

Increased climate variability and sedentarization in Tanzania: Health and nutrition implications on pastoral communities of Mvomero and Handeni districts, Tanzania

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ARTICLE INFO

Keywords:

Sedentarization
Climate change
Pastoralism
Nutrition transition

ABSTRACT

African pastoralists are undergoing significant changes in livelihood strategies, from predominantly mobile pastoralism to agro-pastoralism in which both livestock raising and cultivation of crops are practiced, to agro-pastoralism combined with wage labor and petty trade. These changes often result in fixed settlements or a process known as sedentarization. Previous research indicates that sedentarization and increased climate variability are prominent forces shaping livelihood opportunities and constraints in East Africa, but the effects of these co-occurring processes have yet to be investigated. This paper develops theory, using qualitative data collected in Morogoro and Tanga Regions of Tanzania, explaining the relationships between climate variability, pastoral sedentarization, livelihood outcomes, and resulting nutritional status. We observed that the co-occurring processes of increased climate variability and sedentarization among pastoralists in these regions have dramatic impacts on communities' economic prosperity, health status, and nutritional outcomes. Due to risks associated with climate and sedentarization, land tenure policies that allow continued practice of highly mobile livelihood strategies, namely, legal recognition of collective land rights, should be adopted.

1. Introduction

The practice of mobile pastoralism has long been an important livelihood system of East Africa. However, social, political, and environmental pressures from climate, population expansion, and land-use policies have catalyzed the process of adaptation of less mobile livelihoods, including agro-pastoralism, or where part of the household farms while other members herd livestock in mobile herding units, a process known as sedentarization (FAO, 2001).

Previous work in this area, such as the Double Exposure Framework developed by O'Brien and Leichenko (2008) provides a useful frame from which to begin to understand how the co-occurring processes of economic globalization and climate change intersect and impact communities. In its application to other pastoralist communities (McKune and Silva, 2013), the Double Exposure Framework has been utilized to

examine how individual experiences of food insecurity are rooted in responses changing economic and environmental conditions. Thus, we must first explore the manner in which Tanzanian pastoralists understand and experience these processes before we can understand their downstream effects.

Research suggests that increasing climate variability, especially the increased frequency of droughts, is a strong driver of sedentarization in East African pastoralist communities (Galvin, 2009). Pastoralists, including those in Tanzania, are uniquely vulnerable to increased climate variability due to their dependence on weather conditions, which shape both the grazing land and water sources which provide the natural capital to sustain their livelihood. Thus, the impacts of an increasingly variable climate cannot be ignored. 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

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<https://doi.org/10.1016/j.gfs.2021.100516>

Received 31 January 2020; Received in revised form 8 February 2021; Accepted 9 February 2021

Available online 3 March 2021

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twenty-three percent of the Gross Domestic Product (GDP) (Central Intelligence Agency, 2018).

Within the context of this changing environment, there is continued political and social pressure for pastoralists to partake in increasingly sedentary livelihoods practices, transitioning from the practice of transhumance to settled farming. 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 which 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 under the control of local communities but rather, the central government, under the control of the President of Tanzania, who then has the power to determine how this natural resource is allocated and utilized (Beal et al., 2015).

Not immune from international pressures and globalization, the Tanzanian government is receiving increased requests from multinational corporations to gain access to historic rangelands for their own cultivation and livestock raising, often labeled as “land grabs” (Strauss, Manji, & Donovan, 2015; Lind et al., 2020). Thus, Tanzania’s approximately 1.5 million pastoralists who are responsible for nearly all of the country’s 21 million cattle are potentially disenfranchised and increasingly unable to practice the mobility that has historically sustained them (Beal et al., 2015; International Work Group for Indigenous Affairs, 2016; Maliasili Initiatives, 2012).

While it is understood that both increased climate variability and sedentarization of Tanzanian pastoralists will impact livelihood outcomes, their synergistic impact on nutritional outcomes remains under-researched (Wheeler and von Braun, 2013). To address gaps in understanding of their synergistic impact on nutritional outcomes, this research uses qualitative data to explore how increased climate variability and sedentarization are being experienced by pastoral communities in Mvomero, and Handeni, districts of Tanzania, their impacts on livelihood decisions, and ultimately food access. This research further explores how changes in food access affect diet choice and the potential implications of these choices on nutrition. To understand the impacts of increased climate variability, we examine the changes experienced by pastoralists through the lens of the sustainable livelihoods framework, namely the livelihood assets elements, comprised human, natural, financial, physical, and social capital, as these categories aptly align with the key areas of change experienced by Tanzanian pastoralists (Scoones, 1998). We then examine how these assets align with the Double Exposure Framework, ultimately leading to reduction in human capital (Leichenko and O’Brien, 2008).

2. Methods

This research study, conducted through partnership between the International Livestock Research Institute (ILRI), Sokoine University of Agriculture (SUA), and Emory University (EU) seeks to understand how shifting livelihoods strategies among Tanzanian pastoralists influence socio-cultural and gender norms, food access, and food valuation and how the intersections of these ultimately influence food choice.

2.1. Study population

Data for this study was collected in the Mvomero and Handeni districts in eastern Tanzania, with collection embedded within the context of an ongoing research and development project within the regions. Mvomero district, located in the Morogoro region, is a productive agricultural zone, dominated by a large number of smallholder farms. The region is characterized by regular conflicts between large farm owners and mobile pastoralists seeking grazing lands. The latter group often must traverse farming areas en route to pastures, which

contributes to land-based conflicts (Food Economy Group, 2014b). Handeni district, located in the Tanga region, has fewer large farms 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 pasture and water related to changing rainfall patterns (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 villages for ILRI’s Dairy Development Project (MoreMilkIT) 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, six villages, three in Handeni and three in Mvomero, were purposively selected from the sampling frame based on the observed levels of sedentarization, proximity to a market, demographic characteristics, and participation in the MoreMilkIT program. Three categories of sedentarization (mobility) defined by ILRI for purposes of their MoreMilkIT program were used to classify villages: intensive sedentary ($n = 1$), extensive sedentary ($n = 2$), and extensive pastoral ($n = 3$). Extensive pastoral villages were those in which the predominant cattle-management strategy comprised large herds (i.e. more than 20 cattle) of typically indigenous breeds with household members practicing transhumance, defined as regular seasonal movements of cattle. Extensive sedentary villages were those with smaller herd sizes of hybrid breeds that practiced farming during the study period and did not practice seasonal mobility. Intensive sedentary villages were strongly crop-cultivation focused; households possessed smaller numbers of cattle typically using a zero-grazing system (i.e., no movement of livestock).

2.2. Study design

2.2.1. Data collection

Qualitative data collection, comprising focus group discussion (FGDs), in-depth interviews (IDIs), key informant interviews (KIIs) and market surveys, occurred in two rounds distinguished by seasonality. The first round occurred during the rainy season (February–March 2017) and second round occurred in the dry season (September–October 2017).

FGDs, KIIs, and IDIs were recorded after obtaining participant consent in local languages. Audio files were transcribed verbatim in the local language, confirmed by another member of the study team, then translated verbatim into English and verified by bi-lingual members of the study team for purposes of analysis.

Data collection used a grounded theory approach whereby findings from the first-round informed lines of inquiry in the second round. Participants were selected from the roster of participants in previous research and development projects conducted by ILRI and their partners. Purposive sampling was applied to select a sample diverse in ethnicity, livelihoods strategy and women’s empowerment using data from previous research surveys. Sample sizes for each of the data collection approaches were determined to be adequate when thematic and meaning saturation were reached, meaning that no new ideas or themes were emerging from the data (Hennink et al., 2017, 2019). Due to resource constraints, only the three extensive pastoral villages were included in round two of data collection. Extensive pastoral villages were selected to gain deeper understanding of trends in diets and food choice as they related to pressures and challenges pastoralists experienced with respect to their livelihoods and food security.

Focus Group Discussions: A total of fifty-four FGDs were conducted, thirty-seven in the first round and seventeen in the second round of data

collection. Groups were stratified by gender and life-stage, and included 6 groups with male and female youth, men and women of reproductive age, and elder men and women. Each group comprised participants from various ethnicities. 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. Across both rounds FGDs lasted approximately 1 hour and 42 minutes and averaged 8 participants.

Key Informant Interviews: A total of fifty-four KIIs were conducted, forty-eight in the first round of data collection and six in the second round. These interviews were semi-structured and 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, all of whom had spent at least several years in their respective communities, represented a broad spectrum of areas of expertise, including livestock and agricultural extension agents, community and religious leaders, community health workers, community development officers, market managers and various ministry officials.

Household In-depth Interviews: Household IDIs 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. Women were interviewed face to face using a questionnaire.

2.3. 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 and 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. As part of an iterative process, 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. A similar process was undertaken for the analysis of the second round of qualitative data including a codebook from round one with additional inductive codes for emerging issues. These two codebooks were then merged and data coded by trained research assistants.

Following the grounded theory approach ensured that findings and conceptualization were supported by and rooted in the data (Strauss and Corbin, 1998). Building off the description and comparisons of key codes, researchers were then able to understand the depth, breadth, nuance and, variation within and across the codes.

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.

2.4. Ethical considerations

Study protocol and tools were reviewed by Tanzanian Institutional

Review Boards (IRBs) and IRBs at ILRI, EU, and SUA. Verbal informed consent was obtained for each study participant before their participation in data collection activities. Participating communities have been de-identified to protect study participants.

3. Results and discussion

In household IDIs, KIIs, and FGDs, participants consistently discussed the increasing frequency of droughts, the decreasing predictability of rains, and the role these play in various aspects of their livelihood approaches, food choices, and nutritional outcomes. As described by participants, These changes in climate were understood as influencing communities' economic prosperity, health status, and nutritional outcomes, all of which are, according to literature, also influenced by the process of sedentarization (McPeak and Little, 2005; Roth et al., 2004; Thornton et al., 2007).

Table 1 provides representative quotes, which demonstrate some of the major changes communities experience as a result of the impacts of the co-occurring 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 increased climate variability and sedentarization on dimensions of food security.

Economic	Health	Nutrition
Reduced profit from cattle sales <i>"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."</i> (Kambala Elder Male FGD Participant)	Increased human disease <i>"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."</i> (Kambala KII Participant)	Reduced number of meals <i>"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."</i> (Konje Elder Women FGD Participant)
Reduced profit from milk sales <i>"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."</i> (Kambala Elder Male FGD Participant)	Poor mental health outcomes associated with increased stress <i>"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."</i> (Mela KII Participant)	Reduced intake of "healthy" foods <i>"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, not enough milk, not enough bananas and general balanced diets."</i> (Konje Elder Women FGD Participant)
Increased Market Price of Staples <i>"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 2000 or Tsh 3000."</i> (Manyinga KII Participant)	Increased incidence of nutrition related non-communicable diseases <i>"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."</i> (Manyinga Elder Male FGD Participant)	

3.1. The double burden on natural capital has cascading effects throughout the food system

Among pastoralists in Morogoro and Tanga Regions, changes in diet were understood as being rooted in changes to the land itself, with cascading effects throughout the entire food system. Participants consistently expressed that both increases in large-scale farming and climatic changes served as drivers to changes in the land availability, ultimately resulting in a large reduction of land size within which to practice historical, highly mobile, pastoralism.

3.1.1. Increase in large-scale farming

With shifts towards more sedentary lifestyles, both FGD and IDI participants noted the number of large-scale farms has increased, a reflection of the processes of globalization. This increase in large-scale farms was explained to further restrict 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 and water to increased demand of land for agricultural purposes (Gustafson et al., 2015).

3.1.2. Climatic changes

Despite a local consensus on increased droughts and decreased predictability of seasonal rains, participants expressed varying beliefs about the causes of these changes. Most respondents cited proximate causes of increased climate variability as predominant, including increased clearing of forests for cultivation and movements of cattle for water and pasture. In contrast, a minority of participants viewed climate change as a much larger issue that resulted from the “environmental pollution” that accompanies global carbon emissions from mainly wealthy Northern countries. This understanding of the manifestations and drivers of increased climate variability is similar to those found among other groups of Tanzanian pastoralists in previous research (Gustafson et al., 2015; Kimaro et al., 2018).

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 influence patterns of sedentarization. We also examine how these interactions lead to differential access to the necessary forms of capital for sustainable livelihoods and different coping strategies.

3.1.3. Impacts on natural capital

Participants noted that requirements for a well-functioning livestock system are sufficient pasture and water, both forms of natural capital. However, the changing climate and increase in large scale-farms impact both of these elements, making pastoralism and livestock rearing increasingly difficult to practice.

Participants consistently discussed that one of the key impacts of increased drought was reduced availability of grazing land for cattle. Without this essential element, participants expressed a sense of both desperation and frustration, stating that there is no way to overcome a lack of pasture. This frustration is fitting given the local importance of cattle as the prominent form of financial capital within pastoral communities (Hart and Sperling, 1987; McPeak et al., 2012). Lack of adequate pasture as a result of increased climate variability and large-scale farming contributes to malnutrition among cattle, subsequently causing decreased milk production and increases in cattle disease. These issues have a range of cascading effects on livelihood strategies and outcomes, explored in later sections.

Within the study population, cattle have traditionally been understood as resiliency assets, representing multiple forms of capital that can be sold or consumed during emergencies (Truebswasser and Flintan,

2019). However, the practice and benefits of livestock sales as a resiliency and coping strategy have reduced due to 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 quantity of 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. In addition, as large segments of the population lean upon this strategy, markets become flooded with livestock and the value of livestock products decreases further. This is consistent with previous research on climate change and coping among pastoralists in East Africa (Speranza, 2010). Participants attributed an increase in cattle death to myriad causes including rising air temperatures and increasing cattle disease. Regardless of the cause, communities understood that poor cattle health and increased cattle death mean decreases in highly liquid financial capital.

3.1.4. Impacts on financial capital

Increased climate variability and sedentarization along with their amplified impacts on traditional pastoral livelihoods, also have negative implications for financial capital of pastoralists through the impacts on daily milk sales. Participants noted that women were most impacted by this reduced access to milk for sale, as they mainly are responsible for this livelihood activity. They further explained that income generated from the sale of milk has generally been directed to paying for school fees, and thus, with reduced access to milk for sale, children's ability to attend school is impacted.

With communities increasing valuation of education for their youth, the inability to afford school fees due to limited milk for sale was talked about in a negative and shameful light by a majority of the participants, especially women during FGDs. 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.

3.2. Coping strategies in response to loss of natural capital

Both FGD and KII participants discussed myriad coping strategies they employed in response to changes they were experiencing. These most included 1) shifting livelihoods, 2) changing household roles and responsibilities, and 3) changing food consumption patterns.

3.2.1. Livelihood shifts and increased sedentarization

Participants described how livestock rearing used to serve as the primary livelihood, and was highly mobile whereby whole families moved together with the herd between resource patches to acquire necessary resources. This highly mobile practice often is referred to as nomadism (Little et al., 2014). However, given the aforementioned changes to financial and natural capital, participants reported a shift away from a highly mobile form of pastoralism to more sedentary lifestyle with an increased focus on crop cultivation and casual waged labor. When asked about changes in livelihood approaches, participants directly linked these livelihood decisions with increased climate variability: “We (Maasai) originally are pastoralists; we have decided to engage in crop production due to climate change which has affected our livestock” (EP3 Adult Male FGD Participant¹).

When rains were more reliable and the climate was less arid,

¹ A standard naming convention, based on livelihood approach, will be used throughout to attribute quotes. This convention is as follows: 1. EP signifies an 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.

pastoralists were able to practice livelihood diversification, including casual waged labor and crop cultivation, as a method of coping with challenges in livestock rearing and to provide additional income. Under the scenario of increased climate variability, 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. However, in this increasingly variable climate, the reduction in natural capital is so much so that these livelihood-based coping mechanisms are increasingly less viable.

Participants noted that changing 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 impacts of climate change but this has been limited to individuals of higher socio-economic status.

Additionally, as outlined above the increased presence of large commercial farms as a result of rangeland appropriation and development initiatives in the area have further reduced the amount of arable land small-scale farmers can cultivate, amplifying the impacts of climate variability on pastoral communities. Small-scale farmers who do not have access to either financial or human capital to secure land through political avenues are left with ever shrinking amounts of land upon which they can attempt to diversify their livelihoods.

All livelihood options have been constrained due to the shrinking availability of natural capital associated with increased climate variability and sedentarization. For example, 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 casual labor on large-scale farms as they too face both natural and financial capital constraints. 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.

3.2.2. Changing household roles and responsibilities

As a way to cope with change, many 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 breads or charcoal, to supplement shrinking milk and produce sales. Male participants perceived these changes as negatively affecting the family, especially children. A male 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 perceived this shift in a more ambivalent light, with some seeing positive consequences especially in terms of family health and wellbeing as increased income was understood to provide both greater food security and access to educational opportunities.

3.2.3. 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 greater dependence on staples and what is available and affordable in markets. This shift in food sourcing, increasingly outward from the home, has contributed to shifts in diet, specifically changes in meat and animal sourced food consumption. Shifting diets did not appear motivated by changes in preferences around traditional foods, but rather, the increasing scarcity and expense of these foods as participants consistently discussed their persistent belief in the benefits of both milk and meat. One participant shared *“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” (EP3 KII Participant).

While reduction in meat was mentioned, the reduction in milk production and consumption was mentioned more frequently by participants. Further, they explicitly linked the impacts of climate on livestock and 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).

Despite the shift towards more sedentary livelihoods and increased crop cultivation, the majority of participants noted a decreased utilization of wild and home cultivated vegetables. Shifts are linked to several factors, including climate but also changes in access to public lands. 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 rains 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). Participants also understood reduction in available wild produce as being due to increased allocation of land for farming which was previously left untended. Reduction of wild produce generally represents a reduction in dietary diversity, a key concern when we consider the nutritional impacts of sedentarization and increased climate variability.

Across communities, pastoralists commonly expressed a prioritization of the sale of their limited quantities of animal sourced food in order to fund their children's education. This, in conjunction with 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 including more processed foods such as refined maize meal and chips as choices become limited to what is available and affordable at markets, leading to a reduction in animal sourced food consumption. Participants understood this shift towards new foods as primarily driven by decreased access to livestock products, consistent with previous research among pastoralists in sub-Saharan Africa (Galvin et al., 2015; Iannotti and Lesorogol, 2014).

3.3. Changes in coping strategies and their impacts on human and social capital

The health impacts explored in this study reduced the human capital within communities by affecting their capacity to work and thus generate income. 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 and 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. This finding aligns with previous research on the negative impacts of food insecurity on mental health, which indicate that chronic food insecurity is linked with adverse psychological consequences (Nanama and Frongillo, 2012).

Aside from these direct impacts on health, 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 malnourished. If you give them milk, their health straightens up and they become well and good again”* (EP3 Youth Male FGD Participant).

Even though participants consistently referenced the feeding of children in times of food shortage as a priority, 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).

Changing food availabilities and livelihood strategies have also affected food preparation. In discussing changes to food preparation, participants most commonly discussed how increased availability and affordability of refined oils, has led to an increase in frying and the consumption of fried foods. 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 cooking oils which participants believe to be less healthy than traditional animal fats, ultimately resulting in decreased health among 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.

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).

4. Discussion and future recommendations

Changing weather patterns have had a clear impact on livelihood approaches, food choices, access to natural capital, and nutritional outcomes. 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; Thornton, et al., 2009; USAID, 2018).

Thus, the impacts seen with small scale changes are expected to be magnified in the future as weather patterns become more extreme.

Fig. 1 provides a conceptualization of how increased climate variability and globalization both contribute towards sedentarization, all of which subsequently lead to reduction in natural capital which has ramifications for other elements of the sustainable livelihoods’ framework, impacts abilities to utilize short- and long-term coping mechanisms, and ultimately reduces human capital. These changes in capital create a cycle of “loss” for the community that has detrimental consequences, both acute and chronic.

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 variability and change are further exacerbated by the effects of globalization, sedentarization, nutritional transition (Galvin et al., 2015; Iannotti and Lesorogol, 2014; Keding et al., 2011; McKune and Silva, 2013; Pedersen and Benjaminsen, 2007). Understanding how the synergistic effects of both increased climate variability and sedentarization impact Tanzanian pastoralists can provide insights on possible interventions to support the health and livelihoods of these groups as they undergo further transitions.

4.1. Policy recommendations

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

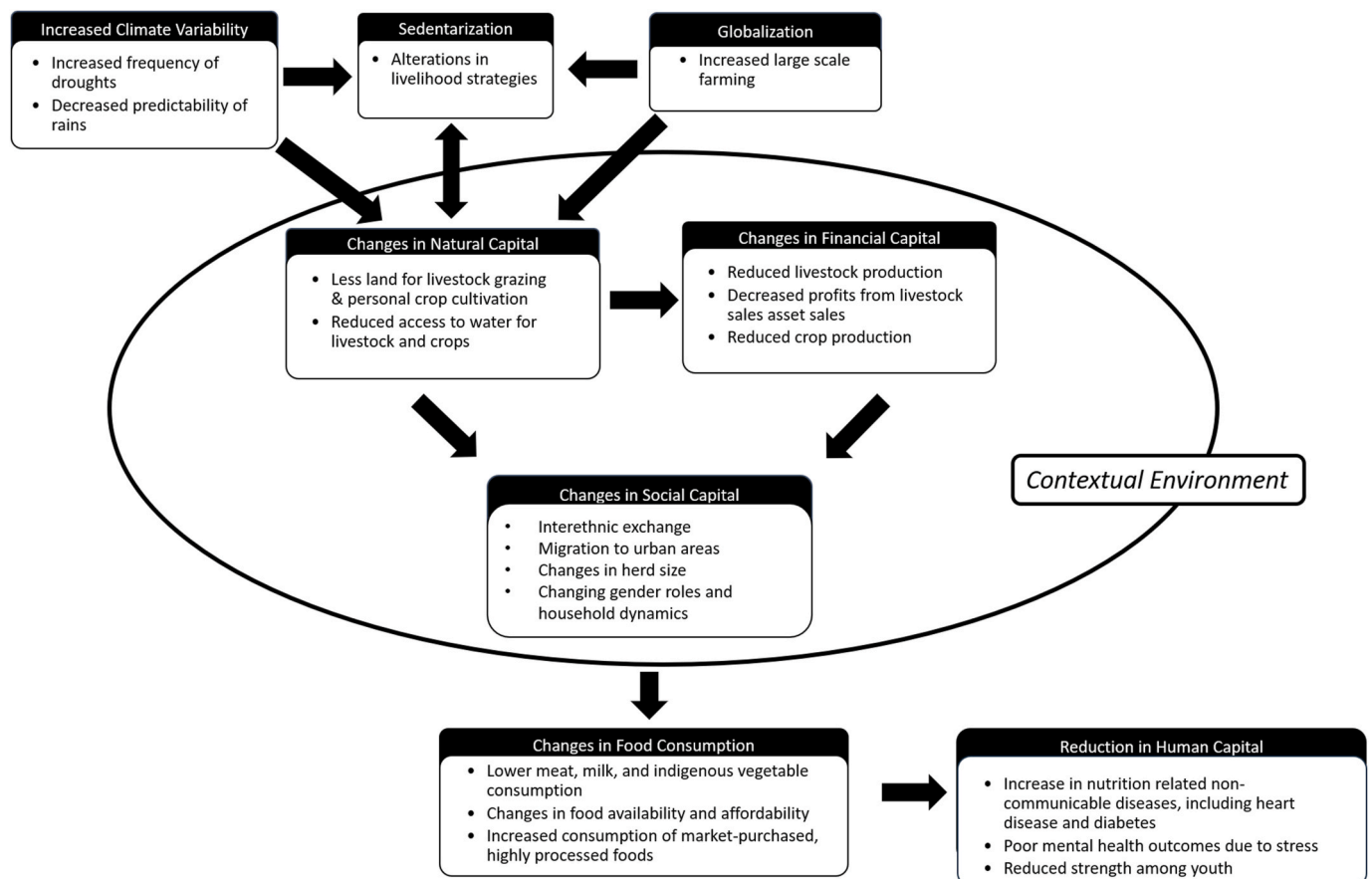


Fig. 1. Conceptual framework explaining impacts of increased climate variability, globalization, and sedentarization on livelihood assets.

lands which are unsuitable for other livelihood strategies including crop cultivation. As predicted climate changes occur, the marginal lands that highly mobile pastoralists have historically occupied will continue to increase. This in turn will expand the amount of land for which only mobile pastoralism is suitable. However, given shifts to sedentary lifestyles and livelihood approaches, pastoralist may face increasing barriers to accessing these marginal lands; lands which research indicates can only be efficiently utilized and protected by pastoralists (Aboud et al., 1996; Behnke et al., 1996, 2020; McGahey et al., 2008).

One crucial way to support this livelihood strategy and ensure pastoral mobility is to ensure that pastoralists maintain access to communal grazing areas. Previous research indicates that changes national land policies that support herd mobility and land access are crucial to 1) maintaining the viability of mobile pastoralism in this ever-changing environment and 2) promoting conservation of rangeland's biodiversity in the most economically efficient way possible (Homman et al., 2004; Niamir-Fuller, 1999; Notenbaert et al., 2012).

4.2. Research recommendations

Further longitudinal research into the synergistic effects of climate variability and sedentarization is necessary to map out impacts on livelihood assets in greater detail in order to identify additional intervention points. One specific area that provides rich potential for study is the exploration of gendered impacts of these co-occurring transitions as previous research indicates that each of these processes have substantial gendered impacts individually (Sellers, 2016; Talle, 1988).

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 Community Animal Health Workers (CAHWs) 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.

5. Conclusions

Decreased predictability of rains and increased droughts, compounded with increased pressures to reduce mobility and pursue sedentary livelihoods have had a dramatic impact on Tanzanian pastoralists and the land that they depend on for the livelihoods and health. These changes to "natural capital" have had cascading effects throughout the entire food system, reducing financial, social, and human capital and ultimately positioning participants to experience the double burden of food insecurity and nutrition-related non-communicable diseases (NR-NCDs).

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 past methods of coping are no longer viable under the current environmental and political climates.

The increase in 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. As such, 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.

6. Limitations

Due to resources constraints, only half the study sites received follow

up data collection. As such, the research team was unable to make comparisons over time and varying levels of sedentarization which could have offered additional insight into the nuances of how increased climate variability is experienced by pastoralists in the study area.

Additionally, the first author involved analysis and theory generation was not involved in primary data collection and thus there may be some loss of context and the nuance when presenting participant 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. Further, the first author grounded their research in existing literature and theory and regularly checked in with team members based in the region and who were involved in the primary data collection to verify findings and interpretations emerging from the data. Lastly, the wider research question that drove data collection focused on drivers of food choice and not specifically climate change. As a consequence, the depth of information provided on climate change 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.

Funding

This research has been funded by the Drivers of Food Choice (DFC) Competitive Grants Programs, which is funded by the UK Government's Department for International Development and the Bill & Melinda Gates Foundation, and managed by the University of South Carolina, Arnold School of Public Health, USA; however, the views expressed do not necessarily reflect the UK Government's official policies.

Author contributions

AWG, PDS, PDL, JK, AM conceptualized the original research questions and study design. CR, AWG and PDL developed the analytical strategy for the paper. CR conducted the analysis. CR, AWG, PDL contributed to interpretation of findings. CR wrote the first draft of the manuscript. All authors reviewed or provided inputs to the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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 community participants without whom this work would have been impossible.

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