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The Loss of Ecological Control, Pastoralist Migration and Indigenous Knowledge in Tanzania

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Abstract

This article is based on a study on the implications of climate change in bringing about loss of ecological control and climate induced, forced pastoralist migration from one ecosystemic basin to another. It brings out a discussion that migration between different ecosystems lead to the inevitable loss of location-specific indigenous knowledge. This in turn contributes to loss of epidemic control which lead to increased livestock and human vulnerabilities in the destination areas. The article is based on empirical evidence demonstrating that pastoralists are increasingly becoming a vulnerable population group, and internally displaced to new ecosystems as a result of migration as a coping mechanism from extreme weather variations. The study was guided by three objectives: a) to determine whether such migration trends are induced by climate change and loss of ecological control; b) to determine recent trends of pastoralist and livestock migration in Tanzania, and c) to determine the implication of pastoralist migration and loss of indigenous knowledge. The article is based on a study that interviewed 544 pastoralist households in seven districts in Tanzania. A total of 54 Focus Group Discussions and 17 Key Informant Interviews were conducted to complement the household survey. The study provided evidence derived from case-study areas in which recent climatic changes and extreme weather conditions have had accelerated loss of ecological control leading to forced out-migration, depletion of location specific indigenous knowledge and increased vulnerability to epidemics. The article concludes that loss of ecological control is closely associated with loss of epidemic control.

Keywords: *climate change, loss of ecological control, pastoralist migration, indigenous knowledge*

1. Introduction

Pastoralism is a way of life that predominantly depends on livestock husbandry as a primary means of deriving livelihood (Frantkin, 2001). According to Foster (2013), Butt (2016), and Gemenne and Blocher (2017), there is an inherent relationship of co-existence between livestock, human activity and nature in the meaning of flora and fauna (Kjekshush, 1977, 1996; Harvey, 1993). Boone and Wang (2007) and Araujo (2017) have gone at length to explain the phenomenon of 'land carrying capacity' referring to the limit to which the landmass could support a certain number of livestock. To this end, Harvey (1993) wrote

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extensively on the tradition of Malthusianism, that relative imbalance between land and its resources depletion on the one hand, and human and livestock population increases on the other, would inevitably lead to either an ecological, and/or population disaster. According to Malthus, "disasters" would be the option that offsets imbalances between population, nature and resources. According to Boone and Wang (2007) and Kimaro, et al. (2018), climate change has a direct bearing on loss of forage in Northern Tanzania. Climate-induced loss of forage contributed to reduced land carrying capacity in several tropical countries including Ethiopia, Kenya, Somalia and Northern Uganda (Coppolillo, 2000). This diminished capacity in two related phenomena. Frantkin (2001), Lankester and Davis (2016) and Sonneveld et al. (2017) argued that climate induced growth led to loss of ecological control where increasing livestock population in the midst of climate change typically tipped the balance of land carrying capacity in traditional pastoralist areas near the tropics. Second, as a coping mechanism, Frantkin (2001) and Lankester and Davis (2016) report that pastoralists in Tanzania were actually mitigating this through out-migration to the southward parts of the country (NBS, 2006). This increasing loss of ecological control was reported as a source of recent population and livestock movements to high vegetation areas.

NBS (2015) and Stahl (2015) argue that there was an interesting contrast between pastoralist out-migration and in-migration areas. Whereas out-migration areas experienced loss of ecological control as a result of livestock overrunning natural cover provided by land and vegetation, the in-migration areas had already historically suffered from loss of ecological control as a result of population decline from epidemics, slave trade, and intermittent tribal wars. Population decline caused high increase of thick natural vegetation cover which provided cover for disease-carrying vectors mainly tsetse and rinderpest overran to diminish human and livestock population in the areas. According to Stahl (2015) this led to loss of epidemic control in the areas.

Several challenges faced Tanzania pastoralist as they migrated southwards in search of greener pastures. According to Frantkin (2001) and Lankester and Davis (2016) the main challenges included conflict with land cultivators, frequent evictions by the government, infringement and evictions from protected areas, exposure and vulnerability to new livestock and human diseases, and loss of indigenous knowledge (IK) from previous familiar ecosystems. The net effect of this situation included increased vulnerability, poverty, loss of livelihood and internally displacement of pastoralists (NBS, 2014).

The study used the Political Economy Theory in analysing human relations with nature in the production process, and the consequent relationship between population, production relations, and socio-economic development in relation to ecology. The theoretical analysis departs from Kjekshush's (1977) seminal work on the relationship between population, nature and development.

Kjekshush (1977, 1996) drew a relationship between rapid human and livestock population decline due to a series of epidemics including rinderpest and tsetse fly, loss of ecological control, and under-development that followed in the coastal and western parts of Tanzania. The main factors associated with loss of ecological control were: (a) migration and disruption due to constant warfare and destruction caused by tribal, colonial warfare and slave raiding; (b) internal displacement undermining any purposeful human activity on land and its surrounding flora and fauna environment; (c) depopulation due to epidemics and mortality leading to an ecological imbalance in favour of vegetative cover; (d) rapid spread of tsetse fly taking advantage of the bush cover to spread thus limiting livestock husbandry and men to confined settlements; and finally, (e) a shift in agriculture method to an environmentally destructive shifting or slash and burning cultivation method due to loss of man's permanent control of land [in that order] (Hyden, 1980; Kjekshush, 1996; Hodgson, 1997). Kjekshu's (1997) work drew from Hegelian-Marx 'dialectics' tradition which conceived human struggle with nature as material struggle resulting in social and economic development (Araujo, 2017; Bates, 1975; Foster, 2013).

In Marx's tradition, knowledge production and dissemination such as IK was constantly being developed by human beings in the course of their struggle with nature. This was aptly summarized by Foster (2013) who maintained that "our very knowledge of nature, in Marx's view, is a product of our productive relation to the natural world." The study extended this analysis to determine how IK was being lost as a result of loss of ecological and epidemic control, and migration from traditional areas (Hodgson, 2002). It was guided by three main objectives: (a) to determine whether those migration trends were induced by climate change and loss of ecological control; (b) to determine recent trends of pastoralist and livestock migration in Tanzania, and (c) to determine the implication of pastoralist migration and loss of IK.

2. Methodology

The study was conducted in seven districts located in the Northern, Central, Southern Highlands and Lake zones of Tanzania. Specifically, the study districts included Longido, Hanang, Kiteto, Mvomero, Iringa Rural, Bunda and Geita. These districts represented high livestock-keeping and pastoralist areas, diversity, and participation in the CARE National Pastoralist Programme (NPP).

2.1 Sampling Frame

The study used a stratified sampling technique that involved two sampling procedures. The first stratum used the purposive judgmental sampling procedure to arrive at the sample for the first and second strata of the study (district and ward). The main criteria followed in the first stratum was the selection of districts with large numbers of livestock pastoralist households, and participating districts

in the NPP. The criteria followed to arrive at the second sample stratum were locations where NPP participating pastoralist community based organizations (CBOs) were operating. The third sample stratum of beneficiary pastoralist households was selected through simple random sampling. This involved obtaining a list of beneficiary pastoralist households from respective pastoralist CBOs, then dividing the list according to the number of households preferred to participate in the study. The actual households which participated in the study were then selected through simple random sampling.

The sample size for the study was arrived at through the probability proportion to size (PPS) method. The PPS was deployed to ensure that respondents from particular districts to the total study sample were proportional to the overall number of NPP beneficiaries in a particular district. In the final analysis, the study sample covered 544 households, 17 focus group discussions (FGDs), and 54 key informant interviews (KIIs), as illustrated in Table 1.

Table 1: Distribution of Study Sample

S/N	Zone/District	Wards	No. of HH	HH Survey	KIIs	FGDs
1.	**Northern**					
1.1	Kiteto	Ndedo	594	90	10	02
1.2	Hanang	Bassotu	4,379	35	04	02
1.3	Longido	Engikaret	**1,322**	59	09	03
2.	**Lake**					
2.1	Bunda	Mcharo	**659**	85	08	04
2.2	Geita	Nyugwa		69	08	02
3.	**Central**					
3.1	Mvomero	Mvomero	8,679	120	08	03
4.	**Southern**					
4.1	Iringa (R)	Idodi	2,581	86	07	01
5.	**Total**		**542**	**54**	**17**	**542**

Source: Survey data, loss of ecological control, pastoralist migration and indigenous knowledge in Tanzania (2023)

2.2 Data Collection

The study used mixed methods to triangulate data sources to achieve an in-depth understanding of the dynamics of pastoralism, ecological control, migration and the loss of IK. The study used four main data collection methods: a semi-structured quantitative household questionnaire, open-ended FGDs, open-ended KIIs, and observation.

The semi-structured questionnaire was administered to households through a survey using enumerators. The objective of the semi-structured questionnaire was to produce quantitative data for the study. Qualitative surveys were also conducted to complement the quantitative survey with more open-ended,

exploratory and in-depth information about the study. FGDs involved women and girls, youths, and mixed community groups. KIIs targeted elderly people, the community, clan and household heads, and community leaders. Observation studies were conducted in four case-study pastoralist and agro-pastoralist villages of Muwiro and Mkurlu in the pastoralist migration push-zone; and in Msowero and Mvumi in the pull-zone. The study also consulted archival, secondary data sources, and published materials on the subject matter.

Data analysis for the structured quantitative questionnaire survey was conducted using the SPSS software. Qualitative information from FGDs and KIIs was transcribed into interview transcripts and analysed using the NVIVO software, and the taxonomic domain analysis method.

2.3 Ethical Statement

Ethical considerations as articulated by the research ethics policy of the Open University of Tanzania (OUT) were taken into account when conducting the study. The study research objectives were clearly read out to respondents before interviews were conducted. All study respondents were asked to provide their consent before embarking on an interview.

The study used cassette tape-recorders in the qualitative in-depth FGDs. In all occasions, group participants were clearly informed of their intended use, and the eventual archiving and disposal of the tape recordings. The protection of identity and confidentiality of respondents were explained and followed. All responses were anonymous, thus protecting the individual identity of the respondents. None of the respondents were minors below 18 years of age.

Research ethics and integrity guidelines as stipulated in the research ethics policy of the OUT were followed, including citation of all published materials and secondary data sources. All published materials and secondary data sources that have been cited are those which are in the public domain, and whose copyrights permit citation as long as the sources are duly acknowledged. The study has acknowledged sources from all such published materials in both the main text and list of references.

3. Findings and Discussion

A review of existing empirical literature on pastoralism showed that extreme weather variability aggravated a myriad of livestock diseases (Western & Manzolilo, 2003). A combination of livestock diseases and climate change contributed to the loss of epidemic control for livestock. The loss of epidemic control within specific locations was cited as a major push-factor prompting pastoralists to migrate to new ecological areas. Decisions to migrate were normally reached after IK practices generated to handle disease outbreaks during predictable climatic states could no longer cope with new epidemic proportions brought by new states of climatic disequilibrium.

According to the findings, climate change effects on the loss of pasture land and forage was the single most important factor that led to a large number of deaths of pastoralist livestock. More than half (57.2%) of pastoralist households that participated in the study admitted that unavailability of sufficient grass to pasture their livestock contributed to the deaths of a large number of their livestock.

The study established from KIIs that deaths of large numbers of livestock were an important factor that determined the migration of pastoralist households from their place of abode. The study respondents from KIIs further held that deaths of a very large number of pastoralist livestock from diseases was considered to be a determining factor for long-range migration of pastoralist household away from their existing ecosystem. Moreover, empirical literature suggests that climate change, loss of ecological control and loss of epidemic control are intertwined. Boone and Wang (2007) found that climate disturbances increased the prevalence of vector-borne diseases since it created favourable conditions for vector breeding, proliferation of pathogens and parasites, and thus the transmission of new diseases. Consequently, this affected the prospects of livestock size as survival rates drastically fell during prolonged drought seasons.

Climate change affected the balance between nature and livestock as dry months and even dry years meant there were less prospects for cattle to consume the same amount of forage as they were used to. This relates to the great hypothesis by Boone and Wang (2007) that lower forage quantity and quality resulting from effects of climate change led to less conversion and transformation of forage into energy within the bodies of cattle, and therefore lower disease immunity and survival (Gifford-Gonzalez, 2015).

Pursuant to this, Tafesse and Samson named *coenuruses* as a newly emerging disease most prevalent in the dry season, affecting the brains of goats and cows. In addition to *coenuruses, PPR, CBPP, tick infection, FMD, trypanosomiasis, salmonellosis,* liver diseases, tumour, bleeding and bloating, sudden death, black leg, and anthrax: all were reported to be climate change-sensitive, and on the increase. As a result, these diseases caused mass livestock deaths following climate disturbances occurring in the greater East-African Rift Valley region. Increasingly, deteriorating conditions and multiple emerging uses of rangeland were also exposing animals to increasingly graze on degraded pasture exposing them to the risk of a variety of soil-borne diseases (Frantkin, 2001; Oba, 2012; Butt, 2016). Cumulatively, these factors contributed to increased stress on pastoralism as a livelihood system leading to the loss of epidemic control to sustain livestock and pastoralism, and migration by pastoralists to new untested ecological zones (FAO & Cirad, 2017).

Empirical literature testified that the causes of livestock deaths among pastoralist households were diverse. According to Boone and Wang (2007) and FAO and Cirad (2017), loss of forage resulted into low energy intake by livestock which affected the capacity of livestock to reproduce, develop immunity to

diseases, and when migrating, the capacity to travel a long-distance. This analysis drew attention to the positive relationship between climate change, loss of ecological control and livestock epidemics. Other effects of the loss of ecological control cited by pastoralist households were the loss of cattle from dehydration because of the loss of drinking water sources. This was especially experienced during the dry season with no option for transhumance or 'micro-migration' as a traditional coping or adaptive mechanism to extreme climate variations. Such mechanism was difficult to use due to multiple changing land-use patterns, which blocked traditional transhumance corridors (Stahl, 2015; Venugopal et al., 2018).

The factors mentioned above were confirmed by study the findings from the pastoralist household survey. Less than a half (45.2%) of pastoralist households interviewed in the study reported that a large number of their livestock had died from epidemic and disease outbreaks. It was further confirmed during the FGDs that epidemic and disease outbreaks were on the increase, and that this was affecting other small livestock, and humans. The study established from KIIs that when the frequency and intensity of climate change increase, epidemic outbreaks increased; leading to the loss of disease control.

According to Venugopal (2018), another effect of climate change, and extreme and prolonged dry conditions was the loss of sources to drinking water for livestock. This was confirmed by the study findings where 38.38% of the pastoralist households in the surveys said they had lost a large number of pastoralist livestock from the lack of sources of drinking water. Information obtained from FGDs and KIIs conducted by the study confirmed that the general perception of pastoralist households was to begin long-range migration when there was an increase, and intermittent issue of insufficient sources of drinking water for their livestock. The study findings further showed that when depletion of these key resources intensified, they perpetuated violent conflicts among the pastoralists themselves, and with other population groups. Therefore, it came as no surprise that conflicts have characterized the lifestyles of pastoralist in Tanzania over decades. These conflicts have led to livestock deaths and theft as retaliation for perceived 'trespassing' in other land-use population areas. Physical—often violent and fatal confrontations—have been known to happen, contributing to distant pastoralist settlements from mainstream serviced settlements (Awinia, 2015). In many cases, local authorities took sides with permanent land settlers because the legal and regulatory framework was not embedded in the pastoralist way of life (Shao, 1986). Violent conflicts were confirmed by the study findings, where 36.16% of the pastoralist households reported that they were experiencing livestock theft in the course of migration. Nearly a quarter (24.72%) said they were experiencing violent conflicts with other pastoralists, and with other population groups.

The dilemma facing pastoralists was whether they should face vulnerability and try-out various coping mechanisms or embrace mitigation measures

including micro-migration; or migrate to other areas completely out of their current climatic zones in search of pasture, water or improved human and livestock health conditions. Information obtained by the study from FGDs and KIIs was that these were not easy decisions for pastoralist households to make. However, on the whole, migration has been a more popular choice for an increasing number of pastoralists, particularly since livestock herds in Tanzania begun increasing, thanks to improved veterinary services (Awinia, 2015; NBS, 2016). The study findings showed that 23.06% of the study respondents owned more than 50 cattle. In tandem, wildlife population had also drastically increased following increased conservation and management measures, including through wildlife epidemic control (WTTO, 2018).

Livestock and other herbivore populations compete for forage in the rift valley and their rate of energy intake is reflected in their rate of reproduction and mortality; so, their population would fluctuate around disequilibrium climate conditions compared to a stable condition (Gifford-Gonzalez, 2015). A combination of increased livestock, wildlife size, population and human settlements, agrarian reforms and expanded acreage under cultivation and climate change: all contributed to a disequilibrium state resulting in an increased density of herd sizes and dwindling forage; again, this leading to pressure over grazing land (Boone & Wang, 2007).

This dynamic begs us to revisit the notion of livestock carrying capacity of land. The question of stock size carrying capacity is relative to particular soils. Although the volcanic soils in Arusha were more fragile than in other parts of Tanzania, the number of livestock was much higher in Arusha at 19.2 cattle per hectare compared to the national average of 3.4 per hectare (NBS, 2015). Under normal circumstances, when the livestock carrying capacity rises to higher levels relative to available resources, it leads to the loss of ecological control; which, in turn, is likely to prompt the loss of epidemic control as already explained by Boone and Wang's (2007) great hypothesis. Another push factor for migration was climate change to extreme weather conditions, which further reduced the livestock carrying capacity of soils.

The impacts on the ecosystem and its consequent effects on pastoralism as a livelihood system were at the top of pastoralist household decision-making criteria for migration. Table 2 shows livestock keepers' perception on the criteria for migration based on a score of 1–5, with 5 being the highest.

As seen from Table 2, seasonal variation of rainfall and rising temperature emerged top of the list as criteria that influenced migration induced by climate change. Ogalleh et al. (2012) inform that indigenous people usually reported their perceptions of climate variability in the light of observed impacts. Individual perception is everything to such an individual, and plays an important part in risk assessment and decision to migrate. Wang's (2007) key informants mentioned frequent drought, rising temperature and reduction in the volume of rainfall and

Table 1: Perception of Climate Change Impacts as Criteria for Migration among Pastoralists and Livestock Herders

Criteria	Mean scores
Perception of temperature variability	
Hot dry season temperature increases	4.7
Main rainy season temperature increases	4.1
Temperature increases	4
Cold dry season temperature increases	3.6
Small rainy season temperature increases	3.1
Perceptions of rainfall variability	
The onset of rainfall becomes more unpredictable	4.7
The cessation of rainfall become more unpredictable	4.5
Drought occurrence frequency increase	4.5
Rainfall amount decreases	4.4
Number of main rainy season days decreases	4.2
Number of small rainy season days decreases	2.6

Source: Boone and Wang, 2007

the unpredictability of both the onset and cessation of the rainy season as the main criteria that determined decisions to migrate. These were compounded by non-climate stressors such as increase in livestock and human population pressure, rangeland deterioration, weakening of traditional rangeland management, and depletion of water and pasture resources in the area (Butt, 2016). These factors included perceptions regarding rising frequency and intensity of the occurrences of drought (Oba, 2009; Schwarz, 2015; Desalegn et al., 2017).

This premise was supported by Boone and Wang (2007) who contended that climate change, characterized by rising temperature coupled with falling precipitation, had profound effects on the land carrying capacity in both forage quality and quantity. Climate factors such as precipitation history, seasonal variations, topography and land-use changes affected climatic changes from stable and predictable states, to disequilibrium. A broader disequilibrium of these factors resulted into the loss of ecological control, which prompted hardships and the urgency to migrate to other ecosystems.

Pastoralist households that were interviewed as a part of this study mentioned factors that led to the deterioration of climatic conditions beyond a certain point, up to when livestock died in large numbers. These were the main reasons that triggered the decision to migrate to other ecological zones. Table 3 presents the various reasons that contributed to large loss of pastoralist livestock, and triggered their decision to migrate. According to the study findings, the major push-factors that triggered pastoralist migration to new agro-ecological zones were either loss of livestock or necessary conditions to sustain livestock herds, and rising levels of tension with other land users. The loss of pasture/forage or grass for grazing cattle was cited by the study respondents as the main reason causing deaths of livestock.

Table 3: Causes of Households Losing Livestock

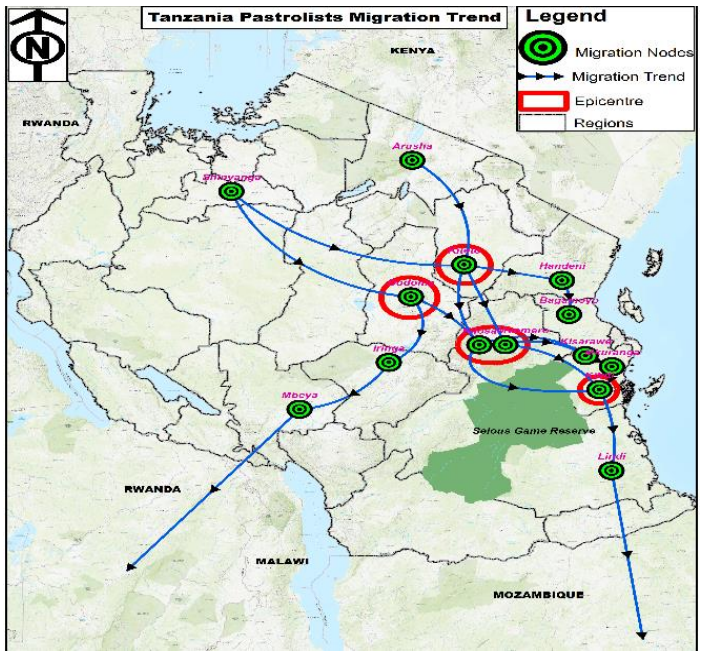
Causes of Loss	Frequency	%
Loss of pasture/forage (grass)	310	57.2
Epidemics	245	45.2
Loss of water (dehydration)	208	38.38
Theft	196	36.16
Conflict with other pastoralists or crop cultivators	134	24.72
Other	61	11.25

Source: Survey data, Loss of Ecological Control, Pastoralist Migration and Indigenous Knowledge in Tanzania (2023)

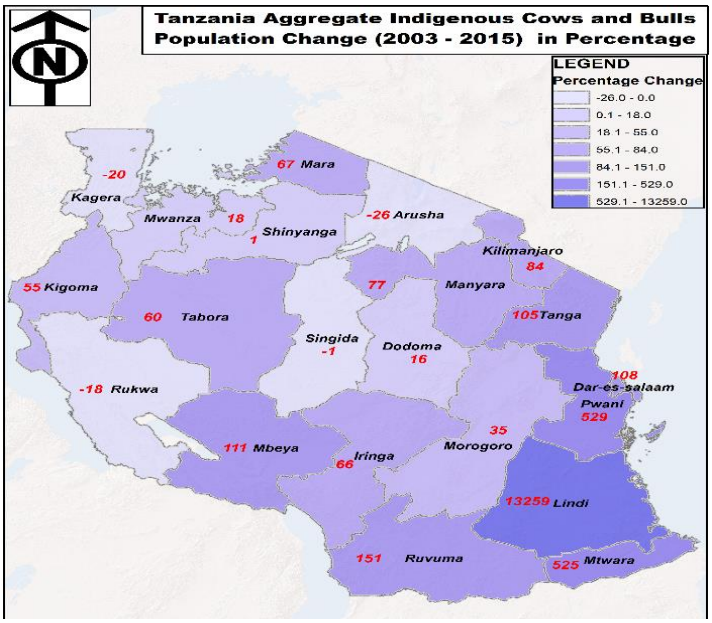
As seen in Table 3, the loss of pasture/forage was a high and pervasive cause affecting over half of the pastoralist households who participated in the study. The Loss of pasture/forage can clearly be alluded to as an effect of climate change resulting from declining precipitation levels or long-spells of dry weather and/or rise in night-time temperature, leading to the loss of livestock.

The cumulative effect of the foregoing cascading impacts of climate change and growing herd size due to improved veterinary services was causing strain on the traditional pastoralist lands. As a result, pastoralists were migrating from the northern parts of Tanzania (mainly Arusha and Shinyanga) southwards to well-known hotspots of convergence, transforming the new areas into corridors and centres of violent conflicts related to pastoralist movement, settlements, migration and internal displacement. This southward migration from the tropics was confirmed by national statistics derived from a review and analysis of secondary data sources from the Tanzania Agriculture and Livestock Census and Annual Agriculture Sample Survey, which showed there was a clear path of pastoralist migration from Arusha, Tarime, Mwanza and Shinyanga in three strands. The first strand was the Kiteto, Handeni and Bagamoyo route. The second was the Kiteto, Mvomero, Kilosa, Ihefu, Iringa route. The third strand included Mvomero, Kilosa, Kisarawe, Mkuranga to Rufiji route. Pastoralists who migrated from Arusha went across Kiteto, Dodoma to Iringa only to be deterred by the tsetse-infested region of Katavi in southwest Tanzania. Failing to move further, they crossed the Selous Game reserve to the south side to Mkuranga, Kibiti and Rufiji districts as illustrated in Maps 1 and 2.

The foregoing trends are backed by empirical data from the 2003 Livestock Census and 2015 Annual Livestock Survey, which show that livestock population increased southwards over the last 12 years; with the highest percentage change in growing livestock population being Kibiti, Rufiji and Lindi areas. According to the findings from secondary data sources, archival and literature review, as well as interviews with pastoralist households and FGDs and KIIs, there were several problems encountered by pastoralist households as they migrated. These problems contributed to their increased vulnerability in the new ecosystems into which they had not adapted. An immediate and natural loss was that of IK that had been acquired from previous ecosystems.



Map 1: General Pastoralist Migration Trends to Southern Tanzania



Map 2: Percentage Change in the Aggregate Number of Indigenous Cows and Bull by Region (2003-2015), Tanzania

Sources: Study empirical analysis derived from NBS 2006, 2016

Interaction between nature and human settlement in previous ecosystems had meant a dialectical struggle to adapt and subdue the vagaries of nature that had been ongoing (Harvey, 1993; Hodgson, 1997). This dialectical relationship over time, and through evolution and adaption, has produced a body of IK. IK relates to ecosystem specific resources and threats (Boone & Wang, 2007). Tafesse and Samson (2009), for example, show evidence of IK in areas either suitable or unsuitable for grazing in times of pasture loss. East African pastoralists had developed IK to avoid pasturing livestock in specific areas to avoid poisonous grass species. However, during drought, due to scarcity of feed and hunger, grazing animals were forced to consume poisonous plants, exposing themselves to phyto-poison (Western et al., 2003).

Coppolillo (2000) noted that migration among Sukuma agro-pastoralists in Tanzania contributed to a decrease in livestock productivity in milk. This was because low water availability, especially in the dry seasons, increased migration distances travelled by herds in search of forage and water. The effects of travelling further from home, often in large herds and across corridors of high settlement density affected intake rates, foraging behaviour, milk yields and body conditions. Coppolillo (2000) clarifies this thus:

> Cattle from larger herds were observed to walk more while actively foraging, taking more than ten steps without taking a bite. The increased walking of large herds explains why they range further from home and its effect on intake rates and milk yields (Coppolillo, 2000).

Frantkin (2001) identified factors contributing to increased out-migration of pastoralists from their traditional lands. The factors were human and livestock population growth; loss of herding land by pastoralists; increase in the size of land being allocated to protected, gazetted, wildlife management areas, hunting blocks, and game parks; and rural-urban growth compounded by drought, famine and land-use conflict with farmers and other land uses (Sen, 1981; Frantkin, 2001).

On the other hand, high mobility of livestock aggravated the spread of cattle diseases such as bovine pleuropneumonia, pasteurellosis and cattle respiratory complex diseases due to contact between animals from different regions, including wild animals. Migration to other ecosystem areas contributed to increased vulnerability through loss of IK accumulated over the years through careful adaption to ecosystem-specific conditions. Boone and Wang (2007) confirmed that traditional veterinarians had accumulated IK to effectively treat livestock diseases (black leg, FMD, CCPP, pasteurellosis, cowdriosis/heart water, bovine) using various plant roots, leaves and burning (blotting) swollen parts.

Sindiga (1994) documents diverse IK content used to treat a range of ailments affecting pastoralist livestock as shown in Table 3; attesting to active IK among pastoralists in Tanzania. Equally, it can be seen that IK was largely extracted from nature, particularly *flora.* Migration had a consequent impact on accumulated IK simply because the same flora and fauna did not exist in out- or in-migration areas.

As a result of loss of IK, pastoralist households were in a weak position to adapt in new in-migration ecosystems, rendering them vulnerable. It has been noted in the foregoing analysis that the challenges faced by pastoralist households were insurmountable; worse still, only few pastoralist households showed the capacity to address them for the lack of locally appropriate coping mechanisms based on IK acquired throughout the evolution period. This was evident from the study findings as shown in Table 4: that the majority of pastoralist households could only address problems caused by loss of ecological control and loss of epidemic control only to 'a modest extent' (32.29%), followed by 'small extent' (19.93%), or either 'not at all' (11.99% or 'do not know' (18.63%).

Table 4: Ability of Pastoralist Households to Apply IK in Climate Change Mitigation Measures

Extent	Frequency	%
Not at all	65	11.99
Small extent	108	19.93
Modest extent	175	32.29
Big Extent	90	16.61
Very big extent	3	0.55
Did not know	101	18.63
Total	542	100

Source: Survey data, Loss of Ecological Control, Pastoralist Migration and Indigenous Knowledge in Tanzania (2023)

It is evident from Table 4 that there were mixed levels of the ability to use IK in mitigating challenges faced in the new ecosystems. Cumulatively, about three quarters (73.25%) of respondents from pastoralist households reported they could not find IK solutions to their climate change-induced problems. They just had to succumb to the vagaries of the economic stagnation resulting from loss of cattle from various climate change induced and related causes.

The study further found that wherever pastoralists had gone, they went through a war path with other pastoralists or land cultivators. This has virtually left them internally displaced as a result of constantly moving around different conflict corridors. In Kibiti area—an area known for radical political views and extreme ideologically motivated violence—pastoralist in-migration has only served to further fuel violence in the area. Extreme violent views in the area were triggered by a ban on charcoal production through forest clearance by people indigenous to the area, while pastoralists were allowed to graze in the forests. In the coastal indigenous population's view, pastoralists grazing in the forest were causing more damage to the vegetative cover of fragile coastal soils compared to charcoal burning.

As pastoralists continued to migrate southwards in the midst of confrontations and cruises, pastoralist migration in Tanzania has fast become

an international issue (Park, 2015; Azcentral, 2018; Bank & Frohlich, 2018; IMO, 2018). Sections of pastoralists from Tanzania have already been sighted in neighbouring Zambia and Mozambique, causing conflicts with alternative land-users in their paths. Cross-border conflicts have inevitably introduced new, more profound and lethal dimensions compared to those within Tanzania (Choe, 2007; Bommes et al., 2014).

4. Conclusion and Recommendations

The study has established that perception levels among pastoralist households were key when pastoralist households were considering to migrate from one locale to another. The more extreme the level of impacts, the more likely pastoralist households would use that to reach a decision to migrate further into other ecosystems. It has been established in the discussion that there were several compounding factors that affected pastoralist lifestyles as a sustainable livelihood system. When the effects of climate change, land-use changes and competing interests over rangeland resources reached a certain stage, they triggered decisions for pastoralist households to migrate into new ecosystems. This was because the compounding effect of these factors, up to a certain critical level, culminated into the loss of epidemic control. The loss of ecological control definitely prompted climate-induced forced migration that has characterized pastoralist migration in Tanzania.

The livestock migration map in Tanzania clearly showed pastoralist migration trends to previously unchartered territories of central, coast and southern Tanzania. Migration into these areas was a double-edged sword causing the loss of IK accustomed to particular ecosystems of emigration, and facing new epidemics in in-migration territories. The study findings showed there was a positive correlation between climate change, rising temperatures, migration, and human and livestock diseases. This was partly caused by the loss of immunity of livestock due to habitat change, pre-eminence of new pathogens due to extreme weather conditions, and exposure to both livestock and human to pathogens in new areas of migration. The overall outcome has been an increased vulnerability to the loss of epidemiological control in new in-migration territories.

The study established that there was positive correlation between climate change, demographic shifts including morbidity and mortality, and migration as an adaptation and mitigation measure. In the final analysis, pastoralist migration in Tanzania presented a vivid illustration of how climate change is inducing pastoralist migration.

The study recommends that, first, further concerted efforts are needed to document, preserve and disseminate IK and innovation that was developed by pastoralists communities to strengthen community resilience and adaption to climate change. There is also need to urgently promote participatory land-use

plans in pastoralist areas. Participatory land-use plans will enlist cultural perspectives that will enable them to accommodate pastoralist needs in the wake of competing interests over land-use in pastoralist areas.

Second, the study recommends the adoption of IK in adaptation strategies to avoid loss of ecological control such as reducing herd size to maintain a manageable land carrying capacity, rotational grazing systems, integrated livestock and wildlife rangeland management, and gazetting of transhumance grazing land within the framework of the participatory land-use plans. Third, there is need for extensive and dedicated studies on pastoralist IK and genetic storage of medicinal plants that is disappearing due to climate change, habitat loss and migration. Lastly, the study recommends the mapping of trans-border transhumance patterns, and preserve and provide open access irrespective of their ward, district, region and international transboundary nature.

Moreover, further research is needed on the sustainability of pastoralism as a livelihood system in the foreseeable future. Studies need to focus on whether an ecological loss is imminent with climate change and extreme weather conditions. There are options that are available to pastoralists to adapt to climate change, including transforming their livelihood systems, mind-set and cosmology in the light of such changes. It is also important to carry out a study on the nature of intra-African migration in the light of changing weather patterns and ecological loss. Emerging disease patterns and epidemics that were previously under epidemic control, and now appear to be under the loss of epidemic control due to underlying loss of ecological control, need to be investigated. Additionally, research needs to look into the main factors driving the loss of ecological control and the role of the loss of IK in it, to complement alternative land-use and settlement patterns that could be adopted to sustain and assert ecological control in changing weather conditions.

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