall livestock mortality was also reported by the interviewees (70.3%, X^2 = 258.24, df = 3, P <0.001), dependent on both respondents' education level (X^2 = 18.141, df = 9, p = 0.034) and livelihood (X^2 = 33.47, df = 12, p =0.001). The tendency for respondents to indicate either no change or a decrease in livestock mortality decreased as level of education increased. Those with any formal education were more likely than uneducated people to respond that they did not know enough to respond. Respondents who ran businesses or were employed were more likely to indicate that mortality had increased compared to those with other primary livelihoods. Agriculturalists were the most likely to respond that they did not know about overall livestock mortality.

A majority (84.5%) of respondents noted that the quantity and quality of available pasture had decreased (87.5%, $X^2 = 484.62$, df = 3, $p < 0.001$); responses were dependent on respondents' livelihood strategy ($X^2 = 26.62$, df = 12, $p = 0.009$) but independent of their education level ($X^2 = 12.12$, df = 9, $p = 0.207$). Agriculturalists were the most likely group to respond that they did not know about changing pasture quality and quantity; and agro-pastoralists and business owners were more likely than agriculturalists or pastoralists to respond that there had been no change.

The plurality (36.4%) of respondents who indicated that water quality had not changed was not significant ($X^2 = 3.30$, df = 2, $p = 0.192$). Only slightly fewer (35.9%) indicated that water quality had decreased, and 27.7% indicated the quality had increased. These responses were independent of respondents' education level ($X^2 = 5.28$, df = 9, $p = 0.508$) and livelihood ($X^2 = 7.94$, df = 8, $p = 0.439$). Perceptions on water quantity and availability, on the other hand, had significant majority opinions, with 51.9% reporting a lower availability of water for domestic and pastoral use ($X^2 = 127.32$, df = 3, $p < 0.001$). These perceptions were independent of both the education level ($X^2 = 5.56$, df = 9, $p = 0.783$) and livelihood ($X^2 = 9.53$, df = 12, $p = 0.657$) of respondents. A larger majority (72.7%) found less water available for use to irrigate crops ($X^2 = 294.49$, df = 3, $p < 0.001$), independent of respondents' education level ($X^2 = 4.51$, df = 9, $p = 0.875$) and livelihood strategy ($X^2 = 5.85$, df = 12, $p = 0.924$).

Household food production and farm yields were noted by a significant ($X^2 = 516.48$, df = 3, $p < 0.001$) majority (89.6%) of respondents to have decreased, and the view was dependent on respondents' level of education ($X^2 = 17.06$, df = 9, $p = 0.048$) but independent of livelihood ($X^2 = 16.77$, df = 12, $p = 0.159$). Respondents with university degrees were much more likely than other groups to indicate no change in food production, while those with a maximum of secondary level education were the most likely cohort to indicate that production had increased. A majority (67.1%, $X^2 = 233.75$, df = 3, $p < 0.001$) of respondents also found household food security to have decreased, a view independent of respondents' level of education ($X^2 = 12.83$, df = 9, $p = 0.171$) and livelihood ($X^2 = 11.98$, df = 12, $p = 0.447$).

A significant ($X^2 = 95.01$, df = 3, $p < 0.001$) plurality (46.3%) of respondents viewed the general health status of households to have decreased, this view being independent of respondents' education level ($X^2 = 16.34$, df = 9, $p = 0.060$) and livelihood strategy ($X^2 = 13.44$, df = 12, $p = 0.338$). There was a significant ($X^2 = 224.46$, df = 3, $p < 0.001$) majority (66.2%) which indicated that economic wellbeing had decreased, a view independent of respondents' level of education ($X^2 = 12.70$, df = 9, $p = 0.177$) and livelihood ($X^2 = 8.13$, df = 12, $p = 0.775$).

3.3: Climate Change Coping Strategies and their Effectiveness

A majority (80.3%) of respondents mentioned that they had at least one method of coping with the impacts of climate change or other environmental forces. Of the many coping strategies provided by respondents (Table 2), the most common were storing food (23.9%), setting aside land for grazing only during the dry season (13.8%), and pursuing alternative livelihoods (11.7%).

Table 2. Strategies used to cope with environmental changes and effects of climate change

#	Response (n = 189)	Frequency of mention	Percentage
1.	Store food during wet season for dry season use	45	23.8
2.	Block grazing from pasture during wet season	26	13.8
3.	Pursue other livelihoods	26	13.8
4.	Move livestock during dry season	16	8.5
5.	Reduce number of livestock	16	8.5
6.	Buy food for livestock	15	7.9
7.	Increase amount of farming	13	6.9
8.	Plant trees, grasses, and/or fruits	10	5.3
9.	Dig boreholes/wells	9	4.8
10.	Switch types of crops grown	7	3.7
11.	Assistance/sharing from community	6	3.2
12.	Irrigating crops	5	2.6

Note: some respondents provided more than one strategy; therefore, percentages do not sum to 100%.

A significant ($X^2 = 21.23$, df = 1, $p < 0.001$) majority (66.3%) of respondents said that the coping strategy they used was effective (Table 3a). Table 3b summarizes the reasons given by respondents who indicated that the coping strategy they were using was ineffective.

Table 3a. Reasons given for strategy effectiveness

#	Response (n = 188)	Frequency of mention	Percent
1.	Provides more food	40	21.3
2.	Preserves livestock	39	20.7
3.	More money	16	8.5
4.	More water	10	5.3
5.	Other benefits	13	6.9
6.	No alternative	7	3.7

Table 3b. Reasons given for strategy ineffectiveness

7.	Not enough/lack of resources	24	12.8
8.	Unreliable	22	11.7
9.	Drought still harms them	17	9.0

Respondents also indicated where or how they learned the strategy or strategies they were using to cope with the impacts of climate change (Table 4). The majority (64.0%) said that individual circumstances, experiences, and observations pushed them to adapt using these strategies, sometimes coming up with the strategies themselves. Over one-fifth (21.1%) mentioned community elders, including parents and grandparents, as sources for learning these strategies.

Table 4. Where or how respondents learned about strategies to cope with climate change

#	Response (n = 185)	Frequency of mention	Percent
1.	Circumstances (i.e. drought), personal experience, own idea, self-determination, and/or personal observation	119	64.0
2.	Elders (parents, grandparents), and/or tradition	39	21.1
3.	Community, neighbors, or other people	19	10.3
4.	Government/NGO/company knowledge	8	4.3
5.	School or education	8	4.3
6.	God	8	4.3

Note: some respondents provided more than one source of knowledge; therefore, percentages do not sum to 100%.

3.4: Activity and Livelihood Change

Most (72.6%) participants (X^2 = 48.02, df = 1, p < 0.001, n = 234) responded that their daily activities had changed in response to long-term environmental changes. This response was dependent on respondents' education level (X^2 = 8.637, df = 3, p = 0.035), but independent of their source of livelihood (X^2 = 2.713, df = 4, p = 0.607). Those with a maximum of secondary level education tended to indicate, more often than respondents with different education levels, that they had not changed their daily activities. Of the majority who had changed their activities, 14.3% had increased agricultural activities, 12.0% had seen an increase in their workload (gathering water, firewood, or other materials), and 10.9% had begun farming, often maintaining some livestock but sometimes abandoning pastoralism. 8.0% had begun running a business.

Slightly more (76.8%) participants (X^2 = 67.06, df = 1, p <0.001) responded that climate change had made them change, or consider changing, their livelihood strategy in some way. These responses were independent of both the education level (X^2 = 3.01, df = 3, p = 0.380) and livelihood strategy (X^2 = 7.381, df = 4, p = 0.117) of respondents. A slight majority (50.3%) mentioned that they were considering increasing their commitment to running a business, while 19.6% mentioned that they were considering beginning or increasing agricultural activity.

3.5: Thoughts on Climate Change in the Amboseli Region and Across the Globe

Respondents' thoughts on climate change included a few common themes. Many people (21.4%) remarked that environmental conditions in the area were getting worse. Slightly more (25.2%) included in their response that the communities in this region, including themselves, needed outside help from the Kenyan government, NGOs, or others. Water (22.6%) and trees or grass (10.7%) were commonly stated as materials that were needed by communities, and 8.5% of interviewees suggested that communities needed better education and awareness of climate change and its impacts. Some respondents (13.7%) stated that they had no thoughts on climate change in the Amboseli region.

In regards to global climate change, 11.5% claimed that climate change was only a problem in Kenya, whereas 29.1% felt that it was affecting the entire world and needed to be responded to on that scale. Some respondents (10.7%) felt that only God was able to solve the problems presented by climate change and that people could not do anything other than pray. The most frequent response (42.7%) was

that the respondent did not know about climate change outside of Kenya, or felt they did not know enough to answer the question.

The majority (63.2%) of respondents mentioned that personal observation of changes was at least one way they learned about climate change (Table 5), and 25.9% cited elders or the community as sources of knowledge about climate change. A significant number (42.1%) mentioned media sources, like TVs and radios, as sources of information

Table 5. Where or how respondents learned about climate change

#	Response (n = 228)	Frequency of mention	Percent
1.	Personal observation and/or experience (i.e. droughts, livestock, market prices)	144	63.2
2.	From the news on TV/radio, or from other media (magazines)	96	42.1
3.	Elders (parents, grandparents); community (meetings)	59	25.9
4.	School education	31	13.6
5.	From God	8	3.5

Note: some respondents provided more than source of knowledge; therefore, percentages do not sum to 100%.

3.6: Community Elders' Views on Climate Change and Impacts on the Community

Community elders indicated that the amount of rainfall in the study area had decreased significantly since the 1960s. They noted a decline in the number of trees and other woody plants, as well as a decline in the abundance of highly nutritious grasses. Wildlife, like rhinos and buffalos, that used to inhabit riparian habitats were less common now that water levels in rivers and swamps had reduced. An increase in the number of farmers and the amount of cultivated land was commonly stated as a primary reason for the decreases in precipitation levels and vegetation abundance. The elders also noted that more Maasai households were turning to agriculture or increasing the number of crops they planted. Subdivision and the increasing number of non-Maasai people were also mentioned as reasons for the environmental degradation. Elders indicated that a common result of this degradation was a change in Maasai culture, noting that more people were abandoning pastoralism in favor of growing crops, and that fewer people were friendly with each other and willing to help out other community members.

The elders reported that they had noticed both climate change and human actions making livestock much harder to manage successfully. Subdivision had been observed to have made pasture harder to

access, and reduced rainfall had lowered the amount of grass on pastures. They mentioned two primary methods community members use to protect their livelihoods: communities agreeing to set aside land to be reserved from grazing until the dry season, and storing crop leftovers to feed livestock during the dry season. The elders also mentioned that, because droughts are increasing in severity, these coping strategies were becoming less effective. In general, they expressed concern with increasing agricultural activity, claiming that new pests and diseases were lowering yields, pesticides were damaging nearby grasses, and farms required private land, which they saw as hurting the Maasai way of life.

4.0: Discussion

4.1: Community Views on Climate Change and Variability

Most respondents indicated that they had noticed a change in local climate or weather patterns over the past 10-15 years, and significant majorities noted negative trends in five climate characteristics. There was no consensus, however, on climate change itself in the Amboseli region. Many noted that conditions were worsening, and that people needed water if they were going to live in the region successfully. A quarter mentioned that government or other outside assistance was needed, as individuals themselves could not drill boreholes or wells. There were some people who said they had no thoughts on the issue, which indicates a need for community members to be made more aware of how climate change is responsible for many of the environmental changes they are witnessing. Some community members themselves seemed aware of this, and recommended that the government raise awareness of climate change, its impacts, and potential solutions or adaptations within the community.

Thoughts on global climate change was a very different story, as more than sixty percent indicated that either humans had no control over it or that they did not know about climate change outside of Kenya. More than forty percent offered no thoughts on the topic whatsoever. Although a portion of respondents felt that climate change was broad enough to merit a global response, the responses as a whole indicate a severe lack of information among communities in the study area. Being unaware of the scope of climate change, including its causes and long-term impacts, makes effectively adapting to the changes much harder for individuals and communities (Bobadoye et al., 2016). And without adapting, resource-dependent livelihoods (i.e. pastoralism, agriculture) will remain vulnerable to climate change impacts, like reduced precipitation and longer droughts, and people relying on those livelihoods will suffer economic losses.

Respondents did not learn about climate change from the government. Many had a combination of information sources, but these were predominantly personal observation, instruction from parents or other elders, and education in school. This suggests that most community members are learning about local environmental changes, and perhaps the local impacts of climate change, but were not learning about the forces behind those changes or their global scale. A large number did indicate that they heard about climate change from the media, particularly TV and radio news, but this does not replace the Kenyan government's responsibility to educate people about the specific aspects of climate change which apply to them (GoK, 2018). Relying on TV and radio news also prevents individuals who cannot afford these technologies from being aware of climate change, decreasing the ability of already vulnerable populations to be protect themselves from its impacts (Bobadoye et al., 2016).

4.2: Impacts of Climate Change and Variability on Natural Resources and Local Livelihoods

Livestock production in the study area was found to have suffered a noticeable decline over the past 10-15 years. Respondents indicated that they had noticed more livestock dying each year, largely due to an increase in disease and pest prevalence, as well as a reduction in pasture quality and availability. A warmer average temperature creates a more hospitable environment for zoonotic disease vectors and parasites (Kimaro & Chibinga, 2013), increasing the prevalence of these diseases and pests among livestock and leading to more deaths caused by them. Reduced rainfall lowers the quantity of vegetation that can grow on pasture land each wet season, thus reducing the quantity of forage available to pastoralists (Kimaro & Chibinga, 2013; Taruvinga et al., 2013) and leading to malnourishment or starvation amongst livestock. Study participants also noticed a decrease in household dependence on livestock, indicating that pastoralists were coping with the impacts of climate change in one way by diversifying their livelihoods away from raising livestock. Community elders responded with skepticism about the future of pastoralism in the region. They saw the increase in amount of cultivated land, especially as it generally came along with private land ownership, as directly inhibiting the success of raising livestock. They noted that pasture was harder to access because of the higher number of farms, and that once people owned land themselves, they were no longer willing to help their neighbors and allow pastoralists to graze on their land. Without this access to as much pasture as in previous years, pastoralists were forced to reduce herd sizes; and without community support during droughts, when large numbers of livestock often die from dehydration and starvation, pastoralists were less able to recover their herd population sizes.

Apart from pasture availability, community elders remarked that the grasses which now covered much of the surrounding land were not as nutritious as the grasses they had grown up with. Trees and other woody plants were also much less frequent now than they had been a few decades ago. These plants used to provide a plentiful source of fuel for households, and their fruits were often used as medicine or dry season food for livestock and people. Higher temperatures and decreased rainfall brought by climate change have changed species compositions of pastureland (Taruvinga et al., 2013) in ways harmful to pastoralists, and have decreased the abundance of woody vegetation. Increasing human consumption of trees and shrubs for fuel has also greatly reduced the abundance of these resources.

Many respondents were increasing their agricultural activities. This increase in activity, however, has combined with decreased precipitation due to climate change to decrease the amount of water available for crop irrigation (Huho et al., 2010). Community elders and household interviewees reported that crop yields and food production were decreasing substantially, due in part to less available water but also to a significant increase in pest and disease prevalence among crops. Pesticides were heavily used, but farmers often claimed that they were ineffective. Community elders felt that these pesticides, aside from just being ineffective for protecting crops, were killing grass seeds around farms, and thus exacerbating the issues of pasture degradation. With decreasing crop yields comes a reduction in the amount of food available to farming households and the community in general. This reduces food security among households, increasing the risk of malnutrition and disease, increasing time spent trying to obtain food, and reducing economic welfare as household members are less able to perform economically gainful activity.

Water availability for household use was reported to have decreased, and although there was not a significantly agreed upon change in water quality, this reduction in quantity may be contributing to the observed decrease in household health status (Howard & Bartram, 2003). A decrease in economic wellbeing was also observed by participants, which can be attributed to environmental changes suppressing the economic returns from raising livestock or growing crops. Such wide-spread reductions in individual household economic wellbeing indicate an increase in the level of poverty across the community. This indirectly affects everyone in the community, as impoverished households input less into the community, reducing the overall availability of goods and services to other community members.

4.3: Effectiveness and Sustainability of Community Coping Strategies

Climate change was noted to have reduced the number of livestock the land could support as well as placed increased pressure on farming activities. Community members primarily tried to cope with these impacts of climate change by saving resources produced during the wet season for use during the dry season. This included two strategies mentioned by community elders as well: communally setting aside pasture land as reserve for dry season grazing only, and saving food or crop leftovers (like maize stalks) to feed people and livestock when the rains receded. Most household interviewees felt that these strategies were effective, but community elders indicated that the effectiveness was decreasing as droughts became more frequent and longer and wet seasons became shorter. These strategies have been traditional methods for dealing with bimodal rains in a semi-arid landscape, but they are being stretched to their limits by the effects of climate change. As climate change decreases the amount of rainfall during wet seasons, both pasture and farm production decrease as a result of diminished water available to crow grass or crops. Coupled with longer dry seasons and droughts, the lower amounts of resources produced during wet seasons are more frequently not lasting throughout dry spells. Livestock consume all the grass on reserved land, and people and livestock consume the saved food and crop leftovers, before the rains come and production resumes. This tendency, increasing in frequency across the community, shows that these coping strategies are not sustainable as climate change continues to shrink wet seasons and extend dry periods.

Individuals in the study area are adapting to the longer-term impacts of climate change by diversifying, or completely changing, their livelihood strategy. Many household respondents had either begun farming or increased the intensity of their farming efforts in order to make up for decreasing returns on livestock. Even more stated that they were considering a push towards more agriculture in the near future because of climate change. Respondents who only had small agricultural operations (who often raised livestock as well) felt that this change would help them get food without suffering from diminishing pasture access. But respondents with larger farms cited pests and diseases, as well as overuse of irrigation water by other farmers, as reasons that their farms were becoming less productive each year. While trading the production of livestock for crops may help small farmers initially, the impacts of climate change (diminishing water resources and increasing disease and pest prevalence) make large increases in agriculture unsustainable in the study area over the long term.

While few people had actually started running a business, more than half of respondents mentioned that they were considering it, as it offered a source of income that they felt was not as dependent on the environment and natural resources. Although large increases in agricultural activity is

unsustainable, such a large number of people considering business could increase the risk of a collapse in food production in the area if enough people stop agricultural activity. But many people still saw it as the only way they could earn a livelihood during a time when depending on natural resources means depending on a rapidly diminishing supply.

And if the trend towards increased agricultural activity continues or accelerates, the physical environment of the Amboseli region faces multiple risks. Agriculture demands much more water in a permanent place than livestock do (Kioko & Okello, 2010), especially during the dry season when livestock can be moved to other areas where water and grass is more abundant but farms require a continuous supply of water in one place. The rivers and swamps in the Amboseli region, already stressed by higher temperatures, increased evaporation rates, and reduced recharge from rains, will continue to be drained by agriculturalists trying grow food in this landscape (Kioko & Okello, 2010). More permanent farming settlements will transition more forested landscapes to farmland, and demand more woody vegetation to use as fuel, exacerbating the trend of forest loss in the region (Mango et al, 2011). And while community elders are aware of these impacts, most household interviewees were either unaware of how they may contribute to further environmental degradation, or were more focused on ensuring that they had enough food and money to survive between the rains.

5.0: Conclusions

This study aimed to understand how climate change and variability is impacting communities in the Amboseli region of Kenya, and how communities are responding. Results showed that there has been a change and variability in the climate of the Amboseli region. Community members were generally aware of these local environmental changes, but were not very aware of the entire global scope of climate change or its implications in their lives. The impacts of climate change were severe, including increasing livestock mortality, decreasing farm yields, decreasing water availability, and a decline in household economic welfare. These resulted from climate change as the reduced rainfall and increasing temperatures manifested through decreasing supplies of natural resources like water, pasture, and woody vegetation. Impacts were also exacerbated by human actions such as increased utilization of forest and river resources and land subdivision.

Communities coped with environmental challenges in two primary ways: communally setting aside pasture land for grazing exclusively during the dry season, and individually saving food or leftover plant material to feed people and livestock during the dry season. Both strategies were seen to be decreasing in

their effectiveness, due to diminishing quantities of the resources being saved for later use over longer periods. Many households were coping with environmental challenges by diversifying or switching primary livelihood strategies. More people were practicing agriculture and fewer practice pastoralism, and many are considering beginning businesses if climate change continues to negatively impact their attempts to earn a living using and depending on natural resources.

6.0: Recommendations

The findings of this study suggest that support from the Kenyan government is required to ensure that communities in the Amboseli region can adequately adapt to a changing climate. Most directly, individuals stressed a great need for boreholes and other technologies to make water available to households and farms. This is a solution which the government can facilitate, but it ought to be accompanied by an in-depth study on the hydrology of the local area. This will provide essential information on how much water can sustainably be pumped for community use without draining groundwater supplies. Implementation of technologies that reduce water use, such as drip-irrigation, should be heavily considered as ways to mitigate community groundwater withdrawal, but with the understanding that most community members cannot fund these projects without support.

The raising of livestock are less damaging to ASAL environments than agriculture, and efforts should be made to raise awareness in the study area of pastoralism's advantages, although financial support may be required to offset the difficulties of raising livestock in this region. The government or other organizations may be able to facilitate community meetings in order to re-establish communal use of land and other resources. This would be in an effort to mitigate the negative impacts seen by community members to be a result of land subdivision.

This study also strongly recommends the implementation of climate change awareness initiatives targeting communities similar to those in the study area. There is a significant lack of knowledge about the full scope of climate change, including its causes and impacts, both direct and indirect. Nationwide, and global, climate change adaptation will require people and communities living in ASAL regions to cope with hardship and adapt their livelihoods. For this to succeed, the people and communities who will be forced to adapt in order to survive must be urgently made aware of why, and how best to prepare themselves.

Acknowledgements – The author of this paper would like to thank: supervisor Dr. John Kiringe; fellow researchers Cameron Bonnell, Emma Brentjens, and Mia Craven; and interpreters Francis, James, and Nelson

References

Aduma, M. M., Said, M. Y., Ouma, G., Wayumba, G., & Njino, L. W. (2018). Projection of Future Changes in Elephant Population in Amboseli under Representative Concentration Pathways. *American Journal of Climate Change*, *07*(04), 649–679. https://doi.org/10.4236/ajcc.2018.74040

Amwata, D. A. (2013). *The influence of climate variability and change on land-use and livelihoods in Kenya's southern rangelands* (PhD Thesis).

Australian Academy of Science. (2015). *The science of climate change: Questions and answers.* 5.

Bharwani, S. (2011, March 25). Overview of Climate Change in Kenya. Retrieved from https://www.weadapt.org/knowledge-base/national-adaptation-planning/kenya.

Bobadoye, A., Onono, J. O., & Ouma, G. (2016). Assessing climate change adaptation strategies among rural Maasai pastoralist in Kenya. *American Journal of Rural Development*, *4*(6), 120-128.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of Environmental Management*, *114*, 26–35. doi: 10.1016/j.jenvman.2012.10.036

Cloudsley-Thompson, J. L. (1978). Rangeland Management and Ecology in East Africa, *Environmental Conservation*. *5*(4), 316–316. https://doi.org/10.1017/S037689290000655X

Cullen, N. J., Mölg, T., Kaser, G., Hussein, K., Steffen, K., & Hardy, D. R. (2006). Kilimanjaro Glaciers: Recent areal extent from satellite data and new interpretation of observed 20th century retreat rates. *Geophysical Research Letters*, *33*(16), 1–6.

Dooley, E., & Chapman, S. (2014). Climate-smart agriculture and REDD+ implementation in Kenya. *Environmental Management*, *4*, 23.

Government of Kenya (GoK). (2010). *National climate change response strategy*. Nairobi. 1-120.

Government of Kenya (GoK). (2016). *Kenya National Adaptation Plan: 2015-2030*. 1–53.

Government of Kenya (GoK). (2018). *National Climate Change Action Plan (Kenya) 2018-2022.* Ministry of Environment and Forestry, Nairobi, Kenya. 2–131.

Howard, G., & Bartram, J. (2003). Domestic Water Quantity, Service Level and Health. *World Health Organization*. 1-33.

Huho, J. M., Ngaira, J. K. W., & Ogindo, H. O. (2010). Drought severity and their effects on rural livelihoods in Laikipia district, Kenya. *Journal of Geography and Regional Planning, 3*(3): 35-43.

Huho, J. M., Ngaira, J. K. W., & Ogindo, H. O. (2011). Living with drought: the case of the Maasai pastoralists of northern Kenya. *Educational Research, 2*(1): 779-789.

Intergovernmental Panel on Climate Change (IPCC). (1995). *Radiative Forcing of Climate Change*. 353. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-06.pdf

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate Change 2007: The Physical Science Basis*. 5–17, 53, 115-116, 747–847. Retrieved from https://www.ipcc.ch/report/ar4/wg1/

Kajiado County Government (2014). About Kajiado [Population]. Kajiado county, Kenya: Kajiado Government.

Kimaro, E. G., & Chibinga, O., C. (2013). Potential impact of climate change on livestock production and health in East Africa. *Livestock Research for Rural Development, 25*(7), 1–14.

Kioko, J. M., & Okello, M. M. (2010). Land use cover and environmental changes in a semi- arid rangeland, Southern Kenya. *Journal of Geography and Regional Planning*, *3*(11), 322-325.

Kiringe, J., Okello, M., Tome, S., & Seno, S. (2009). The Water Situation Analysis in Kimana Area: Causes and Consequences of Water Quality, Quantity and Distribution Dynamics (p. 151) [Final water situation analysis]. Kimana, Kenya: The School For Field Studies.

Kovats, R. S., Campbell-Lendrum, D., & Matthies, F. (2005). Climate Change and Human Health: Estimating Avoidable Deaths and Disease: Climate Change and Human Health. *Risk Analysis*, *25*(6), 1409–1418. https://doi.org/10.1111/j.1539-6924.2005.00688.x

Mango, L. M., Melesse, A. M., McClain, M. E., Gann, D., & Setegn, S. G. (2011). Land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya: Results of a modeling study to support better resource management. *Hydrology and Earth System Sciences*, *15*(7), 2245–2258.

McKenzie, R. L., Aucamp, P. J., Bais, A. F., Björn, L. O., Ilyas, M., & Madronich, S. (2011). Ozone depletion and climate change: Impacts on UV radiation. *Photochemical & Photobiological Sciences*, *10*(2), 182–198.

Misra, A. K. (2014). Climate change and challenges of food and water security. *International Journal of Sustainable Built Environment, 3*, 153-165.

Musoi, K., Muthama, T., Kibor, J., & Kitiku, J. (2014). A study of crime in urban slums in Kenya: the case of Kibra, Bondeni, Manyatta and Mishomoroni slums. Nairobi, Kenya: Security Research and Information Centre (SRIC).

Naqvi, S. M. K., & Sejian, V. (2011). Global climate change: Role of livestock. *Asian Journal of Agricultural Sciences*, *3*(1), 19–25.

Nicholson, S. (2000). Land surface processes and Sahel climate. *Reviews of Geophysics*, *38*(1), 119–122.

Ntiati, P. 2002. Group ranches subdivision study in Loitokitok division of Kajiado District, Kenya. LUCID Working Paper, no. 7. Nairobi (Kenya): ILRI

Okello, M. M., & D'Amour, D. E. (2008). Agricultural expansion within Kimana electric fences and implications for natural resource conservation around Amboseli National Park, Kenya. *Journal of Arid Environments*, *72*(12), 2179–2192. https://doi.org/10.1016/j.jaridenv.2008.07.008

Ongoro, E. B., & Ogara, W. (2012). Impact of climate change and gender roles in community adaptation: a case study of pastoralists in Samburu East District, Kenya. *International Journal of Biodiversity and Conservation*, *4*(2), 78–89.

Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., & Munang, R. (2015). Drought adaptation and coping strategies among the Turkana pastoralists of Northern Kenya. *International Journal of Disaster Risk Science*, *6*(3), 295–309. doi: 10.1007/s13753-015-0063-4

Patterson, B. D., Kasiki, S. M., Selempo, E., & Kays, R. W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. *Biological Conservation*, 507-516.

Ravishankara, A. R., Daniel, J. S., & Portmann, R. W. (2009). *Nitrous Oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century*, *326*, 123–125.

Reay, D. S., Davidson, E. A., Smith, K. A., Smith, P., Melillo, J. M., Dentener, F., & Crutzen, P. J. (2012). Global agriculture and nitrous oxide emissions. *Nature Climate Change*, *2*(6), 1.

Taruvinga A., Muchenje, V., & Mushunje, A. (2013). Climate change impacts and adaptations on small-scale livestock production. *International Journal of Development and Sustainability, 2*(2), 664–685.

Taylor, C. M., Lambin, E. F., Stephenne, N., Harding, R. J., & Essery, R. L. H. (2002). The influence of land use change on Climate in the Sahel. *Journal of Climate*, *15*, 3615–3629.

Thompson, L. G., Brecher, H. H., Mosley-Thompson, E., Hardy, D. R., & Mark, B. G. (2009). Glacier loss on Kilimanjaro continues unabated. *Proceedings of the National Academy of Sciences*, *106*(47), 1–6.

United Nations (UN). (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, 1–20.

United Nations (UN). (2009). *Copenhagen Accord*, 3–43.

United Nations (UN). (2015). *Paris Agreement*, 1–25.