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Climate Change and Sedentarization among Pastoralists in Morogoro and Tanga Regions of Tanzania: Impacts on Health and Nutrition

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Global Health

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B.A.

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2016

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An abstract of

A thesis submitted to the Faculty of

the Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Public Health in Global Health

2019

Abstract

Climate Change and Sedentarization among Pastoralists in Morogoro and Tanga Regions of Tanzania: Impacts on Health and Nutrition

By Carrie Ripkey

Pastoralists are undergoing rapid shifts in livelihood strategies, from predominantly highly-mobile pastoralism to an increase in agro-pastoralism in which both livestock raising and cultivation of crops are practiced. This shift away from mobile to more sedentary livelihoods is a process referred to as sedentarization. Previous research indicates that both sedentarization and climate change are prominent forces shaping livelihood approaches in East Africa, but the effects of these co-occurring processes have yet to be investigated.

This paper develops theory, grounded in qualitative data, explaining the relationships between climate change, pastoral sedentarization, livelihood outcomes, and resulting nutritional status. Data examined in the development of this theory was collected through focus groups and key informant interviews among pastoralists in Morogoro and Tanga Regions of Tanzania, using a grounded theory approach.

Results indicate that the co-occurring processes of climate change and sedentarization among Tanzanian pastoralists in these regions have dramatic impacts on communities' economic prosperity, health status, and nutritional outcomes. Due to the risks posed by climate change and sedentarization pressures, land tenure policies that allow them to continue to practice highly mobile livelihood strategies, namely, legal recognition of collective land rights, need to be adopted. Legal recognition of collective rights will help abate further reduction of natural capital and the cascading effects that come with such losses.

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Acknowledgements

The phrase, “takes a village” is perhaps the best way I can sum up the process of working on this thesis, and I am grateful for every member of the “village” that has supported me throughout this past year. First and foremost I would like to thank my thesis advisor, Dr. Aimee Webb-Girard. Throughout the thesis process you have demonstrated not only what excellence looks like in the practice of public health research, but also what it means to be a kind and decent human being. Working with you has forever changed the way I approach the practice of public health, and for that I am eternally grateful. I would also like to thank other Emory GRAs on the DRIVERS study team, Caroline Owens, Janelle Kibler, Courtney Bursuc, and Sydney Herndon, who have provided invaluable wisdom. To my friends and family both near and far, thank you for your accountability and support. Your words of encouragement have helped me push through difficult times. Lastly, to Justin Willingham who has supplied countless amounts of goldfish, sour patch kids, and unconditional support, without which I would not have been able to complete this thesis.

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Chapter 1: Introduction

Context of the Project

Pastoralists, a society organized around livestock raising as the primary economic activity, account for between 300 and 600 million people globally, with an estimated 20 million pastoralists located in sub-Saharan Africa (World Bank, 2014). However, in Sub-Saharan Africa the livelihoods of this group are rapidly shifting, from predominant pastoralism to an increase in agro-pastoralism in which populations participate in both livestock raising and cultivation of crops. This shift away from mobile livelihoods towards much more sedentary livelihoods is a process referred to as sedentarization. The sustainable livelihoods framework was developed by British Department for International Development (DFID) and proves useful for understanding the drivers of this change and the resulting impacts on food security. It does so by looking at the ideas of vulnerability context, livelihood assets, transforming structures and processes, livelihood strategies, and livelihood outcomes (Advanced Training Program on Humanitarian Action [ATHA], 2014). Most important to the analyses presented here are the livelihood assets, comprised of human, natural, financial, physician, and social capital (ATHA, 2014).

Climate change, as defined by the Intergovernmental Panel on Climate Change (IPCC), is a statistically significant change in the mean or variability of the state of the climate that remains for a significant period of time (United Nations Framework Convention on Climate Change [UNFCCC], 2011). Climate change disproportionately impacts developing countries, such as the United Republic of Tanzania, the context in which this research was conducted (Halim et al., 2018; O'Brien & Leichenko, 2000; United Nations [UN], 2015). Pastoralist in Tanzania are uniquely vulnerable to the impacts of climate change due to their dependence on climate, grazing land, and

water sources. Thus, it is not surprising that past research has indicated that some of the salient factors causing the shift in livelihood strategies are extreme climate events, as pastoralists are intimately dependent on the land and its productivity for their livelihood. In Sub-Saharan Africa, climate changes most notably manifest themselves as increased droughts and decreased predictability of rains (Connolly-Boutin & Smit, 2015). These two factors lead to reduction in grazing lands and water sources, which in turn diminish livestock health and increase the time and distance needed to secure adequate water and fodder for animals. Collectively, these changes negatively impact the financial viability of livestock herding as a primary livelihood strategy.

Aside from climate pressures, social, economic and political pressures contribute to shifts in livelihoods among Tanzanian pastoralists, including land-use policies that increasingly restrict grazing lands (Beal et al., 2015). While all these factors have been identified as salient drivers for shift in livelihoods among Tanzanian pastoralists, the exact nature of their relationship and their resulting impact on food security, diet choices, and resulting health outcomes remain unknown.

Problem Statement

It has been widely acknowledged that climate change does not affect the world's population equally, with studies repeatedly showing that the health consequences of climate change disproportionately affect developing countries like Tanzania (IPCC, 2007; O'Brien & Leichenko, 2000). These disproportional effects have a drastic impact on the context in which pastoralists carry out their livelihoods, but the pathways through which they do so is not fully understood. In light of this gap in understanding, this thesis seeks to address the following research question: *What role does climate change, specifically the increase in extreme weather patterns, play in the process of*

sedentarization among Tanzania pastoralists and how does this impact livelihood outcomes in food choice and nutrition?

Specific Aims

In order to answer this research question there are two primary aims:

1. To understand how climate change and sedentarization impact livelihood strategies and coping mechanisms in study communities
2. To understand how these changes in livelihood strategies and coping mechanisms result in changes to dietary choice and nutritional outcomes

Purpose

The purpose of this paper is to develop theory, grounded in qualitative data, which explains the relationships between climate change, pastoral sedentarization, livelihood outcomes, and resulting nutritional status. It will begin by exploring the current research on climate change, pastoral sedentarization, and health and livelihood outcomes in the Tanzanian context, and will then utilize qualitative data in the form of focus groups and key informant interviews to develop a novel theory. A more robust understanding of these relationships will provide valuable insights towards developing effective programs to support pastoralists undergoing the process of sedentarization to achieve sustainable livelihood outcomes that can withstand the impacts of climate change.

Chapter 2: Comprehensive Review of the Literature

Pastoralism

Pastoralists, people for whom "at least half of their household gross revenue comes from livestock of livestock related activities", have long played an essential role in their respective national economies (Galvin, Thornton, Boone, & Sunderland, 2004; Swift & Toulmin, 1992). While individual practice of pastoralism as a livelihood strategy varies greatly depending on context, there are some characteristics that typically mark its practice. These include: mobility, seasonal migration, herd splitting, large herds, herd structure dominated by female cattle and diversity of resilient animal species (Food and Agricultural Organization [FAO], 2001).

One way to categorize different practices of pastoralism is through level of mobility. Highly mobile nomads are most likely to be exclusive pastoralists, wholly dependent on animal products for their livelihoods. They make their movements entirely based on the availability of grazing lands and do not typically have established homesteads (FAO, 2001). Pastoralists who engage in transhumance are often marked by a permanent base where females, young children, and older members of the family remain throughout the year along with a group of lactating female livestock. In this approach, males, along with the majority of the herd, make regular, seasonal movements along established migration routes in search of seasonal pastures (FAO, 2001).

The practices of nomadic pastoralism and transhumance have long been the predominant livelihood systems of East Africa, but increasing pressures from climate, population expansion, and land-use policies have helped catalyze the process of sedentarization, which is the adaptation of less mobile livelihoods (FAO, 2001). One such example of a less mobile livelihood strategy is the practice of agro-pastoralism. In this livelihood approach, a smaller percentage of household

gross revenue, 25-50%, comes from livestock. With this approach, herds are usually smaller, and their rearing is combined with cultivation of land (FAO, 2001).

Sedentarization Pressures

Increased pressures are being placed upon pastoralists to make changes to their livelihoods. Pastoralism has long been looked down upon both by colonizing governments and in the transition to independent nations, national governments as well. These negative perceptions are based on the beliefs that pastoralism makes inefficient use of land and that their mobile lifestyles make the provision of "modern" services, such as health care and education, difficult (Davies & Hagelberg, n.d.).

Political Pressures

Within the context of this changing environment, we see continued political and social pressure for pastoralists to partake in increasingly sedentary livelihoods practices, transitioning from the practice of transhumance to agro-pastoralism. Land use patterns in Tanzania have created increased pressure on pastoralists to shift to sedentary livelihood approaches. Several policies are in place that shape land tenure and resulting land use in Tanzania. Two of the most notable are the 1995 Land Policy and 1999 Land Act and Village Land Act. These acts designate three types of land, reserved land, village land, and general lands. Much of the land that is used for pasture is considered part of the general land category and is under the control of the government. Thus, patterns of land use in Tanzania are not entirely market driven but rather, the President of Tanzania has the power to determine how this natural resource is allocated and utilized (Beal et al., 2015). The Tanzanian government is receiving increased requests from multi-national corporations to gain access to historic rangelands for their own cultivation and livestock raising

in “land grabs”(Strauss, Manji, & Donovan, 2015). Thus, Tanzania’s approximately 1.5 million pastoralists who are responsible for nearly all of the country’s 21 million cattle are feeling disenfranchised and unable to practice the mobility that has historically led to their success (Beal et al., 2015; International Work Group For Indigenous Affairs, 2016; Maliasili Initiatives, 2012).

Environmental Pressures

In addition to these social and political pressures, pastoralists face unique environmental pressures due to climate change. Climate change, as defined by the IPCC, is a statistically significant change in the mean or variability of the state of the climate that remains for a significant period (UNFCCC, 2011). These changes arise as a result of both natural variability in the climate and human activity. Although, scientists are increasingly certain that the warming of climate systems is indeed attributable to human activity (UNFCCC, 2011).

Models of climate change often look at large-scale, global changes in climate and their resulting impacts. However, the felt impacts of climate change are highly context specific (Herrero et al., 2016; Thornton, Steeg, Notenbaert, & Herrero, 2009). In some higher-latitude regions the increasing temperatures will remove restraints on growing seasons, resulting in increased rangeland productivity. While in, semi-arid, lower-latitude regions these temperature changes are predicted to have overall negative impacts on rangeland productivity and resulting livestock productivity (Herrero et al., 2016).

Climate changes in Sub-Saharan Africa are largely comprised of the following: increases in temperature, changes in rainfall intensity, increased incidence in extreme weather events, increased desertification, and alterations in disease vectors (Connolly-Boutin & Smit, 2015).

The impacts of a changing climate cannot be ignored, especially among the 80% of Tanzania's who are intimately dependent upon the land for their livelihoods (World Bank Group, n.d). These changes will also have a large impact on the national economy as forty four percent of Tanzania's land is utilized for agriculture, which in turn contributes twenty-four percent of the Gross Domestic Product (GDP) (United States Agency for International Development [USAID], 2016).

For those who practice strict pastoralism and are entirely dependent on livestock for their livelihoods, adequate rainfall is essential to ensure sufficient forage growth in rangelands. For agro-pastoralists who depend on agriculture to completement livestock-oriented livelihoods, sufficient and timely rainfall is essential for crop growth, as nearly 70% of Africans depend on rain-fed agriculture (Challinor, Wheeler, Garforth, Craufurd & Kassam, 2007). However, average annual precipitation for Tanzania has decreased significantly, by 3.3% per month per decade (McSweeney, New & Lizcano, 2010a; McSweeney, New, Lizcano & Lu, 2010b). Additionally, Tanzania is doubly impacted by changing rainfall patterns, as large portions of the country depend on a historically bi-modal rainfall pattern, with a short, "Vuli" rainy season in November- December, and a longer rainy season, "Masika" in February-March. These rainfall patterns have become increasingly variable, meaning farmers can no longer depend on two growing seasons, ultimately leading to reduced crop yields. Average annual temperatures are also increasing under climate change. The period from 1960-2006 saw a 1°C increased in annual mean temperatures and these increases are expected to accelerate (World Bank Group, n.d.). For example, mean annual temperature is expected to increase by 2.7 degrees Celsius by 2060 and by 4.5 degrees Celsius by 2090 (McSweeney et al., 2010a; McSweeney et al., 2010b). This

combination of more frequent drought along with increased temperature has dangerous impacts on the economy and food security of Tanzania as a whole.

Impacts of Sedentarization on Nutrition and Health

Food Security

Changes in livestock and agricultural production as a result of climate change is likely to significantly undermine food security. As defined by the Food and Agricultural Organization (FAO), food security occurs when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). Food security is impacted by underlying "pillars" of food availability, food access, and food utilization (Connolly-Boutin & Smit, 2015).

Food availability is determined by the physical presence of food items in sufficient quantities. Food access addresses the economic and physical ability to get sufficient quantity and quality of food. Food utilization examines a household's or individual's ability to actually consume and process the food that is available to them. Utilization is impacted by social and cultural factors such as food preparation techniques and gendered differences in food intake, along with biological factors such as the ability of one's gut to process the nutrients provided by food (Pietzsch, Talley, & Navarro-Colorado, 2018). The complex interaction between these elements, both over time and in response to sudden shocks, contribute to food security or lack thereof (Connolly-Boutin & Smit, 2015). Understanding the impacts of climate on and ultimately sedentarization upon these areas of food security will help to better model the effects of climate changes and livelihoods shifts on nutrition and health outcomes.

Health and Nutritional Outcomes

Food security is crucial for positive nutritional outcomes among any population and the pastoralists of Tanzania are no exception. Studies undertaken among pastoralists and agro-pastoralists in sub-Saharan Africa have shown statistically different nutritional outcomes between pastoralists and agro-pastoralists, with pastoralists exhibiting significantly more dietary diversity than their more sedentary counterparts. These differences remained statistically significant across growing seasons (Mayanja, Rubaire-Akiiki, Morton, Young, & Greiner, 2015). One of the largest differences in consumption patterns between agro-pastoral and pastoral households, was the reduced intake of milk and milk products among agro-pastoralists, with 50-70% of households not consuming these products (Mayanja et al., 2015). However, reduced access to milk products may not be entirely harmful, as work done in Northern Tanzania with the Datoga indicate the abundance of cattle among nomadic pastoralists and the subsequent access this provides to non-human milks may be a driver of early supplementation, a deviation from international breast feeding recommendations (Sellen, 1998).

Politicians and NGOs have made the case for sedentarization of pastoralists with the promise of increased access to “modern” services” including medical and veterinary services along with schooling. It has long been theorized that more sedentary lifestyles and livelihoods approaches would result in better health and nutritional outcomes through increased access to increased livelihood assets, most notably increased financial, human, and physical capital. There have been some positive health outcomes as a result of sedentarization, such as decreased rates of tuberculosis, brucellosis, syphilis, trachoma, and child mortality(Roth, Nathan, & Fratkin, 2004). However, studies have also shown that the health impacts of sedentarization are not entirely positive, especially for women and children. Research demonstrates markedly different nutrition

patterns among sedentary and pastoral communities. Pastoral communities consistently have lower rates wasting and stunting, evidence of acute and chronic undernutrition respectively (Roth, Nathan, & Fratkin, 2004). Reduced nutritional outcomes among sedentary groups are largely associated with reduced milk intake, as pastoral children consumed almost three times as much milk compared to sedentary children (Roth et al., 2004). This reduced milk consumption among sedentary groups is thought to come as a result of increased separation of women and children from herds (Roth et al., 2004). The actual drivers of this reduced milk intake remain largely unstudied and provides a rich and pertinent study opportunity, which this study will seek to explore in part.

Impacts of Climate Change on Nutrition and Health

Food Security

It is anticipated that global food demand will continue to rise, but the increasing constraints placed on the environment due to climate change will make meeting this demand increasingly challenging (Myers et al., 2017). Previous research has explored the impacts of climate change on food security but has focused on large scale issues of access and availability rather than a more nuanced understanding of nutritional outcomes. Other authors have commented on lack of exploration of this crucial nexus. In their review, Schmidhuber and Tubiello note that previous assessments of global food insecurity tend to focus on issues of access and availability without considering their interactions with nutritional outcomes (Schmidhuber & Tubiello, 2007).

Health and Nutritional Outcomes

There are many potential pathways through which climatic changes are anticipated to have impacts on health and nutritional outcomes (Myers et al., 2017). Previous work on global

maternal and child nutrition provides a framework for understanding the basic, underlying, and immediate causes of maternal and child undernutrition, with immediate causes identified as disease and inadequate dietary intake (Black, et al., 2008). The combination of increased rainfall volume and unpredictability, extreme weather events, and temperatures are anticipated to lead to increased human exposure to enteric pathogens, resulting in increased incidence of diarrheal and enteric diseases (Myers et al., 2017). Increased enteric and diarrheal disease incidence is expected to impact the ability of individuals to properly biologically process and utilize the nutrients contained in the food they consume, thus contributing to undernutrition (Black, et al., 2008). Further, climatic changes are expected to pose new challenges in food production and distribution, leading to increased difficulties in achieving adequate dietary intake (Black et al., 2008; Myers et al., 2017).

Adaptations

Adaptations are "adjustments in social or economic systems made in response to actual or expected climate effects" (Galvin et al., 2004). Historically pastoralists have been well equipped to adapt to changing climates, employing many different strategies to maintain the feasibility of their livelihood. These strategies include: diversification of livelihoods approaches including cultivation and off-farm labor and livestock diversification (Herrero, et.al, 2016). However, continued climate changes and variability, along with increased political, social, and economic constraints have presented challenges to adaptation. As access to historic rangelands decrease due to increased land fragmentation, the traditional adaptation strategy of mobility becomes less viable and pastoralists are forced to rely upon strategies which require greater levels of input for success (Herrero et al., 2016). Further, climate changes and their resulting impacts require additional strategies for adaptation and mitigation that have not previously been utilized by this

population. For example, a 2°C temperature increase, which at this point is likely unavoidable, will result in a reduction of plant growth in dry climates with a corresponding reduction of grazing land. Rising temperatures will require changes to livestock breeding to produce increasingly heat tolerant animals and alterations to the traditional herd management techniques to ensure sufficient fodder. (Ash, Thornton, Stokes, & Togtohyn, 2012)

Previous studies have shown that the ecosystem in which Tanzanian pastoralists operate is biophysically resilient. However, the short-term impacts on human food security and resulting nutritional outcomes which have been previously outlined are far more negative and pronounced (Galvin et al., 2004). Thus, moving forward we should remain concerned about the impacts of a changing climate and sedentarization on the nutritional outcomes of pastoralists even if these changes do not pose as large of a long-term threat on the environment as originally theorized.

Remaining Gaps

While it is understood that both climate change and sedentarization of Tanzanian pastoralists impact health outcomes, their synergistic impact on nutritional outcomes remains largely unexplored (Wheeler & von Braun, 2013). We anticipate that both these processes will have impacts on the basic, underlying and immediate causes that lead to maternal and child undernutrition, but the nature of these impacts, along with their resulting consequences has yet to be examined in the context of Tanzanian pastoralists (Black et al., 2008; Myers et al., 2017).

To address these gaps, this study uses qualitative research to explore how climate change and sedentarization are being experienced by pastoral communities in Tanzania and the impacts these two phenomena have on livelihood decisions and ultimately food access. This research will further explore how these changes in food access affect diet choice and the potential implications

of these choices on nutrition. Qualitative data is particularly suited for this objective as it provides the insider's perspectives of Tanzanian pastoralists on these issues. Such a perspective is essential when looking to the future to design programs to mitigate the health impacts upon this population, as insight into their perspective and values will help to design interventions with specific behavioral drivers in mind (Wheeler & von Braun, 2013).

Chapter 3: Manuscript

Abstract:

Pastoralists are undergoing rapid shifts in livelihood strategies, from predominantly highly-mobile pastoralism to an increase in agro-pastoralism in which both livestock raising and cultivation of crops are practiced. This shift away from mobile to more sedentary livelihoods is a process referred to as sedentarization. Previous research indicates that both sedentarization and climate change are prominent forces shaping livelihood approaches in East Africa, but the effects of these co-occurring processes have yet to be investigated.

This paper develops theory, grounded in qualitative data, explaining the relationships between climate change, pastoral sedentarization, livelihood outcomes, and resulting nutritional status. Data examined in the development of this theory were collected through focus groups and key informant interviews among pastoralists in Morogoro and Tanga Regions of Tanzania, using a grounded theory approach.

Results indicate that the co-occurring processes of climate change and sedentarization among Tanzanian pastoralists in these regions have dramatic impacts on communities' economic prosperity, health status, and nutritional outcomes. Due to the risks posed by climate change and sedentarization pressures, land tenure policies that allow them to continue to practice highly mobile livelihood strategies, namely, legal recognition of collective land rights, need to be adopted. Legal recognition of collective rights will help abate further reduction of natural capital and the cascading effects that come with such losses.

Introduction:

Pastoralists, people for whom "at least half of their household gross revenue comes from livestock of livestock related activities", have long played an essential role in their respective national economies (Galvin, Thornton, Boone, & Sunderland, 2004; Swift & Toulmin, 1992). While individual practice of pastoralism as a livelihood strategy varies greatly depending on context, there are some characteristics that typically mark its practice. These include: mobility, seasonal migration, herd splitting, large herds, herd structure dominated by female cattle and diversity of resilient animal species (Food and Agricultural Organization [FAO], 2001). The practices of nomadic pastoralism and transhumance have long been the predominant livelihood systems of East Africa. However, increasing pressures from climate, population expansion, and land-use policies have helped catalyze the process of adaptation of less mobile livelihoods, known as sedentarization (FAO, 2001).

Sedentarization Pressures

In the Tanzanian context in which this study takes place, land use patterns have created increased pressure on pastoralists to shift to sedentary livelihood approaches, as the Tanzanian government is receiving increased requests from multi-national corporations to gain access to historic rangelands for their own cultivation and livestock raising in "land grabs"(Strauss, Manji, & Donovan, 2015). Thus, Tanzania's approximately 1.5 million pastoralists, who are responsible for nearly all of the country's 21 million cattle, feel disenfranchised and unable to practice the mobility that has historically led to their success (Beal et al., 2015; International Work Group For Indigenous Affairs, 2016; Maliasili Initiatives, 2012).

Research suggests that climate change is a strong driver of sedentarization in East African pastoralist communities (Galvin, 2009). Climate change, as defined by the Intergovernmental

Panel on Climate Change (IPCC), is a statistically significant change in the mean or variability of the state of the climate that remains for a significant period time (United Nations Framework Convention on Climate Change [UNFCCC], 2011). These changes arise as a result of both natural variability in the climate and human activity. Although, scientists are increasingly certain that the warming of climate systems is indeed attributable to human activity (UNFCCC, 2011).

Climate changes in Sub-Saharan Africa are largely comprised of the following: increases in temperature, changes in rainfall intensity, increased incidence in extreme weather events, increased desertification, and alterations in disease vectors (Connolly-Boutin & Smit, 2015). Pastoralists in Tanzania are uniquely vulnerable to climate change due to their dependence on climate, grazing land, and water sources for their livelihood. Thus, the impacts of a changing climate cannot be ignored, especially among the 80% of Tanzania's who are intimately dependent upon the land for their livelihoods (World Bank Group, n.d). These changes will also have a large impact on the national economy as forty four percent of Tanzania's land is utilized for agriculture, which in turn contributes twenty-four percent of the Gross Domestic Product (GDP) (United States Agency for International Development [USAID], 2016).

Changes in Nutrition and Health

Studies undertaken among pastoralists and agro-pastoralists in sub-Saharan Africa have shown statistically different nutritional outcomes between pastoralists and agro-pastoralists, with pastoralists exhibiting significantly more dietary diversity than their more sedentary counterparts. These differences remained statistically significant across growing seasons (Mayanja, Rubaire-Akiiki, Morton, Young, & Greiner, 2015). One of the largest differences in consumption patterns between agro-pastoral and pastoral households, was the reduced intake of

milk and milk products among agro-pastoralists, with 50-70% of households not consuming these products (Mayanja et al., 2015).

It is anticipated that global food demand will continue to rise, but increasing constraints placed on the environment due to climate change will make meeting this demand increasingly challenging (Myers et al., 2017). Previous research has explored the impacts of climate change on food security but has focused on large scale issues of access and availability rather than a more nuanced understanding of nutritional outcomes. Other authors have commented on lack of exploration of this crucial nexus, for example, Schmidhuber and Tubiello note that previous assessments of global food insecurity tend to focus on issues of access and availability without considering their interactions with nutritional outcomes (Schmidhuber & Tubiello, 2007).

Remaining Gaps

While it is understood that both climate change and sedentarization of Tanzanian pastoralists will impact livelihood outcomes within these populations, their synergistic impact on nutritional outcomes remains under- researched and poorly understood (Wheeler & von Braun, 2013). We anticipate that both these processes will have impacts on the basic, underlying and immediate causes that lead to maternal and child undernutrition, but the nature of these impacts has yet to be examined in the context of Tanzanian pastoralists (Black et al., 2008; Myers et al., 2017).

To address these gaps, this research uses qualitative data to explore how climate change and sedentarization are being experienced by pastoral communities in Morogoro and Tanga districts of Tanzania, their impacts on livelihood decisions, and ultimately food access. This research will further explore how changes in food access affect diet choice and the potential implications of these choices on nutrition. Qualitative data is particularly suited for this objective as it provides

the insider's perspectives of Tanzanian pastoralists on these issues. Such a perspective is essential when looking to the future to design programs to mitigate the health impacts upon this population, as insight into their perspective and values will help to design interventions with specific behavioral drivers in mind (Wheeler & von Braun, 2013).

To understand the impacts of climate change, we apply the sustainable livelihoods framework, namely the livelihood assets elements, comprised of human, natural, financial, physical, and social capital (Advanced Training Program on Humanitarian Action [ATHA], 2014). Additionally, we will explore how changes in these assets impact coping mechanisms. Coping strategies are defined as sets of behavioral patterns used to overcome challenges to livelihood strategies. To do so we will apply concepts from the Coping Strategies Index, which classifies coping strategies as either 1) short-term changes to food consumption patterns or 2) longer-term alterations to livelihood strategies or income earning or food production patterns & one-off responses such as asset sales (CARE, 2008).

Methods:

This research is based on secondary data analysis of qualitative data collected as part of a mixed methods study on the drivers of food choice in Tanzania. The study was conducted in partnership between International Livestock Institute (ILRI), Sokoine University of Agriculture (SUA), and Emory University (EU). Data were collected by local study team members, trained in qualitative research methods.

Study Population:

Data were collected in the Mvomero and Handeni districts in eastern Tanzania. Mvomero district, located in the Morogoro region, is a productive agricultural zone, dominated by a large

number of private farms. The region is characterized by regular conflicts between large farm owners and pastoralists seeking grazing lands (Food Economy Group, 2014b). Handeni district, located in the Tanga region, has fewer large plantations and their agriculture system represents rural production for rural consumption. Conflicts between pastoralists and farmers are less frequent in Handeni than in Mvomero and tend to be more localized and driven by scarcity of rains (Food Economy Group, 2014a).

These districts, which collectively contributed 30 villages to the sampling frame, were selected based on their participation in ongoing research and development projects conducted by International Livestock Research Institute (ILRI). Within these districts, intervention communities for ILRI's Dairy Development Project were selected using a two-phase process: 1) the development of a village list, based on the available information on the number and type of cattle keepers and cattle population obtained from the district livestock officials and 2) an in-depth study of villages using participatory scoping and observation. SUA and ILRI facilitated the purposive selection of intervention villages. In this qualitative study, communities were selected within these districts to maximize diversity of livelihood strategies, village sizes, and access to urban and rural markets. In total, six villages were selected for qualitative data collection in round one and of these, three were followed up with in round two. These communities represented diverse livelihood strategies including: extensive pastoralism systems, in which farmers practice extensive pastoralism with large mobile herds; intensive sedentary systems, in which crop cultivation is practiced and a limited number of livestock are managed intensively through zero-grazing strategies, and extensive sedentary systems, in which farmers practice a mix of pastoralism and crop cultivation.

Study Design:

Data Collection

All data collection occurred in the local language, Kiswahili or Maasai. Focus group discussions (FGDs), key-informant interviews (KIIs), and in-depth interviews (IDIs) were recorded with participant consent. Audio files were transcribed verbatim into English and verified by bi-lingual members of the study team for purposes of analysis. These translations were verified by another bi-lingual member of the study team not responsible for the original translation.

Qualitative data collection occurred in two rounds, one in the lean season (September-October 2017) and one in harvest season (February-March 2017). Data collection used a grounded approach whereby findings from the first-round informed lines of inquiry in the second round. Data collection included focus group dicussions, key informant interviews, and in-depth interviews. Participants were selected purposively, utilizing networks developed through previous research and development projects through ILRI and their partners. Sample sizes for each of the modalities were determined to be adequate when saturation was reached, meaning that no new ideas or themes were emerging from the data.

Focus Group Discussions (FGDs): A total of fifty-four focus groups were conducted, thirty-seven in the first round and seventeen in the second round of data collection**.** Groups were gender and life-stage stratified, and included groups with male and female youth, men and women of reproductive age, and elder men and women. FGDs sought to illicit participants' perspectives on the following subjects 1) typical diet in the community 2) valuation of foods, including identification of foods that are "healthy", "prestigious", "non-prestigious" 3) reasoning for these distinctions 4) household roles and responsibilities around production, sale, purchase,

and preparation of foods, and 5) changes in these subjects over time. FGDs employed a range of participatory approaches including ranking and pile sort activities to understand participant perspectives in greater detail.

Key Informant Interviews (KIIs): A total of fifty-four key informant interviews were conducted, forty-eight in the first round of data collection and six in the second round. These interviews were semi-structured, in-depth interviews, designed to elicit information on community beliefs, values, and experiences around how diets are changing within the community and potential drivers of these changes. Key informants represented a broad spectrum of areas of expertise including, livestock and agricultural extension agents, village and religious leaders, community health workers, and various ministry officials.

Household In-depth Interviews (IDIs): Household in-depth interviews were conducted with a total of sixty head of households with thirty-nine occurring in the first round and twenty-one in the second round. Households were purposively selected to represent diversity of food security status, livelihoods strategies, and presence of young children.

Data Analysis:

Analysis of the qualitative data collected in both rounds used a grounded theory approach. This methodology was chosen for analysis as its end goal, theory development, is in line with the purpose of our study: to develop theory to explain the relationships between climate change, pastoral sedentarization and livelihood outcomes in the Tanzanian pastoral context (Strauss & Corbin, 1998).

De-identified, English language transcripts were analyzed using MaxQDA2018 Qualitative Analysis Software, which aided in the organization, memo-ing, and coding of data. Analysis of

the first round of data began with the development of inductive codes, derived from the data itself. Codes were included in the final codebook after consensus was reached that they merited inclusion based on their relevance to the research question, and their possession of a clear definition that could be applied consistently to the data. While initial intercoder agreement was at 63%, subsequent intercoder agreement activities facilitated discussion amongst team members about the clarity of code definitions, relevance to the research question, and differences in coding styles, and intercoder agreement subsequently increased.

A similar process was undertaken for the analysis of the second round of qualitative data. Given the similarity of the guides in the first and second rounds of data collection, a similar codebook was used in the second round. This built on the existing codebook with additional inductive codes for ideas that emerged in this round of data collection due to changes in guides. Before commencing coding on the second-round data, an inter-coder agreement exercise was undertaken, with initial inter-coder agreement at approximately 60%. Improvements were made to codes to ensure clear understanding and application of code definitions, along with improvements to code definitions to increase their clarity, and intercoder agreement subsequently increased. Once the codebook was finalized, with clear definitions for each of the codes, research assistants applied these codes to the transcripts from the focus group discussions, household in-depth interviews, and key-informant interviews.

Following the grounded theory approach ensured that this theory and conceptualization was supported by and rooted in the data. Building off the description and comparisons of key codes, researchers were then able to zoom into the data and understand the depth, breadth, nuance and, variation within the codes. One key benefit of this approach was an understanding that some codes originally developed for the purpose of the larger study were meta-codes requiring further

development of sub-codes to provide adequate understanding of relationships. For example, within the coping mechanisms code, several sub-codes emerged that characterized distinct types of coping mechanisms.

Validation of this theory and demonstration of academic rigor was achieved through use of the concept indicator model, which required researchers to return to the data to ensure that all concepts in the framework were grounded in the data (Glaser, 1978). Applying this model, the team systematically considered different sub-groups, including age, gender, and sedentarization level, to ensure that the conceptual model explained all the data, not just limited sub-groups.

Ethical Considerations

Verbal informed consent was obtained for each study participant before their participation in data collection activities. Study protocol and tools were reviewed by Tanzanian Institutional Review Boards (IRBs) and IRB boards at ILRI, EU, and SUA. All participants provided verbal informed consent.

Results[1]:

In interviews and focus group discussions, participants consistently discussed the increasing frequency of droughts, the decreasing predictability of rains, and the role these play in various aspects of livelihoods approaches, food choices, and nutritional outcomes. These changes in climate were described as influencing communities' economic prosperity, health status, and nutritional outcomes, all of which previous research indicates are also affected by sedentarization

[1] Participating communities have been de-identified to protect study participants. A standard naming convention, based on livelihood approach, will be used throughout to attribute quotes. This convention is as follows: 1. **EP** signifies and extensive pastoral community 2. **IS** signifies an intensive sedentary community 3. **ES** signifies an extensive sedentary community. Specific communities within each livelihood category are denoted by a number. For example, the first extensive pastoral community is labeled EP1, the second, EP2, etc.

(McPeak & Little, 2005; Roth, Nathan, & Fratkin, 2004; Thornton, et al., 2007). So, beyond their individual impacts on natural capital, the synergistic effects of climate change and sedentarization shape pastoralists ability to utilize short and long-term coping mechanisms. Differential access to these coping strategies is mediated primarily through changes in traditional practices of pastoralism but also impacts on crop cultivation and other means of income generation. The combined effects of these changes notably drive changes in human and social capital. Table 1 provides representative quotes which demonstrate some of the major changes communities experience as a result of these two processes *(See Table 1)*. Negative changes were noted across geographic location, age, and livelihood practice, indicating that no group is immune from these large-scale changes.

Table 1. *Synergistic impacts of climate change and sedentarization on dimensions of food security.*

Economic	Health	Nutrition
Reduced profit from cattle sales	**Increased human disease**	**Reduced number of meals**
"There is no food, and there is no cattle for which to sell so as he can buy some food, and there is no money." **(EP2 Elder Male FGD Participant)**	*"Eruption of diseases, so far we don't know why some other diseases erupt in our community, we think it is due to weather change and existence of industries."* **(EP2 KII Participant)**	*"We used to have three meals per day, breakfast, lunch and dinner but nowadays we take a single meal per day and most of us do depend on porridge, so this is a big change and effect."* **(ES1 Elder Female FGD Participant)**
Reduced profit from milk sales	**Poor mental health outcomes associated with increased stress**	**Reduced intake of "healthy" foods**
"Women used to milk cows and sell milk to other people, this enabled them to earn some money to sustain the family but nowadays due to these changes, cows have decreased in number thus leading to little production of milk, thus most women are no longer selling milk and earning some money." **(EP2 Elder Male FGD Participant)**	*"drought a lot of cattle died due to lack of pasture and water, this situation made other households to suffer a lot because they depend on milk and meat, some other people were about to commit suicide, but we thank God it did not happen."* **(EP3 KII Participant)**	***"****In the past when we had enough milk and bananas, children used to grow faster and healthier because they used to be fed with enough milk mixed with marshed bananas, but nowadays most children do experience dwarfism because of malnutrition, no enough milk, no enough bananas and general balanced diets."* **(ES1 Elder FGD Participant)**
Increased Market Price of Staples	**Increased incidence of nutrition related non-communicable diseases**	
"The food prices are hiked several times by sellers because food is scarce. For example, the quantity that usually sells at Tsh 1000 is increased to Tsh 2,000 or Tsh 3,000." **(IS1 KII Participant)**	*"The food trend we have now as compared to the past is different; in the past people were cooking anyhow; they were just taking the food and boiling it putting in a very minimal number of ingredients to the food; but nowadays the cooking is done with a lot of oils which is resulting in Blood pressure. In the past there were no Blood pressure but nowadays there is that and many ailments that were not experiencing in the old days. Nowadays a person can't eat food without the food being put a good number of cooking ingredients which in more ways than one affects our health."* **(IS1 Elder Male FGD Participant)**	

Climate change negatively impacts pastoral livelihoods through a cascade of effects on natural and financial capital.

Major impacts of climate change were widely understood as increased droughts and decreased predictability of seasonal rains. However, participants expressed varying beliefs about the causes of these changes. Most respondents cited proximate causes of climate change as predominant, including clearing of forests for cultivation and movement of cattle for pasture. In contrast, a minority of participants viewed climate change as a much larger issue that resulted from the "environmental pollution" that accompanies globalization. This understanding of the manifestations and drivers of climate change is similar to those found among other groups of Tanzanian pastoralists in previous qualitative research (Gustafson, et al., 2015; Kimaro, Mor, & Toribio, 2018).

> *"The climatic change was caused by prolonged droughts season which is a result of the cutting down of trees. There are no forest covering the mountains and the water sources also dried up because of deforestation."* **(IS1 KII Participant)**

Understanding decreased predictability of rains and increased droughts as the central mechanism through which pastoral communities are experiencing climate change, we can then examine the wide-reaching effects of this phenomena and how they interact with sedentarization. Further, we will examine how these interactions lead to differential access to the necessary forms of capital for sustainable livelihoods and how that impacts utilization of different coping strategies.

Participants noted that requirements for a well-functioning livestock system in the traditional model are few: sufficient pasture and water, both forms of natural capital. However, the changing climate impacts both elements, making traditional, highly migratory, livestock rearing increasingly difficult to practice. Additionally, with shifts towards more sedentary lifestyles, participants noted the number of large-scale farms has increased, further restricting movement of cattle, and the amount of available high quality grazing land and water resources. These

restrictions were explained to have compounded the degradation of remaining grazing lands due to decreased rainfall and increasing aridity. Similar concerns have been raised among other groups of pastoralists in Tanzania, who also linked lack of pasture to increased demand of land for agriculture purposes (Gustafson, et al., 2015).

> *"Nowadays there is severe sunshine and drought, cows are dying because of scarcity of pasture and water to feed them."* **(EP2 Elder Male FGD Participant)**

Participants consistently discussed that one of the key impacts of increased drought, something they understood as resulting from climate change, was reduced access to grazing land for cattle. Without this essential element of sufficient grazing land, participants expressed a sense of desperation and frustration, stating that there is no way to overcome a lack of pasture. This frustration is fitting given the traditional importance of cattle as the prominent form of financial capital within pastoral (Hart & Sperling, 1987). Lack of adequate pasture as a result of climate change leads to starvation among cattle which resultantly decreases milk production from these cattle, which has a range of cascading effects of livelihood strategies and outcomes, which will be further explored in later sections.

In this increasingly arid climate, cattle are often forced into closer proximity leading to further reduction in natural capital including grazing land and water. When asked about the impacts of climate change on traditional livelihood strategies, one participant explained: *"So, in order to overcome this situation, we decided to graze in the same places regardless of smallness"* **(EP1 Adult MFGD Participant)**. Participants have noted a connection between crowding and livestock disease and are attempting to address it to the best of their ability, explaining *"We are taking measure on avoiding the concentration of animals as it can be the source of diseases"* **(IS1 Elder Woman FGD Participant)**. However, with the general reduction in grazing lands

described previously, communities are left with few options to mitigate this serious risk to their financial capital.

Our findings of increased cattle disease are also supported by wider literature on impacts of climate change on livestock systems. Two of the primary livestock diseases mentioned by participants, East Coast Fever and African Animal Trypanosomiasis (AAT), have been shown to be major barriers to improved cattle productivity in Tanzania (Haji, et al., 2015; Kimaro, Toribio, & Mor, 2017; Laisser, et al., 2017). The brown-ear tick, *Rhipicephalus appendiculatus,* is the primary vector of East Coast Fever, while the tse-tse fly, *Glossina* spp., is responsible for transmission of AAT (Gul, et al., 2015; Masumu, Tshilenge, & Mbao, 2012; Rogers, 1996; Thornton et al., 2009). Both diseases are responsible for great amounts of mortality, morbidity, and significant losses in livestock yields, including milk and meat (Gachohi, Skilton, Hansen, Ngumi, & Kitala, 2012; Holt, Selby, Mumba, Napier, & Guitian, 2016). Pastoralists' observations of increasing disease incidence corresponding with changes in rainfall and temperature align with outside studies which identify these two factors as crucial to determining seasonal numbers of these vectors as well as vector population dynamics (Kimaro et al., 2017; Olwoch et al., 2008; Norval, et al., 1991; Rogers & Randolph, 1986).

Within the study population, cattle have traditionally been understood as resiliency assets, representing multiple forms of capital. However, the practice and benefits of livestock sales as a resiliency and coping strategy have reduced due to the changes in cattle herding and health. Historically, when facing financial struggles, participants noted they would sell off a small portion of their herd to access quick financial capital and make purchases to avoid food insecurity. However, reduced quality pasturelands and increased cattle density on land able to support grazing, has reduced cattle health and subsequently the prices pastoralists can get for

cattle sales. Given declining herd sizes, the declines in cattle value mean that sale of a few cattle, which previously would have represented a small portion of a pastoralist's herd, now represents a much larger portion of the herd and presents a much greater risk to future financial security. Further, participants noted that once a pastoralist decides to sell cattle, they frequently receive a much lower rate of compensation than historically given. This is due to decreased cattle health and the overall increase in number of cattle being sold as a coping mechanism, representing an increase in supply without an increase in demand, driving cattle value down.

Participants cited increasing numbers of cattle dying from starvation, further limiting one's ability to sell cattle. For example, one participant noted: *"It is because of starvation which is caused by lack of rainfall and aridity in general, cows and other livestocks are dying because they lack pasture and water"* **(ES1 Elder Male FGD Participant)**. Participants also attributed an increase in cattle death to the rising temperatures and the resulting increase in disease among cattle which was said to make the cattle thin and frail. Regardless of the cause, communities understood that poor cattle health and increased cattle death mean decreases in quickly liquefiable financial capital.

> *"Women were affected more [**by drought**] because they depend mostly on milk as their business and to get income for household use and pay for fees. Therefore, for some children did not go to school due to lack of money to pay for fees."* **(EP2 KII Participant)**

The intersection of a changing climate and sedentarization and their amplified impacts on traditional pastoral livelihoods also have negative implications for financial capital of pastoralists through their impacts on daily milk sales. A youth male explained the connection as follows, *"On the side of cattle, the big challenge is lack of grazing pasture as well as epidemic diseases which attack the cows. These challenges have been caused by climate change and now have led to low production of cattle products"* **(IS1 Youth Male**

FGD Participant). Changes in livestock herding practices as a result of both sedentarization and climate change, which will be explored later, have also led to decreased access to milk for sale.

Participants noted that women were most impacted by this reduced access to milk for sale, as they have traditionally been responsible for carrying out this livelihood activity. They further explained that income generated from the sale of milk has generally been directed to paying for school fees for children, and thus, with reduced access to milk for sale, children's ability to attend school becomes limited. With communities increasing valuation of education for their youth, the inability to afford school fees due to lack of milk for sale was talked about in a negative and shameful light by a majority of the participants, especially women. This shift in valuation around education is largely driven by concerns about the future of pastoralism and a desire to engage in further means of livelihood diversification. In a context in which historical livelihood diversification methods are becoming less effective, education provides the hope of engaging in new livelihoods.

Pastoralists have adopted a range of coping strategies in response to the effects of climate change and sedentarization.

Coping strategies most frequently included 1) changes in livestock management, 2) shifting livelihoods, 3) changes in household roles and responsibilities, and 4) changes in food consumption patterns.

Changes in Livestock Management

Participants described that, traditionally, livestock rearing, which served as both the primary livelihood and food production mechanism, was a highly migratory practice in which whole families moved together with the herd between resource patches to acquire necessary resources.

This pattern is consistent with traditional nomadic pastoralism and transhumance reported elsewhere in East Africa (Fratkin, 2001).

Given changes in natural capital described earlier, participants noted a change in approaches to herd mobility, including reduced migration of women and young children. One participant described changes thus, *"In the past we also used to shift from one place to another with all the family and livestocks to look for water and pasture but nowadays, only livestocks are shifted to other places to look for pasture, but the family remains stationary"* **(EP1 Elder Female FGD Participant)**. Our findings regarding changing migration practices are consistent with previous research on changes to pastoral mobility in East Africa which suggest an emerging "base residence-satellite camp" model as a solution to increased fragmentation of adequate natural resources (McPeak, Little, & Doss, 2012; Xiaogang, 2007).

Livelihood Shifts Towards Sedentarization

Given the aforementioned changes to financial and natural capital, participants reported pressure to shift away from highly migratory practices of pastoralism to more sedentary livelihood approaches such as crop cultivation. When asked about changes in livelihood approaches one participant noted: *"We Masaai originally are pastoralists; we have decided to engage in crop production due to climate change which has affected our livestock"* **(EP3 Adult Male FGD Participant)**. This shift towards sedentary lifestyles, predominately agro-pastoralism, has been seen elsewhere among East African pastoralists (Fratkin, 2001). While sedentarization does have the potential to provide benefits associated with livelihood diversification, including positive impacts on income, agricultural productivity, and food security, previous research also indicates greater sedentarization results in greater vulnerability to drought related livestock losses (McPeak & Little, 2005; Loison, 2015).

When rains were more reliable and the climate was less arid, pastoralists were able to practice livelihood diversification, including day laboring and crop cultivation, as a method of coping with challenges in livestock rearing and to provide additional income. Under climate change, the dependence on alternate livelihoods has increased. For example, many participants mentioned that the increased droughts and the subsequent death of cattle were salient factors in shifting to increased crop cultivation for both personal consumption and sale for profit.

> *"As you know the Masai depend on livestock so when cattle die it is like they lack the most important food such as milk and meat. Now people are looking for another alternative activity apart from depending only on cattle."* **(EP3 KII Participant)**

However, these longer-term coping mechanisms are increasingly less viable. For example, crop cultivation as a livelihood strategy is also negatively impacted by changes in weather patterns due to climate change. Changes in rainfall patterns have disrupted traditional planting seasons and climate changes have led to a reduction in overall arable land. Given the limited irrigation infrastructure that exists within the study area, participants are largely dependent on rain fed agriculture and thus, attribute decreased crop yields to decreasing predictability and sufficiency of rainfall. For some, use of technology in cultivation has served as a buffer against the impact of climate change. However, this has been limited to individuals of higher socio-economic status as they have the financial capital to invest in irrigation systems to mitigate the changing rain patterns.

> *"This climate change has also disturbed farmers objectives in crop cultivation because there is no longer specific time to expect rains for growing crops."* **(IS1 Youth Male FGD Participant)**

Additionally, increased presence of large commercial farms as a result of globalization and development initiatives in the area have further reduced the amount of arable land small-scale famers can own and cultivate, amplifying the impacts of climate change on pastoral communities. Small-scale famers who do not have access to either financial or human capital to

secure tenure of additional land through political avenues are left with ever shrinking amounts of land upon which they can attempt to diversify their livelihoods.

Historical challenges with irrigation have dramatically increased in the current climate. In the past, farmers have been able to count on predictable seasonality of rains and plan planting and harvest around expected rain patterns. With decreasing predictability of rains, farmers expressed having to stick to these traditional timelines for planting and hoping that rains will eventually come. In years of drought, crop production drastically decreases, leaving families with reduced access to food for both household consumption and sale. One participant explained that with drought, *"There is severe decline in crop production, for instance we used to produce twenty sacks of maize per acre but nowadays we produce seven sacks per acre"* **(ES1 Elder Female FGD Participant)**.

In response to changing weather patterns, some farmers attempted to mitigate the impacts of drought by changing the types of crops cultivated but this has been largely unsuccessful. As one participant noted, *"when there is no rain, nothing grows"* **(EP2 Elder Female FGD Participant)**.

> *"In the past we were growing sorghum, cassava and potatoes but currently most of them have disappeared but last year we started to grow cassava, and all was due to extreme drought."* **(EP1 KII Participant)**

Given the constraints on natural capital, other methods of livelihood diversification have become almost non-existent in the current environment. One such common practice that is no longer viable is tending to large-scale farms of wealthy farmers to supplement income from raising livestock or cultivating one's own smaller plot of land. The changing rain patterns reduce crop production on farms of all scale, and thus, when there is no rain, there are fewer opportunities for small-scale pastoralists to supplement their income with this petty labor. This presents a

challenge to communities as livelihood diversification has historically been agriculturally focused and other, non-agricultural, livelihood strategies are limited within the area.

Changing Household Roles and Responsibilities

Considering these restrictions, participants, most often elders, also discussed a shift in household roles and responsibilities. These changes were primarily mediated through changes in livelihood strategies among women, as they increasingly engaged in small business activities, such as selling buns or charcoal to supplement shrinking agricultural income.

Male participants largely understood this to be a negative shift away from traditional roles and responsibilities within households, as they believed this to have a negative impact on children. An elder explained: *"Due to them [women] going to do business and leave children at home without enough food and tend to take long time to return home so you may find children are suffering"* **(EP3 KII Participant)**. Women however were more likely to view this shift in an ambivalent light, recognizing the necessity of these changes for the overall health and wellbeing of the household. An elder woman explained the benefits of female employment outside the home as follows: *"but now things have changed women are also participating on increase the income to the family, by working in different kind of jobs like small businesses also they are taking care of cattle. So due to this there is an increase in income so it's easy to buy different kind of foods for the family"* **(EP2 Elder Female FGD Participant)**.

Changes in Food Sourcing and Consumption Patterns

On the immediate and short-term level, communities have been forced to shift from their customary food sourcing, heavily based in livestock products, gathering wild foods, and some homestead crop cultivation, to whatever staples are available and affordable in markets. This

shift in food sourcing, increasingly outward from the home, has contributed to a shift in diet. Participants explicitly linked the impacts of climate on livestock and declines of availability of milk at the household level, and ultimately reduced milk consumption. For example, when asked about changing milk availability, one participant explained this connection very succinctly, saying *"it is hard to get milk when the same cattle are suffering from drought, no food*" **(EP3 KII Participant)** while another explained "*most of the changes in Maasai life have been caused by severe sunshine and aridity which have led to deaths of cows and low production of milk, that's why we have decided to adapt new kinds of food"* **(EP2 Elder Male FGD Participant)**.

Shifting diets are not motivated by changes in preferences or valuation around traditional foods, but rather decreased availability and affordability of these traditional staples. Reflecting this continued valuation of livestock products, participants consistently discussed their belief in the health benefits of both milk and meat. As livestock herds have traditionally served as the source for these staple foods, with their decreasing health, size and geographical proximity, a consequent shift in diet has occurred- namely decreased consumption of milk, blood, and meat.

> *"Animal diseases, now there is eruption of diseases that cause lots of animal to die and also to be able to produce enough and quality milk as it was before."* **(EP2 Elder Female FGD Participant)**

As previously explored, changes to natural capital have resulted in decreased health outcomes among cattle, reducing the amount of livestock products available for consumption and sale. While the impacts of reduced livestock products for household consumption are immediately apparently, lack of livestock products for sale also presents a significant challenge. Lack of products for sale represent a significant loss in financial capital and limits pastoralists' ability to purchase nutritious foods from the market to make up for nutritional gaps created by decreased consumption of livestock products. Thus, changes in cattle

health due to changing access to natural capital acts a powerful catalyst for the dietary shift among pastoralists.

With increased constraints on natural and financial capital, there have been changes in how cattle are shifted in pursuit of adequate resources. This has led to decreased access to milk for those who remain at basecamp, usually women and young children. In the past women and children would have traveled along with the herd, retaining their access to livestock products, but this is no longer the case, leaving those who remain at the basecamp nutritionally. When asked about changes in diet, one FGD participant stated, *"The main reason is shortage of water and pasture, so pastoralists decide to shift their cows to far places where they can get enough water and pasture to feed their livestock, this practice affects the availability of milk in our place"* **(EP3 Youth Female FGD Participant)**.

Despite the shift towards more sedentary livelihood approaches and increased crop cultivation, the majority of participants noted a decreased utilization of indigenous and home cultivated vegetables. Shifts tie to several factors including climate change, but also changes in wild and public lands. Both adults and youth explained that, in the past, households frequently harvested wild vegetables which were used to supplement livestock products and achieve dietary diversity. One participant attributed this shift in food sourcing to changes in rainfall: *"There were vegetables like mushroom which was very accessible in the forests here; when it rain you find many of them just growing around; picking and cooking that you find them very delicious eating with the maize meal. But you cannot find those here now"* **(ES2 Youth Male FGD Participant)**. Another participant explained the shift in food sourcing as resulting from lack of available land: *"This was because there were a lot of farms in which vegetables grew wildly and the women could go there and pick the vegetables. However today there are no such areas"* **(EP1 Youth**

Male FGD Participant). Reduction of wild produce generally represents a reduction in dietary diversity, a key concern when we consider the nutritional impacts of sedentarization and climate change.

> "The women are also affected because in the past there was a lot of pastures, cattle were reproducing smoothly and hence milk was in abundance; some were even extracting ghee from the milk which they use to prepare food but nowadays everything is bought." (**EP2 Adult Male FGD Participant)**

Decreased milk production, constraints on homestead crop production, along with decreased availability of wild sourced foods, have contributed to shifts in food sourcing to more market-sourced foods. This shift has increased consumption of novel foods as people are being forced to eat whatever was available and affordable at the market. This shift in consumption patterns away from diets dominated by livestock products to those dominated by cereal starches and vegetables, has been noted elsewhere in studies on pastoral sedentarization (Ekaya, 2005; Fratkin & Roth, 2005). Reflecting upon this sourcing shift in a different light, participants generally expressed concern with shifts towards market sourced produce. Participants' main concerns were a belief that pesticides and other chemicals are used in their cultivation which pose a threat to community health.

The increased constraints on vegetable cultivation seen with climate changes may explain why the shift towards vegetables was less prominent within this study population. Considering the larger scale effects of rainfall on food security, reduced crop production has also led to increased prices of food at markets, creating a ripple effect and impacting larger segments of the population than those immediately impacted by failed crops.

In this context, dietary changes due to fluctuations in food affordability are characterized by a shift away from animal products to more processed foods such as refined maize meal, and chips. Participants understood this shift towards new foods as primarily driven by decreased access to

livestock products. For example, one participant explained, *"In the former days for instance the Maasai depended much on meat and milk as their main food stuffs but nowadays they consume stiff porridge, rice and other food stuffs available"* **(EP3 Youth Female FGD Participant)**.

Another coping strategy participants explored was the reduction of the number of daily meals consumed. This was explained as being necessary to deal with the higher prices of food at markets. This strategy was more prevalent among members of the community of lower socio-economic status as they have less access to other coping strategies due to their limited access to capital. A community member explained, *"In normal case we used to prepare porridge in the morning, but nowadays we don't do it, some families nowadays prepare single meal per day because of poor financial capability"* **(EP1 Adult Male FGD Participant)**.

Coping strategies in response to climate change have impacted human and social capital.

Participants also shared how they understood the health impacts of changes in natural and financial capital due to sedentarization and climate change along with their resulting dietary changes. The health impacts explored in this analysis represent a reduction in human capital as they effect communities' ability to perform labor and generate income. One participant explained these challenges as follows: *"People are having a hard time nowadays. You find the health of many people have deteriorated to a very big extent. There is no food, and there is no cattle for which to sell so as he can buy some food, and there is no money"* **(EP2 Elder Male FGD)**.

Most directly, a few participants talked about adverse health outcomes due to extreme heat among youth responsible for tending cattle. One participant explained, *"due to the sunny season many people got sick they had to go for treatment in the hospital"* **(EP1 KII Participant)**. Adverse mental health outcomes were also mentioned by participants as they noticed that the

stress created by failed crops, cattle death, and reduced milk production lead some community members to consider suicide *(See Table 1).*

Aside from the direct health impacts, the majority of changes in health and nutritional outcomes were understood to be mediated through dietary changes. Most generally, participants discussed their strong belief that milk was essential for health. Thus, from their perspective, decreased milk production, leading to decreased consumption negatively impacts the overall health of communities. When asked about the importance of milk, one participant explained,*"Even the children who are a bit mal-nutritious. If you give them milk their health straightens up and they become well and good again"* **(EP3 Youth Male FGD Participant)**.

Beyond general nutritional benefits, the majority of participants also understood milk to serve medicinal purposes. As one participant noted, *"Also milk is important in that if a person is poisoned and you give that person milk it can save her/his life"* **(EP3 Elder Female FGD Participant)**, while another explained, *"To us Milk is medicine when you have Malaria when you drink enough milk you get better even without taking malaria medicine"* **(EP2 Elder Female FGD Participant)**.

Even though participants consistently referenced preferential feeding of children in times of food shortage, they were still aware of the negative impacts that food insecurity has on infant and young child feeding practices and resulting health outcomes. One participant described the change as follows, *"But as it is now the mother does not have enough to eat; it means that the child also will not have enough milk. Sometimes the mother has to force giving the infant some soft porridge so as to supplement for the absence of enough milk"* **(EP2 Adult Female FGD)**.

Changes in Food Preparation

> *"In the past we were adding milk to the porridge but currently we do not have that so it's just porridge with salt only."* **(EP2 Elder Male FGD Participant)**

With changing food availabilities and livelihood strategies come changes in food preparation, some of which participants specifically elaborated on while others were eluded to. For example, one community member noted that the loshoroo prepared by their parents contained a much higher milk content than that which is eaten today and directly attributed this difference due to reduced milk availability as a result of decreased rainfall. Participants from the second extensive pastoral community were particularly expressive about changes to food preparation as a result of changing access to foods and talked about these changes in a negative light, expressing a belief in the reduced nutritional value of highly processed foods.

With improved access to refined oils, there has also been an increase in frying as a food preparation method. This represents a shift away from traditional food preparation methods, primarily boiling of meats and vegetables. Traditional animal fats, including ghee, are being replaced with highly refined oils which are believed to be less healthy than traditional animal fats, which results in the decreased health of the general population. This transition from animal fats to commercially available oils was understood to be driven by changes in access to livestock as a result of shifting migration patterns.

> *"In the past, people used healthy natural oils for cooking food unlike today whereby most people use cooking fat that is not healthy and has led to many diseases."* **(IS1 KII Participant)**

Participants consistently talked about increases in diabetes and heart disease within their communities and cited changing diets, especially increased use of processed oils, as the source of these adverse health outcomes. One community member explained,

"they eat foods with much cholesterol and some of foods are industrial processed. Such kind of foods are not good for human health" **(ES1 Elder Male FGD Participant)**.

Exploring more nuanced impacts of climate change and sedentarization, participants talked about how reduction in grazing land and access to water points have led to increased conflicts between pastoralists in search of pasture and water and farmers wishing to cultivate land. Such conflicts have been documented in past research on farmer herder relationships and are not surprising given the increased constraints on access to natural capital (Adano, Dietz, Witsenburg, & Zaal, 2012; Mwamfupe, 2015). Increased conflicts represent a reduction in social capital among communities in which pastoralists and farmers have relied upon each other to achieve sustainable livelihoods.

Conclusions

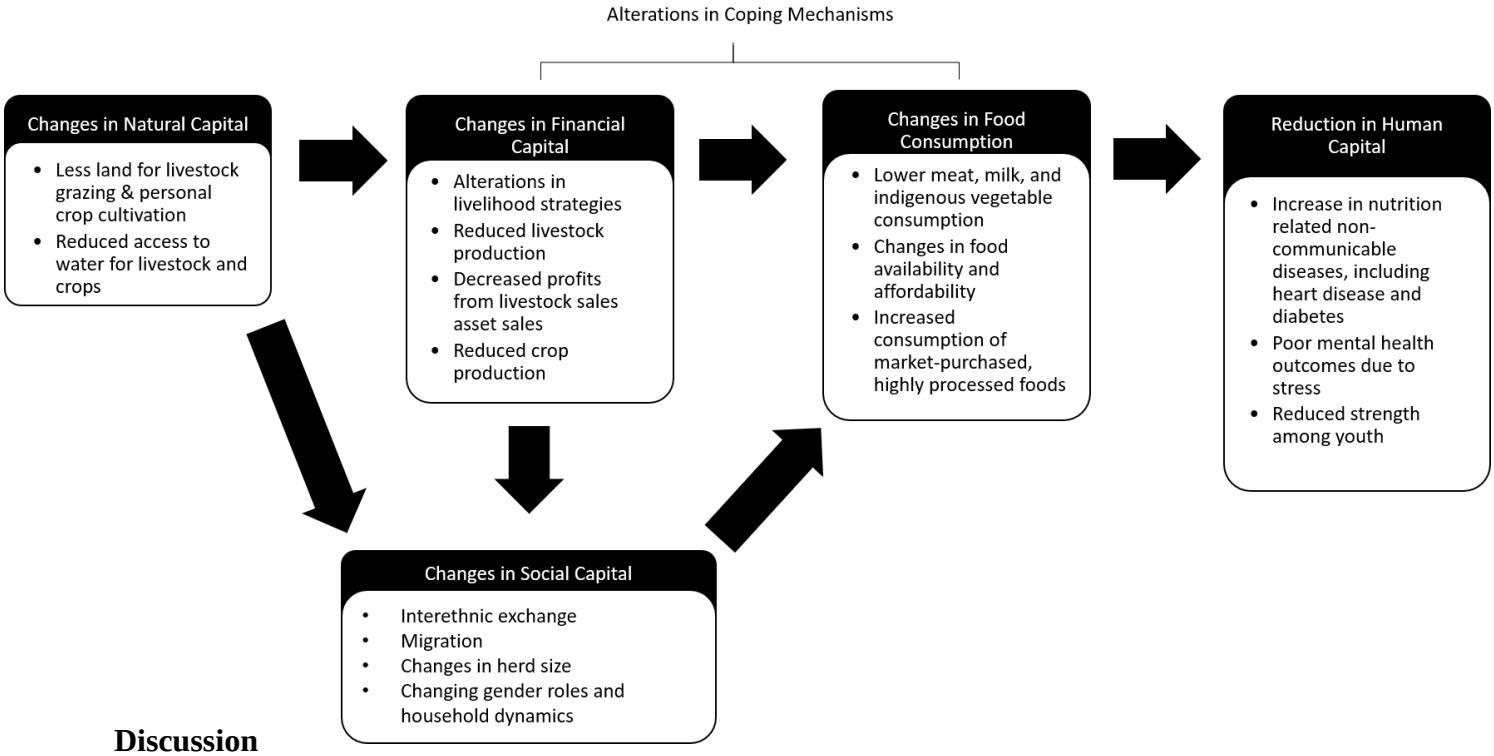
Changes in diet were understood as being rooted in changes to the land itself, with cascading effects throughout the entire food system. In response to changes in natural and financial capital, Tanzanian pastoralists have utilized both long-term and short-term coping mechanisms to achieve sustainable livelihoods. However, these coping mechanisms have produced mixed results, as some of the traditional methods of coping are no longer viable in the current environmental and political climates. Given that some coping mechanisms are no longer viable, participants face challenges in food security and resulting health and nutritional outcomes and now face the double burden of food insecurity and nutrition-related non-communicable diseases.

Findings from this research are consistent with previous research on the nutrition transition in low- and middle-income countries (Popkin, 2002). Historically people have understood the nutrition transition to occur in rapidly urbanizing areas, with much of the previous research on

the health impacts of Tanzania's nutrition transition only examining urban environments such as Dar es Salaam (Maletnlema, 2002; Njelekela, et al., 2002; Villamor, et al., 2006). However, our research and recent evidence suggest that rural communities in Tanzania are not immune from this transition (Keding, Msuya, Maass, & Krawinkel, 2011). The increase in nutrition related non-communicable diseases (NR-NCDs) that traditionally accompanies the nutrition transition in other context would stress the already stretched public health and health care delivery system in Tanzania (Keding et al., 2011). Policies are urgently needed that focus both on related prevention of NR-NCDs through food systems and preparing health care providers and health care delivery systems to manage the dual burden of over and under nutrition.

Figure 1 provides a conceptualization of how changes to natural capital due to climate change and sedentarization have ramifications for other elements of the sustainable livelihoods' framework, impact abilities to utilize short and long-term coping mechanisms, and ultimately lead to a reduction in human capital. These changes in capital create a cycle of "loss" for the community that has detrimental consequences, both acute and chronic.

Figure 1. *Conceptual framework explaining impacts of sedentarization and climate change on livelihood assets*



Discussion

Changing weather patterns have had a clear impact on livelihood approaches, food choices, and nutritional outcomes among Tanzanian pastoralists through their impacts on participants' access to natural capital. Based on climate change models for East Africa, these events will continue to occur with increasing frequency and severity (Galvin, 2009; IPCC, 2007; Kotir, 2010; Thorton, et al., 2009). Thus, the impacts seen with small scale changes are expected to be magnified in the future as weather patterns become more extreme. Further, we have reason to be concerned about the continued proliferation of these negative health and nutritional outcomes, as previous research on climate change, food security, and malnutrition in sub-Saharan Africa predicts a 55% increase in malnutrition in the region by 2050 due to climate change (Lloyd et al., 2011). Finally, previous research suggests that the health and nutritional outcomes associated with climate change are further exacerbated by the effects of sedentarization and nutritional transition (Keding

et al., 2011; Pedersen & Benjaminsen, 2007). Understanding how the synergistic effects of both climate change and sedentarization impact Tanzanian pastoralists now provides insight on creation of sustainable interventions to support the health and livelihoods of these groups as they undergo further transitions.

Future Recommendations

Policy

To ensure that Tanzanian pastoralists can continue to employ sufficient coping strategies to achieve the necessary assets for sustainable livelihoods, there must be an increased recognition and valuation of the benefits of nomadic pastoralism in its ability to make use of marginal lands which are unsuitable for other livelihood strategies including crop cultivation. As predicted climate changes occur, the marginal lands highly mobile pastoralists have historically occupied will continue to expand. This in turn will expand the amount of land for which only nomadic pastoralism is suitable. Additionally, previous research indicates that pastoralists, with their intimate knowledge of and dependence upon the environment can both efficiently utilize and protect the biodiversity of the rangelands upon which they graze (Aboud, Abdikadir, & Hileman, 1996; Benke, Scoones, & Kerven, 1993; McGahey, Davies, & Barrow, 2008)

One crucial way in which to reflect a valuation of this livelihood strategy and ensure pastoral mobility is adjusting land tenure legislation to better reflect the communal nature of pastoral land tenure and resource use. Previous research indicates that shifting land rights to support herd mobility are crucial to 1) maintaining the viability of nomadic pastoralism in this ever-changing environment and 2) promoting conservation of rangeland's biodiversity in the most economically

efficient way possible (Homman, Rischkowsky & Steinbach, 2004; Niamir-Fuller, 1999; Notenbaert, et al., 2012).

Programs

Compounding the challenges presented by increase in livestock disease is a perceived decrease in efficacy of medicines, both traditional and “modern”, to treat these diseases. Participants noted skepticism towards medications provided by “agro-veterinary” companies, making claims that these medications were poisonous for the cattle. Given the impacts of increased livestock disease on productivity and resulting food security of households and communities, programs that address livestock disease are crucial to preserving this form of financial capital.

The use of community-based animal health workers (CAHW) has shown promise in improving human livelihoods, epizootic disease control, and disease reporting and surveillance. For example, in one program in the Simanjiro District of Tanzania, participants attributed use of CAHWs with reductions in calf mortality between 59-93% (Leyland & Catley, 2002; Nalitolela, et al., 2001). Participants also associated this intervention with increased milk availability, claiming it had a "huge impact" on community food security (Nalitolela, et al., 2001). Use of CAHWs has also shown promise as a method for disease surveillance when incorporated into strategies that increase trust and improve communication between all actors (Allport, Mosha, Bahari, Swai, & Catley, 2005; Gustafson, et al., 2015).

Research

Further longitudinal research into the synergistic effects of climate change and sedentarization is necessary to map out impacts on livelihood assets in greater detail in order to identify additional

intervention points. One specific area the provides rich potential for study is the exploration of gendered impacts of these co-occurring transitions.

Additionally, the increased incidence of livestock diseases highlights the need for increased animal disease surveillance systems in areas with significant vector-borne diseases. Previous research has shown promise in utilization of CAHW as part of innovative disease surveillance systems in Tanzanian, but they remain understudied (Allport et al., 2005). Moving forward, further research into integrating CAHWs into existing surveillance systems to protect cattle health will prove essential for protecting this valuable resource which is intimately linked with many of the elements needed for sustainable livelihoods.

Limitations

Results presented are a product of secondary data analysis on a large qualitative dataset. As the researcher responsible for analysis and theory generation was not responsible for data collection, there is a loss of understanding of context and the nuance with which participants presented their experiences and perspective. Further, as an outsider to the study, the researcher responsible for analysis recognizes that their understanding of participant responses was shaped by her own experiences, having grown up in larger urban contexts in the United States. Understanding these limitations, the researcher was intentional about practicing reflexivity in the form of reflexive memo-ing, noting lessons learned from the data and noting their own potential influences on this understanding.

Additionally, the wider research question that drove data collection was not specifically focused on climate change, thus, depth of information provided is lacking in some parts, a more focused

study could provide additional, richer insight into the dynamic shifts in livelihood approaches resulting from climate change and sedentarization.

Acknowledgements

The authors would like to thank research partners, including faculty and research assistants at Sokoine University and International Livestock Research Institute, along with the research team at Emory University. Most importantly we would like to thank the study participants without whom this work would have been impossible.

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Chapter 4: Conclusion and Recommendations

Conclusions

When asked about climactic changes, participants generally focused on more immediate changes in weather patterns such as increased drought and decreased predictability of rains. These changing weather patterns have had a clear impact on livelihood approaches, food choices, and nutritional outcomes. Based on climate change models for East Africa, these events will continue to occur with increasing frequency and severity (Galvin, 2009; Kotir, 2010; Thorton, et al., 2009; IPCC, 2007). Thus, the impacts seen with the smaller scale changes are expected to be magnified with these climatic changes. Further, we have reason to be concerned about the continued proliferation of these negative health and nutritional outcomes, as previous research on climate change, food security, and malnutrition in sub-Saharan Africa predicts a 55% increase in malnutrition in the region by 2050 due to climate change (Lloyd et al., 2011). Finally, previous research suggests that the health and nutritional outcomes associated with climate change are further exacerbated by the effects of sedentarization and nutritional transition (Pedersen & Benjaminsen, 2007; Keding, Msuya, Maass, & Krawinkel, 2011). Understanding how the synergistic effects of both climate change and sedentarization impact Tanzanians now provides insight on how to move forward and create sustainable interventions to support the health and livelihoods of these groups as they undergo further transitions.

Directionality of Changes in Livelihood Assets

While the conceptual diagram presented above, developed from the study data, indicates a linear relationship of the impacts of climate change and sedentarization on livelihood assets, outside literature on poverty suggests a cyclical nature. The ramifications of this type of relationship are

potentially drastic. Continued degradation of natural resources due to climate and sedentarization will continue to lead to aforementioned issues of malnutrition at an accelerating pace. Research has well documented the poverty-malnutrition cycle through which malnutrition in the first 1000 days of life has significant impacts on physical and intellectual development, in turn leading to decreased productivity and income-generating ability, representative of a reduction in human capital (Atinmo, Mirmiran, Oyewole, Belahsen, & Serra-Majem, 2009). This cycle not only impacts individuals but also has negative inter-generational ramifications, as maternal malnutrition is highly associated with reduced health outcomes, namely stunting, in their children (Aoyama, 1999). Thus, the malnutrition pastoralists are experiencing currently has the potential to have powerful impacts on future generations' ability to access sufficient financial capital to engage in sustainable livelihood approaches.

Aside from traditional sources of malnutrition, namely undernutrition due to issues of food security, there is evidence that Tanzania, including rural pastoralist populations, are undergoing the nutrition transition, which also poses issues of over nutrition (Keding, Msuya, Maass, & Krawinkel, 2011). As a result of the nutrition transition, the burden of overweight and obesity, along with NR-NCDs is increasing, representing a loss in vital human capital, again representing a threat to individual and communities' ability to practice sustainable livelihoods.

Policy Recommendations

There must be an increased recognition and valuation of the benefits of nomadic pastoralism in its ability to make use of marginal lands which are unsuitable for other livelihood strategies including crop cultivation. As predicted climatic changes occur, the marginal lands that highly mobile pastoralist have occupied will continue to expand. This in turn will increase the amount of land for which only nomadic pastoralism is suitable.

Previous research highlights the prolific underestimation of the value of pastoralism, pointing out that conversion of rangeland to other uses has fewer benefits than costs when considering the entire system (FAO, 2016). Additionally, fragmentation of rangelands in Kenya demonstrate negative impacts on wildlife that occur when individualization of private ranches become prolific (Norton-Griffiths, 2007). In contrast, it has been shown that in countries where pastoralists can continually practice mobility and traditional governance schemes remain intact, there is much less degradation of rangelands and wildlife can continually occupy traditional habitats (Niamir-Fuller, 1999). Additionally, previous research indicates that pastoralists, with their intimate knowledge of and dependence upon the environment can both efficiently utilize and protect the biodiversity of the rangelands upon which they graze (Aboud, Abdikadir, & Hileman, 1996; Benke, Scoones, & Kerven, 1993; McGahey, Davies, & Barrow, 2008).

They further suggest that such policy changes, including changes to land tenure schemes, may be more effective than investing in technical solutions in dealing with climate change, as historically, pastoralists, when allowed to practice unrestricted mobility, have proven well adept at dealing with climatic changes (Davies & Nori, 2008; FAO, 2016). Far from creating a tragedy of the commons, ensuring collective land rights and securing pastoral tenure allows for pastoralists to carry out their livelihoods in the highly mobile manner that allows them to efficient utilize natural resources, even in constrained environments (FAO, 2016; Hardin, 1968). This assertion is further supported by additional literature which suggests that systems of collective management can and do prove effective (Ostrom, Gardner, Walker, & Agrawal, 1994).

One crucial way in which to reflect a valuation of this livelihood strategy is adjusting land tenure legislation to better reflect the communal nature of pastoral land tenure and resource use. Previous research indicates that shifting land rights to support herd mobility are crucial to 1)

maintaining the viability of nomadic pastoralism in this ever-changing environment and 2) promoting conservation of rangeland's biodiversity in the most economically efficient way possible (Homman, Rischkowsky & Steinbach, 2004; Niamir-Fuller, 1999; Notenbaert, et al., 2012).

With the application of collective land tenure schemes, many of the challenges associated with the changes in mobility, most directly, reduced access to livestock products when relying on a base-satellite model and the resulting dietary shifts associated with this, can be successfully averted. Additionally, shifting policies to reflect the communal nature of natural resource management among pastoralist societies in Tanzania better reflects existing social structures and demonstrates the potential to strengthen social capital among these groups.

Programmatic Recommendations

Compounding the challenges presented by increase in livestock disease is a perceived decrease in efficacy of medicines, both traditional and "modern", to treat these diseases. Participants noted skepticism towards medications provided by "agro-veterinary" companies, making claims that these medications were poisonous for the cattle. Given the impacts of increased disease on livestock productivity and resulting food security of households and communities, programs that address livestock disease are essential for maintaining the viability of this livelihood approach.

The use of community-based animal health workers (CAHW), has shown promise in improving human livelihoods, epizootic disease control, and disease reporting and surveillance. For example, in one program in the Simanjiro District of Tanzania, participants attributed use of CAHWs with reductions in calf mortality between 59-93% (Leyland & Catley, 2002; Nalitolela,

et al., 2001). Participants also this intervention with increased milk availability, claiming it had a "huge impact" on community food security (Nalitolela, et al., 2001).

This perception is in line with other research which sought to model the impacts of various intervention strategies on environmental and cattle productivity which showed improved control of East Coast Fever would lead to a 28.8% increase in milk production among traditional pastoralists in Tanzania (FAO, 2018). The benefits of this approach are not limited to increases in cattle productivity. Prevention of East Coast Fever has also been demonstrated to decrease greenhouse gas (GHG) emission intensity by between 12 and 23 percent relative to baseline (FAO, 2018). Given the role that GHGs play in propagating climate changes, and the fact that traditional dairy systems in Tanzania are responsible for 97% of the countries GHG emissions, this additional benefit is particularly important as a potential mitigation strategy (FAO& New Zealand Agricultural Greenhouse Gas Research Center, 2019).

In a trial to measure the impacts of CAHWs on disease surveillance in Arusha region in Tanzania, Allport et al found that diagnoses by CAHWs were confirmed by veterinarians 88% of the time, and that use of CAHWs improved reporting by 118%. These statistics demonstrate that use of CAHWs has potential to bolster surveillance efforts in Tanzanian, improving cattle health and overall livelihood sustainability (Allport, Mosha, Bahari, Swai, & Catley, 2005). In their work, Allport et al, also note that effective utilization of CAHWs to support zoonotic disease surveillance efforts will require collaboration to increase and improve communication between all stakeholders, as there are tensions between pastoralists and agro-veterinary practitioners (Gustafson, et al., 2015). Allport et al also note that to improve results of disease surveillance systems utilizing CAHWs, CAHWs must receive appropriate legal recognition which will allow for better quality control amongst this group (Allport et al., 2005).

Research Recommendations

Further longitudinal research into the synergistic effects of climate and sedentarization is necessary to map out impacts on livelihood assets in greater detail in order to identify additional intervention points. One specific area the provides rich potential for study is the exploration of gender impacts of these co-occurring transitions. Previous research indicates the impacts of climate change on food security are highly specific to gender and that pre-existing social stratifications have the potential to be worsened due to the impacts of climate change (McKune, et al., 2015; Weiler et al., 2014). Better understanding of gendered burdens will ensure that the interventions designed to address livelihood challenges take into account the unique needs of women and girls.

Previous research done by Thornton et al propose effects on pathogens, hosts, vectors, and infectious disease epidemiology itself due to changing climates (Thornton et al., 2009). However, disease dynamics are highly complex with many interrelated anthropogenic and natural elements. Thus, it has been hard to predict the location and timing of these anticipated outbreaks, making their prevention increasingly challenging. These challenges highlight the need for increased animal disease surveillance systems in areas with significant vector-borne diseases. Moving forward, further research into developing surveillance systems to protect cattle health will prove essential for protecting this valuable resource which is intimately linked with many of the elements needed for sustainable livelihoods.

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