Published in final edited form as:

Glob Environ Change. 2013 June ; 23(3): 588–597. doi:10.1016/j.gloenvcha.2013.02.010.

Adaptive Capacity in Tanzanian Maasailand: Changing strategies to cope with drought in fragmented landscapes

Mara J. Goldman [Assistant Professor] and

Department of Geography, Faculty Research Associate, Environment and Society Program, Institute for, Behavioral Science, University of Colorado at Boulder, Guggenheim 110; 260 UCB, Boulder, Colorado 80309-0260 USA, Phone: 303.492.8794 Fax: 303.492.7501

Fernando Riosmena [Assistant Professor]

Department of Geography, Faculty, Population Program, Institute of Behavioral Science University of Colorado at Boulder, 1440 15th St. 483 UCB, Boulder, Colorado 80309-0483 USA

Mara J. Goldman: Mara.goldman@colorado.edu; Fernando Riosmena: Fernando.Riosmena@colorado.edu

Abstract

This study examines the ways in which the adaptive capacity of households to climatic events varies within communities and is mediated by institutional and landscape changes. We present qualitative and quantitative data from two Maasai communities differentially exposed to the devastating drought of 2009 in Northern Tanzania. We show how rangeland fragmentation combined with the decoupling of institutions and landscapes are affecting pastoralists ability to cope with drought. Our data highlight that mobility remains a key coping mechanism for pastoralists to avoid cattle loss during a drought. However, mobility is now happening in new ways that require not only large amounts of money but new forms of knowledge and connections outside of customary reciprocity networks. Those least affected by the drought, in terms of cattle lost, were those with large herds who were able to sell some of their cattle and to pay for private access to pastures outside of Maasai areas. Drawing on an entitlements framework, we argue that the new coping mechanisms are not available to all, could be making some households more vulnerable to climate change, and reduce the adaptive capacity of the overall system as reciprocity networks and customary institutions are weakened. As such, we posit that adaptive capacity to climate change is uneven within and across communities, is scale-dependent, and is intimately tied to institutional and landscape changes.

Keywords

adaptive capacity; institutions; pastoralism; mobility; coping mechanisms; Maasai; Africa

1. Introduction

Vulnerability and adaptation to climate change are local and context-specific, though connected to complex processes at multiple temporal and spatial scales (Adger et al., 2003, 2005; Smit and Wandel, 2006). As such, there is a growing awareness that place-based

studies of current and past responses to climatic stress can shed light on the capacity of a given system to respond to future climate change (Engle and Lemos, 2010; Eriksen et al., 2005; Liverman, 1990).

There is also a growing appreciation of the importance of institutions—formal and informal—in shaping adaptation strategies and mediating the adaptive capacity of households and communities (Agrawal, 2008, 2010). While rural resource-dependent communities have historically coped with climatic fluctuations, whether such coping mechanisms are still successful today, and will be in the future, depends on the structure of supporting institutions and the way in which they mediate access to entitlements (Mearns and Norton, 2010).

Indeed, most social-ecological systems have undergone dramatic change in the last century due to climatic, landscape, and institutional shifts. Because coping mechanisms are developed in relation to particular landscapes, livelihoods, and institutions (Agrawal, 2008, 2010), social and ecological changes have altered relations across these elements, impacting the effectiveness of particular coping strategies (Wangui et al 2012). For instance, pastoralists have historically deployed a suite of coping mechanisms in response to the highly variable climate of semi-arid and arid landscapes (Barrow et al., 2007; Nassef et al., 2009; Scoones, 1995). Yet, these capacities maybe increasingly compromised in the rangelands of East Africa due to increasing exposure to climate extremes, such as flood and drought *and* shifting institutional environments (Galvin et al., 2004).

The mechanisms that pastoralists in East Africa historically utilized to cope with climate variability were part of a tightly coupled system where livelihoods, institutions, and landscapes were mutually reinforcing (Fratkin et al., 1994; Homewood, 2008). Pastoralists livelihoods were co-produced with a savanna mosaic landscape managed as a common property system by formal and informal customary institutions (Galvin et al., 2008b; Reid 2012). However, these landscapes are undergoing rapid change and fragmentation, with substantial impacts on livelihoods, institutions, and coping capacities (Galvin 2009). The system has decoupled, with increased diversification and privatization of livelihood practices across a fragmented and compartmentalized landscape, divided into different units managed by various competing institutions, with many key resources enclosed inside farms and conservation areas (Homewood et al., 2009).

We argue that, as the relationships between livelihoods, landscapes, and institutions change, so do the particular entitlement bundles needed to effectively cope with climatic variability and extreme events. Through a case study looking at responses to a recent drought by Maasai pastoralists in northern Tanzania, we illustrate that pastoralists are adapting to multiple changes and stressors in addition to a changing climate. We show that adaptive capacity is deployed through the use of new techniques to cope with drought within a changing landscape-institutions nexus. This includes the decline in certain customary strategies (e.g., reciprocity), the adoption of new strategies (e.g., purchasing feed) and the transformation of old strategies (e.g., mobility).

Coping strategies are differentially adopted by households within a community, reflecting varied and changing asset and entitlement bundles. Entitlements to pasture, historically based on relations of reciprocity, are being replaced by new capabilities of obtaining cash to lease exclusive rights to pasture, and new forms of knowledge and connections to secure such pastures outside Maasai controlled territory. Such capabilities are only available to some herders. We thus argue that institutional and landscape changes are leading to the emergence of more uneven capacities within and between communities. Additionally, as several of the new strategies further reinforce the very processes undermining pastoral land use in the region—fragmentation, and privatization—we posit that they are not contributing to the overall capacity of the larger social-ecological system to adapt to climate stresses within changing institutional settings.

We present household level data on herders' response to the 2009 drought in two Maasai communities in northern Tanzania differentially affected by the event. Maasai refer to this as the most severe drought in living memory, because pastures were severely depleted and mobility occurred on such a large scale. Yet droughts in 2000 and 2006 resulted in less rainfall, highlighting that vulnerability is not only a function of environmental susceptibility. Our analysis hinges on an appreciation that institutions mediate access to resources and that entitlement and asset bundles enable households to navigate institutions. This approach may enable increased understanding of adaptive capacity to such events in the future among pastoralists and other societies.

2. Adaptive Capacity, Institutions, and Entitlements

Adaptive capacity is a central concept of both vulnerability and adaptation analyses (Adger, 2006). It is defined as the ability of a system to adapt to climate-related hazards by designing and implementing new strategies or by expanding coping capacity to reduce vulnerability to these hazards (Brooks and Adger, 2004).

We focus on the specific ways in which pastoral communities are modifying coping mechanisms and how such changes reflect longer-term adaptive capacities to cope with climate variability in a fragmented landscape. While coping mechanisms are often seen as short-term reactions to events (Turner et al., 2003), they can also be understood as a part of an adaptive strategy, particularly when reflecting modifications on old behavior (Gallopín 2006). Our analysis is not a vulnerability assessment, which would require multiple measurements at various scales of impact. Rather, we use one particular measure of impact during the drought: loss of cattle, the key asset in pastoralist communities, and analyze how it is related to the use of a suite of coping mechanisms. Based on these results, we draw conclusions about the adaptive capacity of different pastoralists to deal with climate variability and extreme events, both predicted to increase with climate change (IPCC, 2012). Our data capture evidence of evolving drought-coping mechanisms amidst a backdrop of ecological and institutional change, which have increasingly restricted historical coping strategies, namely mobility. New strategies enable households with the right entitlement bundle (e.g., access to money, new knowledge, and connections) to proactively create new opportunities for mobility in a fragmented landscape. Our analysis reflects an understanding

of adaptive capacity as 1) tied to entitlement and asset bundles, 2) intimately connected to (formal, informal; local, trans-local) institutions, and 3) scale-dependent.

Adaptive capacity depends on the suite of environmental, social, economic, and political entitlements that particular individuals, households, or communities can mobilize to cope with risk (Leach, Mearns and Scoones 1999). According to Adger (2006: 270) entitlements are “the actual or potential resources available to individuals based on their own production, assets or reciprocal arrangements.” This includes livestock and other forms of wealth; farmland, reserve grazing areas (*alalili*), tenurial rights; gender norms, education, knowledge, and reciprocal relations enabling access to resources. Altogether, entitlements are ‘the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces’ (Sen, 1984, p. 497; cited in Adger 2006).

The entitlements approach is most commonly used to discuss vulnerability. In turn, adaptive capacity is the component of vulnerability best explained by the entitlements approach. The less capacity an individual, community, or society has to adapt to change and variability (including extreme events), the more vulnerable they are. Some people have access to certain entitlements while others do not, because of historically contingent processes of social differentiation and development (Ribot, 2010). These uneven entitlement bundles promote differentiated adaptive capacities among households in a community, and between communities.

It is common for entitlements and endowments to be linked to narrowly defined poverty measurements. This ignores the agency of social units, the role of knowledge and social relations, and the importance of institutions in mediating access to entitlements (Turner et al., 2003: 8075). Agrawal (2010: 174) argues that institutions have always acted as “the fundamental mechanism through which communities adapted in the past to climatic variability and they will be the primary mechanism mediating adaptation to climate change in the future.” Institutions shape the orientation of responses to climate risks in a given social and ecological context—towards individual or collective responses.

Agrawal's institutions framework, and his five-fold typology of coping strategies (mobility, storage, diversification, communal pooling, and market exchange) are particularly useful for understanding the adaptive capacity of changing pastoral systems. We look at market exchange but focus primarily on mobility, which Agrawal (2010) presents as the most natural and common response to climatic variability and stress, particularly for pastoralists (Niamir-Fuller, M. 1999). Mobility is a key coping mechanism for pastoralists in dealing with seasonal resource variability and drought, with restrictions on mobility negatively affecting adaptive capacity and increasing vulnerability (BurnSilver, Worden and Boone 2008, Oba and Lusigi 1987). While Agrawal's focus is primarily on formal institutions (civic, public, market/private), we follow Upton (2012) in illustrating the important role played by informal institutions such as social norms, rules, relations, and practices in mediating coping mechanisms among pastoralists.

Finally, the scale dependency of adaptive capacity suggests that particular actions or adjustments may produce positive results at one scale, such as the household, while leading to maladaptive outcomes at the larger community or social-ecological system scale (Engle 2011). Though they can refer to the same scale, the community may be a smaller component of a larger social-ecological system. Which strategies can be adopted among different households reflects differences in entitlement bundles, providing herders with uneven abilities to navigate institutions across scales. If newly adopted strategies do not work to build collective action at the community level, especially if they further perpetuate institutional mismatches, this could reduce adaptive capacity at the community/social-ecological system scale.

In East Africa, overlapping social institutions historically enabled a suite of coping mechanisms to support pastoralism across semi-arid landscapes where resources are variable in time and space. We now outline the history of this system and the ways in which landscapes and institutions have become fragmented and decoupled, thereby impacting extant coping capacities, particularly mobility.

3. Background

3.1 Resource management in Maasailand: Coupled Institutions and Landscapes

In this section and the next we draw from historical accounts and the lead author's ethnographic data (2002-4, living in one of the study villages, six-months in 2005) to recount the historical relationships between landscapes and institutions, which mediated Maasai resource use. Maasailand refers to a predominately semi-arid savanna landscape that historically stretched 150,000 km² from northern Tanzania into southern Kenya, where the rural population is dominated by Maa-speaking people (McCabe et al., 2010). The area was historically divided into territorial units, *iloshon* (sing: *oloshon*), referred to in English as 'sections' or 'tribes' (Jacobs, 1965). Each section was managed as a separate common property system, with social rules directing resource management (Galaty, 1981; Homewood and Rodgers, 1991); linked to other sections through joint institutional frameworks organized around clan and age-set affiliations (Spear and Waller, 1993). The age-set and clan links provided formal institutional frameworks for a decentralized system of leadership and informal social relations coordinating access to resources (Potkanski, 1999). The unit of herding was the polygamous household (*olmarei*, sg; *olmareta* pl.: a man, his wives, children, and other dependents). More than one *olmarei* often shared one homestead enclosure (*boma*, Swahili; *engang*, Maa), with cattle often corralled together at night and sometimes herded together.

Pasture access occurred through daily and seasonal mobility (see also Butt et al 2009; Homewood, 2008.), and was coordinated through informal rules within and across *oloshon* boundaries. Reserve pastures (*alalili*) were set aside by groups of households for use by calves and sick cattle. Relations of reciprocity coordinated access to *alalili*, water resources (also sometimes managed by clans), and pasture. During particularly tough times, no needy herder was denied access to water or pasture.

The successful pastoralist, therefore, had more than just cattle: s/he had good relations with age-mates and clan members, links through marriage to additional clan ties, and ties to respected elders and local leaders, all which assured his/her access to resources. This can be thought of as an extended set of entitlements: long-reaching social relations based on trust and reciprocity. Social networks and good relations with age-mates, clan members, and traditional leaders (*ilaigwenak*) were essential for facilitating mobility of livestock across large spatial scales in search of pasture and water (Homewood, 2008, Potkanski, 1994), and particularly important during droughts.

As with pastoralists across Africa, mobility was used to optimize the use of forage and reduce risks associated with disease and resource variability across time and space (Little et al. 2001, Westoby, Walker and Noy-Meir 1989). Today, while mobility remains an important herd management strategy, it has been constrained by fragmentation and conflicting institutional arrangements, with much of Maasailand now inaccessible to many if not all Maasai. The tightly coupled system has fragmented and decoupled.

3.2: Changing Landscapes, Institutions and Adaptations

[Today] even the wind has changed. The country has changed. ...Everybody asks why did you come to this place? Long ago, we moved like the wildebeest. [But today...] people have gone to *Maromboi* [in a neighboring village] and been taken by the police, it has become a park (Elder, Oltukai village, 2003).

Fragmentation has been noted as the single largest factor impacting pastoral rangelands today (Galvin et al, 2008a; Hobbs et al., 2008). In this section, we describe the ways in which fragmentation is occurring in Maasai rangelands covering all three types discussed by Hobbs et al (2008, 778): dissection, conversion, and compression. Landscapes are dissected through the creation of physical, social, and administrative boundaries; conversion turns pieces of rangeland into croplands or protected areas; and compression occurs with sedentarization and the increased density of people and animals in remaining rangelands (see also Fratkin, 2001). Fragmentation disconnects and dissects heterogeneous landscapes, constraining the mobility of people and animals and restricting their access to necessary pasture and water (Hobbs et al, 2008).

In Tanzania dissection and compression began with “operation villagization” in the 1970s, which forced all rural inhabitants to relocate into official organized villages (Hydén, 1980). In Maasailand the process was called operation *Imparnati*, meaning ‘operation permanent settlements’, highlighting the promotion of sedentarization (Ndagala, 1992). The creation of villages created new units of administration and new parameters for settlement, affecting the ways in which people thought about and practiced mobility (Parkipuny 1979). This is expressed by a group of women in one of the study villages when asked when mobility patterns changed (Group interview, Oltukai village 2003):

When the Makaa age-set started as warriors (1971) and when Operation *Imparnati* started to cut up areas for people to stay. People started to get places to stay. Before this, people would move. The elders would say let's go, all of Oltukai, let's move. It is not like this anymore, because we have come to get villages. If we leave to go to

Mswakini [another village] we can't because other people live there and now we have got our own place to stay.

Villages are administered by an elected chairman, council members, and a salaried executive officer. Most villages are too small to encompass all the resources needed by pastoralists throughout the year, especially during the early rains (which vary considerably across space) and during droughts. Mobility still occurs as a part of customary herd management, and is intensified during drought, often taking people and animals beyond village boundaries in search of water and pasture. Yet as expressed by the women in the quote above, today rather than entire families moving, young men often move with cattle to temporary *bomas* (*ronjo*), leaving women, children and elders behind in the resident village (to attend school, protect farms, and attend to small stock).

With increased sedentarization and farming, more land within Maasai villages is being privatized and converted to cropland (Homewood, et al, 2009; McCabe, et al., 2010). This means that mobility both within and beyond village boundaries is complicated by property delineations and conversion. There has also been a trend towards smaller land units, the individualization of settlements and livestock management, and the titling of land for tenure security (Homewood et. al., 2009). Customary formal and informal institutions are giving way to village and regional governance structures and private household heads in regulating access to resources (Cooke, 2007; Goldman, 2006). Much land has been converted into large-scale commercial farms and conservation areas, including parts of Tarangire, Arusha, and Serengeti National Parks, Ngorongoro Conservation Area, Lake Burungi and Enduimet WMAs, Manyara Ranch, and Mkomazi Game Reserve, which enclose drought reserve pastures and water sources for exclusive use by wildlife (Igoe, 2004).

Livelihood changes have also contributed to reduced mobility, while also increasing wealth stratification within Maasai societies (Homewood et al 2009). Those with the right bundle of entitlements cultivate large plots and intensify for-market livestock production using improved breeds. With more children in school, and young men working in cities, many families are often left without the labor needed to move cattle long distances (Goldman 2006). There is also an increased privatization of land and livelihoods with an associated decline in social pooling of resources and labor (Goldman, 2006 and field notes 2009).

All these changes pose a growing challenge to the use of mobility on a regular seasonal basis as a resource management tool. Yet, as mentioned above, mobility is still practiced, if in new and different ways. Research in Kenya has shown that even when lands are divided into private parcels, mobility in response to a drought, referred to as 'escape mobility' (Oba and Lusigi, 1987), still occurs (BurnSilver and Mwangi, 2006). Large-scale 'escape mobility' was witnessed during the 2009 drought when Maasai moved across private, state, and even national boundaries. In doing so, herders drew on remaining customary institutional frameworks while also negotiating with village government leaders, national park personnel, and private landowners in ways that required new forms of social relations, knowledge, and skills. Looking at data from 2009 collected in two related regions differentially impacted by the drought, we show that these new arrangements and capacities

are needed to practice pastoralism across a fragmented landscape with conflicting institutional frameworks.

4. Case Study: The 2009 Drought in Northern Tanzania

4.1. Study area

Research was conducted in two administrative districts: Monduli and Longido, in the *Kisongo* Maasai *olosh*. Data come from specific areas recognized as sub-sections within each district, Emanyara and Longido (Figure 1). Our Monduli sample comes from two Maasai villages recognized as the core of the “Emanyara” sub-section. In Longido, our sample comes from eight villages, recognized as “Longido.” Both areas are characterized as semi-arid: rainfall is bimodal, averaging 300–600 mm/year with high spatial and temporal variability (Homewood et al. 2009). Compared to Emanyara, Longido is slightly more arid, and was more severely impacted by the drought: 2009 was the third straight year of little-to-no rainfall. For this reason, unusually large numbers of herders from Longido migrated to Emanyara in 2009 (the latter was relatively better off, having received some rainfall early in the season). Site selection was influenced by the lead authors long-term research in Emanyara and the large number of migrants to this area from Longido during the drought. These sites capture different impacts of the drought while exhibiting common patterns of landscape fragmentation and livelihood practices for Maasailand.

Both study sites reflect the constraints of an increasingly fragmented landscape (Homewood et al., 2009). The villages in Emanyara, Oltukai and Esilalei, used to be part of one larger village that ran up to a peri-urban center bordering Lake Manyara National Park (LMNP), where herders accessed fresh water springs in the dry season. These springs were taken over by farms, and the larger village split into three smaller ones (Goldman, 2006). Bordered by Esilalei to the north, Oltukai is bound on three sides by conservation units: LMNP to the west; Lake Burunge Wildlife Management Area (WMA) to the south, which is a “community-based” conservation area, established by the state and coordinated by outside conservation agencies (Igoe & Croucher, 2007); and Manyara Ranch to the east, a conservation area run by the Tanzanian Land Conservation Trust led by the African Wildlife Foundation (AWF) (Goldman, 2011). Esilalei also borders Manyara Ranch and LMNP, and is at risk of losing dry season grazing areas to new conservation units in the eastern highlands (Goldman, 2006).

The number of farms more than doubled in both villages between 2002 and 2004 (Goldman, 2006). Individuals have begun to privatize their *alalili* reserve pastures or set them up exclusively for sub-village access. Residents of both villages used to regularly move cattle to *Maramboi*, a wooded pasture on the southern edge of Lake Manyara, at the start of the rains and during droughts, but the creation of the Lake Burunge WMA in 2005 prohibited grazing there. Grazing inside Manyara Ranch is allowed on a limited basis, by village residents in the dry season only, and is enforced by game scouts (Goldman, 2011). Important dry season reserves and water sources inside Tarangire National Park became off-limits with the establishment of the park in the 1970s (Igoe, 2004). Discussions of creating conservation corridors in the area raises the risk of the removal of more grazing land for conservation (Goldman, 2009).

Longido district has also been divided in many ways for conservation, growing agricultural development, and a new administrative center. Longido district is bounded by conservation areas: Ngorongoro Conservation Area to the west, Kilimanjaro and Arusha National Parks to the east and south, and Amboseli National Park just across the Kenyan border to the north (Trench et al., 2009). The Enduimet WMA, where grazing is prohibited, was established in 1997 as a pilot project and today straddles land in eight villages (Benjaminsen et al., forthcoming). There has also been a steady increase in farming by Maasai and non-Maasai throughout the area, further fragmenting the land within Maasai control (Trench et al., 2009).

4.2. Methods

At the end of the drought (January - February 2010), 148 structured interviews were conducted across the two areas: 51 in Emanyara and 97 in Longido. The larger sample for Longido is related to it being larger in size and population and more impacted by the drought. Our estimated average losses for both areas are consistent with estimates reported in a follow up study (2011), and from reports of organizations working in the area. We used these data to look at how the effect of the drought on livestock holdings was mediated by different coping mechanisms, money spent, and site. The impact of the drought was measured by the outcome of cattle loss, or the ratio of cattle that *died* during the drought to the total pre-drought holdings. This is consistent with other work measuring the impact of drought among pastoral societies (McPeak and Barrett, 2001).

Our unit of analysis is the household, measured through the individual herder in charge of livestock, generally the household head. Household level analyses are common in pastoral areas, where a household is usually defined as a male-headed polygamous unit, with multiple dependents and potential contributors to household entitlements (salary, labor, education, and connections) (Homewood, 2008). We interviewed those in charge of managing livestock and making decisions about mobility and overall livestock care (e.g., use of medicines, feed). The contributions of other household members (money and labor) were addressed in particular questions regarding where money came from and what restricted certain activities. While there are clearly some limitations to this approach, it was necessary when interviewing people away from home, and does reflect the entitlements of the entire household through questions on contributions.

Insights regarding adaptive capacity were gained by examining the suite of coping mechanisms used by households. In addition to looking at the amount of money spent in coping activities, we asked whether households bought *pumba* (a mixture of grain shafts and corn husks), illegally grazed inside national parks or on private property, purchased exclusive grazing rights on private land, split herds, sold cattle, or purchased veterinary medicine. Illegal grazing was removed from the quantitative analyses because of concern over accuracy of the data but is addressed in the ethnographic data.

To assess the role of a particular coping strategy, we estimated Poisson regressions on the number of cattle lost. By adding the pre-drought holdings as an offset, the estimation is mathematically equivalent to modeling the rate of loss (Powers and Xie 2008: 189-190), and as such appropriate to studying cattle mortality risks (e.g. see Loneragan et al. 2001). The

exponentiated coefficients of the model are risk ratios, the relative difference in the rate of cattle lost from adopting vs. not adopting a particular coping mechanism, or more generally, the relative effect of an increase of one unit in the scale of the independent variable on the risk ratio.

In addition to the survey data, in-depth ethnographic data were collected at the beginning (March–July 2009) and after (February 2010) the drought. This included unstructured interviews with herders in Emanyara, including migrant herders from Longido, observation of particular individuals and casual conversations through participant and non-participant observation. These data were used to expand findings from the survey, which we first describe on the aggregate with our multivariate analyses and then more detail using descriptive analyses. All names used in the manuscript are pseudonyms. The ethnographic section includes an in-depth profile of “Maika” who was one of our research assistants. He can be seen as representative of the larger population in that his herd size (148) is slightly above the overall average (111), but below the Emanyara average (208) and he is recognized as an average player in the village in terms of politics and livelihood.

4.3. Results and Discussion

4.3.1. The big picture—Herders across both sites averaged 112 cattle pre-drought, and lost on average 55% of their herds to the drought (Table 1). As mentioned above, however, the drought was much more severe in Longido: in Emanyara, the average loss was only 10% while in Longido it was 87%. The increased severity of the drought in Longido may have limited which coping strategies were effective for herders in the area, thus compounding its effects. For instance mobility and the sale of cattle often occurred after animals were already in poor condition, thus bringing little relief.

Herders in both sites spent a lot of money attempting to mitigate the effects of the drought, spending an average of \$US 978 in Longido and \$US 830 in Emanyara. Despite similar averages, the median amount spent was considerably larger in Longido (\$US 715) than in Emanyara (\$US 168), suggesting that the much higher ratio of cattle lost by herders in Longido was not due to investing fewer financial resources.

As shown in Panel A, Table 2, the money spent in attempting to mitigate cattle loss was obtained through various means: selling goats (59%), especially in Longido (85%); selling cattle (38%), particularly in Emanyara (94%); or through loans from family members or friends (33% overall, 12% in Emanyara, 44% in Longido). Only 14% of the sample reported using money from salary wages (15 from Longido and 5 from Emanyara). Finally, five herders in Longido and 1 in Emanyara reported using money from a business and six herders (all from Longido) reported receiving money from a son who worked in town. Although these results suggest that a diversity of sources were used, note they do not denote the percentage of money coming from each source.

Money was spent in different ways in the two sites, as illustrated in Panel B, Table 2. While nearly all Longido herders spent money on *pumba* (100%), veterinary medicine (97%), moving cattle (92%) or splitting their herds (88%), very few purchased exclusive rights to pasture (8.2%). Herders in Longido needed to move their cattle longer distances (and

multiple times) and thus spent a lot of money to carry small calves, scout for grass and water, purchase food and fuel, and for networking (i.e., phone costs, buying food and drinks during negotiations). Although the vast majority of herders from Emanyara also spent money on buying *pumba* (86%) and veterinary medicine (100%), only around half spent money moving their cattle (55%) and on splitting herds (49%) relative to the aforementioned 92% and 88% in Longido. In contrast to Longido, a considerably larger share of herders from Emanyara (51%) spent money on buying exclusive rights to pasture on private land, a strategy that proved particularly effective at reducing cattle losses, as shown next.

These results are further illustrated in our multivariate Poisson model (see Table 3, Model I), where being from Longido is associated with a rate of loss 3.7 times higher than that of Emanyara ($p < 0.001$) after controlling for money spent and the mix of coping mechanisms used by each herder. The model also highlights that money itself did not help to mitigate the effects of the drought after controlling for the strategy mix used; in fact the relationship is significant and positive with a 1% *higher* loss ratio for every \$US 100 spent on coping strategies ($p < 0.001$).

Instead, our results suggest that a significant investment on *specific* strategies was required to avert high loss levels. Some strategies were not effective at all and might have even been counterproductive while drawing on resources. For instance, herders buying *pumba* had a considerably higher loss ratio than the very few not doing so. On the other hand, selling cows was associated with a 25% lower mortality rate for the whole the herd ($p < 0.001$). Concentrating resources by selling cattle is an important coping strategy if done early, before cattle are too thin and the markets too saturated with stock (McPeak and Little, 2006).

Our results also illustrate that several types of mobility requiring a substantial investment were key in reducing loss. Paying for exclusive access to private pasture is associated with 32% lower loss ratios. This practice involved paying a landowner outside of the village for exclusive rights to graze on their land, often in different micro-climatic zones (e.g., agricultural highlands, irrigated lowland farms). Note that this indicator does not include customary forms of mobility (anywhere beyond the homestead and often beyond village boundaries), which were also important: those that moved suffered 22% lower loss ratios than non-movers (the timing of moving mattered as well, as described at the end of this section) In contrast, splitting herds, another customary strategy requiring mobility, was not significantly associated with (lower) loss ratios.

As shown in Table 4, these relationships are even stronger when looking only at those with large herd sizes (> 40 cattle, roughly the median number of pre-cattle holdings, $n = 77$). Those with large herds likely had the necessary bundle of entitlements (access to cash, knowledge and social connections in Maasai and non-Maasai areas) to enact the strategies that worked best. Consistent with this notion, moving cattle and buying pasture were particularly relevant for this group.

In contrast, no strategy was significantly associated with reducing loss ratios among those with small herds ($n=71$). This lack of statistical significance is unlikely to be the result of low statistical power as the sample size of the two groups is similar. Indeed, those with

smaller herds likely had access to fewer entitlements and assets and thus employed fewer coping strategies, which rendered them more vulnerable to the drought. This is illustrated by the fact that small herders in Longido suffered considerably larger loss ratios than their counterparts in Emanyara (11 times, $p < 0.001$) relative to what large herders in Longido suffered compared to those in Emanyara (3.5 times, $p < 0.001$). As the drought was more severe in Longido than Emanyara, this suggests that in worse environmental conditions, those with fewer assets and entitlements are more vulnerable.

In our post-drought interviews, herders were asked to reflect on their ability to protect their cattle during the drought. Only 17 individuals thought they did well, all from Emanyara. Of these, 6 stated they were able to move early—before the drought worsened and before others arrived at a new location. Perhaps most interesting is that 10 of the 17 herders stated that they did well because they had an *alalili* they were able to use, with two of these individuals stating that their success was based on denying others access to these reserve pastures, a violation of Maasai norms of reciprocity. An *alalili* is often managed by a *boma*, or a group of *bomas*, with access available to others as long as the grazing is for calves or sick cows. During the drought, access to *alalili* pastures was denied for the first time herders in Emanyara could recall, which reflects another result of the privatization of management. Of those who thought they fared poorly during the drought, 78 stated the severity of the drought and lack of money as the reason. People also mentioned spending more money than ever before on veterinary medicine. This was likely related to moving cattle to places they had never moved to before.

4.3.2. Personal stories: an ethnographic perspective—We now present ethnographic data of a couple of individuals whose experiences are typical of those who did well in this drought. Their experience demonstrates how access to an entitlement bundle of cash, social networks, and knowledge on how to interact with new institutional arrangements were strategic in mitigating risk during this drought in new ways.

In Emanyara, at early signs of the drought in November–December, a few herders moved their cattle to pastures in Simanjiro district—which had received more rainfall and had more open pastureland. Their ability to do so was based on connections in the area; access to cash to buy veterinary medicine to protect against tick and tsetse-fly borne diseases more prevalent in Simanjiro; a car to survey pastures and carry calves; and the ability to pool labor with other herders. Not everyone was able to move at this early stage. Rains eventually came to Emanyara and village government officials in Simanjiro sent migrant herders back home, though those from places that did not receive rain (e.g., Longido) were allowed to stay. In this way, local government institutions acted to mitigate grazing practices historically negotiated along customary lines.

During the long rains in March–May, Oltukai village was one of the few villages to receive several days of rainfall and have a dam filled with water. It was thus subjected to large numbers of in-migrating herds, particularly from Longido District but also from Kenya. As the rains ended early and pastures were nearly depleted due to the increased number of migrant cattle, those with the ability to do so began to look for places to move their herds.

As rainfall was sporadic, options were few and herders began to look outside the bounds of their customary movement patterns, drawing on new and different social networks.

The story of Maika and his friends is particularly revealing. As migrant herders moved into his village, Maika took advantage of this opportunity to exchange information, make new friends, and link into larger social networks. He befriended Mollel, a wealthy herd-owner from Longido, who was looking for a place to move his cattle. Maika and Mollel complemented each other well. Mollel had money and a car, allowing them to set off on a weeklong tour in search of pasture. Maika, who grew up in the area, had connections with local Maasai and many non-Maasai in surrounding places as he had previously been involved in marketing maize and was currently involved in the cattle market business. Maika's connections proved invaluable in purchasing grazing rights in the nearby agricultural town of Karatu. He relied on a salary advance for the \$US 1,500 required to gain exclusive access to the dried maize husks and grass on the 40 acre farm. With this, Maika moved half his herd to this pasture until the near end of the drought. This was the first time that he had 'bought pasture' in this way, and others began to follow suit.

When pasture was nearly depleted in Oltukai and neighboring Manyara Ranch, Maika once again set off in search of pasture for the remainder of his herd. In the meantime he split his herds up strategically: some cattle were left on the farm in Karatu, some were sent to where they were previously in Simanjoro where he paid for water, while most were sent to Magugu, an agricultural village where he partnered with another friend and paid \$1,000 to access 140 acres of pasture. Magugu is an irrigated area and still had water and grass when other areas were dry. Cattle were fed in farms during the day and snuck into Tarangire National Park at night. This cost additional money and Maika sold 80 goats to have cash on hand to pay fines when caught grazing inside the park, which happened several times. He also had a motorcycle, enabling him to move between split herds and return home if needed. Maika benefitted from the help of a younger brother in charge of cattle in one location far from home while pooling labor with other herders elsewhere. Eventually the pasture in Karatu was depleted and he relocated those cattle to Magugu as well.

Maika returned home with his cattle on November 17, 2009, after several days of rainfall. On the way home with his cattle he paid a fine for grazing inside the WMA. He complained that the drought cost him a lot of money (US\$ 2,554), but he was happy that his losses were minimal in comparison to others, as he lost only 6% of his 148 cattle.

Maika's success during this drought came from his ability to combine old and new sources of knowledge, skills, and capital, and act in a timely manner. He was one of the first in his village to move, to a Maasai area where he had social connections. He was the first to purchase private pasture, a practice he learned about from Mollel, but negotiated through his own connections. His job as a research assistant meant he had access to cash advances of his salary when market prices for cattle were falling.

Further, Maika's connections to non-Maasai and his ability to negotiate village government politics facilitated his movement into nearby agricultural villages. Money to buy pasture from private landowners was not enough; he needed approval from village governments to

be in the area. Sometimes this required obtaining letters from veterinary officers attesting to the health of the herd, buying beer and meat for government leaders, and spending days negotiating access with unfriendly and resistant communities (such as with agro-pastoral neighbors that had previously been subject to Maasai cattle raids). He had social relations and capabilities that extended beyond the traditional Maasai system.

Maika was not the only one able to negotiate this complex landscape of overlapping institutions. In Magugu he was with a group of men who, like him, were involved in the cattle market business and therefore had many non-Maasai connections and well-honed negotiation skills. They all also had access to cash to pay for the movement of their cattle and to pay for exclusive rights to pastures. Two herders who worked together calculated that they spent close to \$4,000 on buying pasture. This does not include money spent on medicine, gas, and other costs of mobility.

Despite these “success” stories, many in Oltukai did not have access to cash, labor, or the connections to move in the ways that Maika and his friends did. Most of them stayed in Oltukai until all the pasture was gone and then moved where they could to neighboring, friendly villages. Some moved to accessible but crowded places in Magugu, from which they illegally entered the National Park and faced the threat of losing their cattle, as they did not have the money to pay fines. Others simply bought the *pumba* mixture and kept the cattle at home (23 herders). As also shown on Table 3, these herders lost on average a higher ratio of cattle than the more fortunate and well-positioned ones who were able to use mobility more strategically.

Despite their larger loss ratios, Longido residents also utilized a wide variety of skills and resources to keep (some of) their cattle alive during this drought. According to herders themselves, those that were able to move early did better than others, as did those with a wide array of connections both within and beyond Maasai society. Further, the majority of Longido herders had cattle of the “improved” breed, Sahiwal. While this was more of a risk, as such cattle are harder to keep alive during a drought, it also provided herders with an added negotiating tool. Many Longido migrants to Emanyara and Simanjiro used these cattle as capital even when market prices were poor, by ‘gifting’ some to local herders, in exchange for assistance in negotiating local networks for access to pasture and water. Others used cash to pay for such assistance.

Some herders from Longido were able to gain early access to pastures by enrolling the support of customary leaders as well as village government leaders. There was also the need to pay for access to pasture in certain places, and for water, and many grazed illegally inside protected areas, including Manyara Ranch, which was only officially open to local herders. Ranch management personnel had such a difficult time restricting access to migrant herders that they demanded Oltukai and Esilalei residents evict migrants from village land, or otherwise lose access to the Ranch for themselves. Such a demand violated Maasai reciprocity norms and was initially met with resistance. Eventually Longido herders were forced to leave the area by Manyara Ranch management and local law enforcement, with the help of many local Maasai. This reflects one of the ways in which new institutional frameworks are affecting Maasai customary grazing norms.

5. Conclusions

In this paper, we looked at responses to the 2009 drought among Maasai in Tanzania to better understand how herders respond to extreme weather events within a decoupled institutions and landscapes context. While pastoralists have always adapted to climatic variability, social relations and coping techniques developed with intact grasslands are no longer sufficient in the current fragmented landscape (Galvin 2009). In examining coping strategies employed by individual herders we highlight that certain coping techniques are being modified (i.e., mobility), and reduced (i.e., reciprocity), while new ones are effectively being adopted by some (i.e., purchasing private rights to pasture). Our data show that herders who lost the fewest cattle during the drought had the right bundle of entitlements to adopt these new strategies and negotiate beyond the current restrictions that fragmentation poses for mobility. They had financial and social capital in the form of connections that stretched beyond the local level and knowledge that stretched beyond Maasai institutions.

Through our analyses we are able to glean insights about future adaptive capacity in relation to long-term climate change with direct implications for pastoral societies and relevant lessons regarding the adaptive capacity of other resource-dependent communities. First, Maasai pastoralists are developing new coping mechanisms to deal with climatic variability and extreme events in line with the current restrictions placed on their old coping strategies, namely mobility. This is consistent with literature on the long-term adaptive capacity of pastoral societies (Scoones, 1995). Those with entitlement bundles that enable them to reach beyond the constraints of fragmentation are likely to have an increased adaptive capacity over those who do not possess such entitlements. This included access to sufficient labor and money, and the right social connections and knowledge to utilize labor and money effectively.

Second, adaptive capacity, as related to entitlements and assets that cannot be defined by wealth and poverty alone, is being mobilized at the household level in uneven ways within and across communities. This finding is consistent with the entitlements framework, but may extend it further by looking at 1) adaptive capacity to changing institutions and landscapes as well as to climate change, and 2) the ways in which the need for new entitlement bundles (i.e., cash, new knowledge and connections) to navigate fragmented landscapes is introducing increased inequality in communities.

A more tentative third conclusion derived from our results, yet applicable to many other SESs, is the important scale-dependency of adaptive capacity: increased adaptive capacity of some households may not lead to increased adaptive capacity for the community or the social-ecological system as a whole. On the contrary, institutional changes might be fostering a rise in inequality within and between communities and, ultimately, leading to coping strategies that may actually undermine the sustainability of the social-ecological system. As mentioned above, fragmentation, and privatization threaten the sustainability of savannas and challenge the practices of mobile pastoralism. Our data show that individual Maasai herders are adapting to climatic extremes (i.e., drought) in ways that capitalize on and contribute to these processes through the purchase of exclusive rights to pasture inside enclosed private (non-Maasai) lands and by denying access to *alalili* reserves.

While only a few individuals in the sample mentioned denying access to *alalili*, the implications for this are far-reaching. During informal conversations with herders in Emanyara in 2010 and 2011, people spoke of this action as the most prominent long-term impact of the 2009 drought. Many attested that while they did not deny access to their *alalili* in 2009, they would do so if such a drought occurred again.

As such, while some households are positively adapting to the constraints of their new environment, this has led and could further lead to increases in stratification within communities as well as a reduced adaptive capacity of the social-ecological system through increased privatization and individualization of land and labor that has already placed the system at risk by reducing reciprocity. Galvin has warned that, “without the trust associated with social capital, herders tend to use individualistic strategies that help them in the short term to access resources but which may actually increase their vulnerability in the long term.” (2009:192). Our results are consistent with this notion and suggest that interventions to improve adaptive capacity across scales should focus on strengthening institutional-landscape linkages and address disparities in the distribution of entitlements within communities. Future research should address this possibility by looking at both household and social-ecological system-level processes facilitating or hindering adaptation to climate change and appropriate institutional supports.

Galvin suggests pastoralists are linking up with political allies and activist organizations to help prevent more fragmentation and land loss (2009: 192). Such linkages may help slow fragmentation down and increase reciprocity and cooperation across administrative boundaries. This could help reunite institutions and landscapes in a way that supports mobile pastoralism and increased adaptive capacity more generally. As stated in the introduction, the ability of resource-dependent communities to adapt to climate change is intimately tied to the ways in which supporting institutions mediate access to resources. As we have illustrated in this paper, the current institutional landscape has complicated access to resources for the average Maasai herder. In this case, adaptive capacity thus needs to be understood as the ways in which some herders (and not others) are able to adapt to climatic events within this new system, and how their actions are impacting both the adaptive capacity of others and of the overall social-ecological system.

Acknowledgments

We thank Ashwini Chhatre and Arun Agrawal for inviting us to participate in the AAG meeting session on Climate Change Adaptation, Landscapes, and Institutions, which greatly influenced the final analysis in this paper. We thank Nicole Smith, Colleen Scanlan Lyons, Jesse Ribot, Meaghan Daly and two anonymous reviewers for valuable feedback on early drafts. We are grateful to COSTECH for permission to conduct this research in Tanzania and we thank villagers in Oltukai, Esilalei and throughout Longido for answering our questions. We thank Mungai Well and Daniel Alais for their assistance in the field. We acknowledge Nancy K. Thorwardson at the Institute for Behavioral Science at CU-Boulder for producing the map for this paper. We acknowledge administrative and computing support from the Eunice Kennedy Shriver NICHD-funded University of Colorado Population Center (grant R21 HD51146). The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of NIH or NICHD.

7. References Cited

Adger WN. Social Capital, Collective Action, and Adaptation to Climate Change. *Economic Geography*. 2003; 79:387–404.

- Adger WN. Vulnerability. *Global Environmental Change*. 2006; 16:268–281.
- Adger WN, Arnell NW, Tompkins EL. Successful adaptation to climate change across scales. *Global Environmental Change Part A*. 2005; 15:77–86.
- Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. *Progress in Development Studies*. 2003; 3:179–195.
- Agrawal, A. The Role of Local Institutions in Adaptation to Climate Change World Bank Social Dimensions of Climate Change Workshop. The World Bank; Washington DC: 2008.
- Agrawal, A. Local Institutions and Adaptation to Climate Change. In: Mearns, R.; Norton, A., editors. *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. The World Bank; Washington DC: 2010. p. 173-198.
- Barrow, E.; Davies, J.; Berth, S.; Matiru, V.; Mohamed, N.; Olenasha, W.; Rugadya, M. IUCN Eastern Africa Regional Office. Nairobi: 2007. Pastoral Institutions for managing natural resources and landscapes; p. 4
- Benjaminsen TA, Goldman MJ, Minwary M, Faustin M. Wildlife Management in Tanzania: Recentralization, Rent Seeking, and Resistance. *for Development and Change*. forthcoming.
- Brooks, N.; Adger, WN. Enhancing Adaptation. In: Lim, B.; Spanger-Siegfried, E., editors. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. United Nations Development Programme; New York: 2004.
- BurnSilver, SB.; Mwangi, E. Beyond group ranch subdivision: Collective action for livestock mobility, ecological viability and livelihoods; Conference on pastoralism and poverty reduction in East Africa: A policy research conference; Nairobi. 2006.
- BurnSilver, SB.; Worden, J.; Boone, RB. Processes of Fragmentation in the Amboseli Ecosystem, Southern Kajiado District, Kenya. In: Galvin, KA.; Reid, R.; Behnke, RH.; Hobbs, NT., editors. *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*. Netherlands: Springer; 2008. p. 225-253.
- Butt B, Shortridge A, WinklerPrins A. Pastoral Herd Management, Drought Coping Strategies, and Cattle Mobility in Southern Kenya. *Annals of the Association of American Geographers*. 2009; 99(2):309–334.
- Cooke, AE. Subdividing the savanna: the ecology of change in Northern Tanzania. University of North Carolina; Chapel Hill: 2007.
- Engle NL. Adaptive capacity and its assessment. *Global Environmental Change*. 2011; 21:647–656.
- Engle NL, Lemos MC. Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*. 2010; 20:4–13.
- Eriksen SH, Brown K, Kelly PM. The Dynamics of Vulnerability: Locating Coping Strategies in Kenya and Tanzania. *The Geographical Journal*. 2005; 171:287–305.
- Fratkin, E. *Surviving Drought and Development: Ariaal Pastoralists of Northern Kenya*. Westview Press; Boulder: 1991.
- Fratkin E. East African Pastoralism in Transition: Maasai, Boran, and Rendille Cases. *African Studies Review*. 2001; 44:1–25.
- Fratkin, E.; Galvin, K.; Roth, EA. *African pastoralist systems: an integrated approach*. Rienner Publishers: Boulder; 1994.
- Galaty J. Land and Livestock among Kenyan Maasai. *African and Asian Studies*. 1981; 16:68–88.
- Galvin KA. Transitions: Pastoralists living with change. *Annual Review Of Anthropology*. 2009; 38:185–198.
- Galvin, KA.; Reid, RS.; Behnke, RH.; Hobbs, NT. Fragmentation in semi-arid and arid landscapes: consequences for human and natural systems. Springer; Netherlands: 2008a.
- Galvin, KA.; Reid, RS.; B, RH., Jr; Hobbs, NT.; Galvin, K. Responses of Pastoralists to Land Fragmentation: Social Capital, Connectivity and Resilience. In: Galvin, KA.; Reid, R.; Behnke, RH.; Hobbs, NT., editors. *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*. Springer; Netherlands: 2008b. p. 369-389.
- Galvin KA, Thornton PK, Boone RB, Sunderland J. Climate variability and impacts on east African livestock herders: the Maasai of Ngorongoro Conservation Area, Tanzania. *African Journal of Range & Forage Science*. 2004; 21:183–189.

- Goldman M. Partitioned nature, privileged knowledge: Community based conservation in Tanzania. *Development and Change*. 2003; 34:833–862.
- Goldman, M. *Sharing Pastures, Building Dialogues: Maasai and Wildlife Conservation in Northern Tanzania*, Geography. University of Wisconsin-Madison; Madison, WI: 2006.
- Goldman M. Constructing Connectivity? Conservation Corridors and Conservation Politics in East African Rangelands. *Annals of the Association of American Geographers*. 2009; 99:335–359.
- Goldman M. Strangers in their own land: Maasai and wildlife conservation in Northern Tanzania. *Conservation and Society*. 2011; 9:65–79.
- Hobbs NT, Galvin KA, Stokes CJ, Lockett JM, Ash AJ, Boone RB, Reid R, Thornton PK. Fragmentation of rangelands: Implications for humans, animals, and landscapes. *Global Environmental Change*. 2008; 18:776–785.
- Homewood, K. *Ecology of African Pastoralist Societies*. Ohio University Press; Athens, Ohio: 2008.
- Homewood, K.; Kristjanson, P.; Trench, P. *Staying Maasai?: Livelihoods, Conservation and Development in East African Rangelands*. Springer; 2009.
- Homewood, K.; Rodgers, A. *Maasailand Ecology: Pastoralist development and wildlife conservation in Ngorongoro, Tanzania*. Cambridge University Press; New York: 1991.
- Hydén, G. *Beyond Ujamaa in Tanzania: Underdevelopment and an Uncaptured Peasantry*. University of California Press; Berkeley: 1980.
- Igoe, J. *Conservation and globalization: A study of national parks and indigenous communities from East Africa to South Dakota*. Wadsworth/Thompson Learning; Belmont, CA: 2004.
- Igoe J, Croucher B. Conservation, commerce, and communities: The story of community-based wildlife management areas in Tanzania's northern tourist circuit. *Conservation and Society*. 2007; 5:432–449.
- IPCC. Summary for Policymakers. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. In: Field, CB.; Barros, V.; Stocker, TF.; Qin, D.; Dokken, DJ.; Ebi, KL.; Mastrandrea, MD.; Mach, KJ.; Plattner, GK.; Allen, SK.; Tignor, M.; Midgley, PM., editors. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press; Cambridge, UK, and New York, NY, USA: 2012. p. 3–21.
- Jacobs, AH. *The Traditional political organization of the Pastoral Masai*. Oxford; Oxford: 1965.
- Little PD, Smith K, Cellarius BA, Coppock DL, Barrett K. Avoiding Disaster: Diversification and Risk Management among East African Herders. *Development and Change*. 2001; 32:401–433.
- Liverman DM. Drought Impacts in Mexico: Climate, Agriculture, Technology, and Land Tenure in Sonora and Puebla. *Annals of the Association of American Geographers*. 1990; 80:49–72.
- Leach M, Mearns R, Scoones I. Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management. *World Development*. 1999; 27:225–247.
- Loneragan GH, Dargatz DA, Morley PS, Smith MA. Trends in mortality ratios among cattle in US feedlots. *Journal of the American Veterinary Medical Association*. 2001; 219:1122–1127. [PubMed: 11700712]
- McCabe JT, Leslie PW, DeLuca L. Adopting Cultivation to Remain Pastoralists: The Diversification of Maasai Livelihoods in Northern Tanzania. *Human Ecology*. 2010; 38:321–334. [PubMed: 21915157]
- McPeak JG, Barrett CB. Differential Risk Exposure and Stochastic Poverty Traps Among East African Pastoralists. *American Journal of Agricultural Economics*. 2001; 83:674–679.
- McPeak, JG.; Little, PD. *Pastoral Livestock Marketing in Eastern Africa*. Intermediate Technology Publications; London: 2006.
- Mearns, R.; Norton, A. *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. The World Bank; Washington DC: 2010.
- Nassef, M.; Anderson, S.; Hesse, C. *Pastoralism and climate change: Enabling adaptive capacity*. Overseas Development Institute; Nairobi and London: 2009.
- Ndagala, DK. *Territory, Pastoralists, and Livestock: Resource Control among the Kisongo Maasai*. Almqvist & Wiksell International; Uppsalla: 1992.

- Niamir-Fuller, M. Managing Mobility in African Rangelands: the legitimization of transhumance. Intermediate Technology Publications Ltd; London: 1999.
- Oba G, Lusigi WJ. An Overview of Drought Strategies and Land Use in African Pastoral Systems. Agricultural Administration Unit, Overseas Development Institute. 1987
- Parkipuny, MLO. Some Crucial Aspects of the Maasai Predicament. In: Coulson, A., editor. African Socialism in Practice: the Tanzanian Experience. Spokesman; Nottingham: 1979.
- Potkanski, T. Property Concepts, Herding Patterns and Management of Natural Resources among the Ngorongoro and Salei Maasai of Tanzania. IIED; London: 1994.
- Potkanski, T. Mutual Assistance among the Ngorongoro Maasai. In: Anderson, D.; Vigdis, BD., editors. The Poor Are Not Us: Poverty and Pastoralism Ohio. University Press; 1999. p. 199-218.
- Powers DA, Xie Y. Statistical methods for categorical data analysis: Emerald Group Publishing. 2008
- Reid, R. Savannas of Our Birth: People, Wildlife, and Change in East Africa. Berkeley: University of California Press; 2012.
- Ribot, J. Vulnerability does not just Fall from the Sky: Toward Multi-scale Pro-poor Climate Policy. In: Mearns, R.; Norton, A., editors. Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World. The World Bank; Washington, DC: 2010.
- Scoones, I. Living with Uncertainty. Intermediate Technology Publications; London: 1995.
- Scoones, I. Sustainable Rural Livelihoods: A Framework for Analysis Institute for Development Studies. Brighton, UK: 1998.
- Smit B, Wandel J. Adaptation, adaptive capacity and vulnerability. Global Environmental Change. 2006; 16:282–292.
- Spear, T.; Waller, R. Being Maasai: Ethnicity and Identity in East Africa. Ohio University Press; Athens: 1993.
- Trench, PC.; Kiruswa, S.; Nelson, F.; Homewood, K. Still “People of Cattle”? Livelihoods, Diversification and Community Conservation in Longido District. In: Homewood, K.; Kristjanson, P.; Trench, PC., editors. Staying Maasai?: Livelihoods, Conservation and Development in East African Rangelands. Springer; New York: 2009. p. 217-256.
- Turner BL, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L, Eckley N, Kasperson JX, Luers A, Martello ML, Polsky C, Pulsipher A, Schiller A. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences. 2003; 100:8074–8079.
- Upton C. Adaptive capacity and institutional evolution in contemporary pastoral societies. Applied Geography. 2012; 33:135–141.
- Wangui E, Smucker T, Wisner B, Lovell E, Mascarenhas A, Solomon M, Weiner D, Munna A, Sinha G, Bwenge C, Meena H, Munishi P. Integrated development, risk management and community-based climate change adaptation in a mountain-plains system in Northern Tanzania. Journal of Alpine Research. 2012; 100:1–16.
- Westoby M, Walker B, Noy-Meir I. Opportunistic Management for Rangelands Not at Equilibrium. Journal of Range Management. 1989; 42:266–274.

Figure 1. Map of Study Area

Table 1
Descriptive statistics on pre-drought cattle holdings, ratio and number of cattle lost during drought, and money spent in attempts to mitigate loss, by site

	Emanyara	Longido	Total
A. Pre-drought cattle holdings (No.)			
Mean	208.5	60.9	111.8
Median	58.0	31.0	41.0
Minimum	5.0	4.0	4.0
Maximum	1,354.0	900.0	1,354.0
Std. deviation	308.0	107.8	211.7
B. Cattle lost during drought (No.)			
Mean	31.5	47.4	41.9
Median	4.0	21.0	16.5
Minimum	0.0	1.0	0.0
Maximum	400.0	810.0	810.0
Std. deviation	73.1	90.1	84.7
C. Ratio of cattle lost during drought to pre-drought holdings (%)			
Mean	10.1	78.4	54.9
Median	6.1	86.5	68.8
Minimum	0.0	13.3	0.0
Maximum	36.4	100.0	100.0
Std. deviation	10.0	21.7	37.4
D. Amount of money spent trying to mitigate cattle loss (USD)			
Mean	830.1	978.3	927.2
Median	168.0	715.0	538.0
Minimum	19.0	62.0	19.0
Maximum	3,846.0	3,846.0	3,846.0
Std. deviation	1,224.2	890.8	1,016.3
N	51	97	148

Table 2
Percentage of herders using specific strategies to attempt mitigating the effects of drought on cattle and sources of money to finance strategies, by site

	Emanyara	Longido	Total
A. Sources of money used to finance strategies (%)			
Sold goats	9.8	84.5	58.8
Sold cows	94.1	8.2	37.8
Loan from friends/relatives	11.8	44.3	33.1
Salaries/wages	11.8	15.5	14.1
Other	3.9	15.5	11.5
B. Strategies used to attempt averting cattle loss (%)			
Pumba	86.3	100.0	95.3
Veterinary medicine	100.0	96.9	98.0
Moving cattle	54.9	91.7	79.0
Splitting herds	49.0	87.6	74.3
Exclusive rights to private pasture	51.0	8.2	22.9
N	51	97	148

Table 3
Risk ratios of place of origin, per 100 USD spent on cattle loss mitigation, and of specific coping strategies on the likelihood of cattle loss

Herder from Longido	3.65 ***
Money spent in cattle loss mitigation (per 100 USD)	1.01 ***
<u>Use of specific coping strategies:</u>	
Used <i>pumba</i>	8.28 ***
Sold cattle	0.75 ***
Purchased exclusive rights to private pasture	0.68 ***
Moved cattle	0.78 ***
Split herds	1.03
N	148
AIC	1,543
Pseudo r-squared	0.73

 $p < 0.001$

**
 $p < 0.01$

*
 $p < 0.05$

$\dagger$
 $p < 0.1$

Table 4
Risk ratios of place of origin, per 100 USD spent on cattle loss mitigation, and of specific coping strategies on the likelihood of cattle loss, by herd size

	Small herders (< 40 cattle)	Large herders (≥ 40 cattle)
Herder from Longido	11.07 ***	3.49 ***
Money spent in cattle loss mitigation (per 100 USD)	0.99	1.02 ***
<u>Use of specific coping strategies:</u>		
Used <i>pumba</i>	<i>a</i>	3.83 **
Sold cattle	0.83	0.77 ***
Purchased exclusive rights to private pasture	1.12	0.64 ***
Moved cattle	0.83	0.81 **
Split herds	1.18	1.01
N	71	77
AIC	348	1177
Pseudo r-squared	0.54	0.76

 $p < 0.001$

**
 $p < 0.01$

*
 $p < 0.05$

†
 $p < 0.1$

^a Coefficient could not be reliably estimated due to separation issues