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Coping with Natural Hazards in a Conservation Context: Resource-Use Decisions of Maasai Households During Recent and Historical Droughts

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Abstract Analyzing people's decisions can reveal key variables that affect their behaviors. Despite the demonstrated utility of this approach, it has not been applied to livelihood decisions in the context of conservation initiatives. We used ethnographic decision modeling in combination with qualitative comparative analysis (QCA) to examine the herding decisions of Maasai households living near Tarangire National Park (TNP) during recent and historical droughts. The effects of the establishment of TNP on herding practices during drought were different than anticipated based on the size and reliability of several prominent resource areas that are now within the park. We found little evidence of people relying on these swamps and rivers for watering cattle during historical droughts; rather, these sites were more commonly used as grazing areas for small stock and wet-season grazing areas for cattle to avoid disease carried by calving wildebeest. Yet during the 2009 drought, many herders moved their livestock – especially cattle from outside of the study area – toward TNP in search of grazing. Our analysis of herding decisions demonstrates that resource-use decisions are complex and incorporate a variety of information beyond the size or reliability of a given resource area, including contextual factors (e.g., disease, conflict, grazing) and household factors (e.g., social capital, labor, herd size). More broadly, this research illustrates that pairing decision modeling with QCA is a structured approach to identifying these factors and understanding how opportunities, constraints, and perceptions influence how people respond to changes in resource access.

Keywords Decision modeling · East Africa · Livelihoods · National parks · Pastoralism · Protected areas · Qualitative comparative analysis

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Introduction

Decision making is the link between people's context and actions. Through decisions, people integrate information about their situation and translate those perceptions into behaviors that have impacts on themselves and their surroundings. Thus, understanding "why people …do what they do" is relevant to a wide range of fields (Gladwin 1989: 7). Decision modeling is a tool that is meant to address this fundamental question, and one that has been applied to a variety of topics including the study of health behaviors (Johnson and Williams 1993; Ryan and Martínez 1996), agricultural economics and practices (Gladwin 1992; 1976), and psychology (Beck 2005).

There have been calls for more decision analysis in political ecology research (Robbins 2004), and decision modeling could be especially informative for studying the ways in which the social impacts of environmental conservation initiatives translate into human behaviors that have environmental consequences (Miller *et al.* 2012). Decision modeling has been used to assess different stakeholder perspectives on

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environmental management options (Redpath *et al.* 2004), but this is distinct from most applications, which evaluate actual behaviors (Ryan and Bernard 2006). It is also different from agent-based modeling, which requires the formalization of "choices" within a simulated environment but does not identify the factors influencing real behaviors. In fact, understanding decision-making processes could reveal key variables affecting resource use and thus be instructive for developing agent-based models (Miller *et al.* 2010).

Livelihood decisions are particularly relevant to conservation issues because they interface with social factors and ecological dynamics. Livelihoods influence social-ecological systems by altering population distributions (de Haan 1999), resource use (Chambers and Conway 1992), land cover (Birch-Thomsen *et al.* 2001), food security (McCabe 2003; Pedersen and Benjaminsen 2008), disease transmission (Masanjala 2007), and social structures (Bryceson 2002). Livelihoods also capture multiple aspects of living and working conditions beyond income, such as activities, resources, and social relations (Barrett *et al.* 2001; Ellis 1998). Furthermore, a focus on livelihoods helps to account for salient differences in the origin and means of attaining household resources, which are characteristics that can be overlooked by metrics such as socioeconomic class (Birch-Thomsen *et al.* 2001). In this view, households draw on assets (i.e., natural, social, human, physical, and financial capital) in order to engage in activities (e.g., farming, herding, wage labor). A household's decisions are influenced by its access to these five types of assets, the accumulation and use of which are mediated by cultural, institutional, economic, and environmental factors (de Sherbinin *et al.* 2008).

Livestock-based livelihoods (broadly referred to here as pastoralism) have allowed people to persist in arid and semi-arid environments around the world. There is great diversity, both within and across pastoralist groups, of social organizations, livestock species, diets, and involvement in alternative livelihoods (Dyson-Hudson and Dyson-Hudson 1980; for a recent review of African pastoralism, see Homewood 2008). Yet several elements of pastoralism are found across a variety of settings: mixed-species herding, mobility, and social institutions for resource management and exchange. These attributes allow herders to capitalize on the spatial and temporal variability in rainfall and primary production that characterize arid and semi-arid rangelands (Coughenour *et al.* 1985; Ellis and Swift 1988).

During droughts, herders typically move their livestock to areas that maintain water and grazing such as rivers, swamps, and forests, but pastoralist access to these drought resource areas (DRAs) can be inhibited by the presence of disease vectors (e.g., tick, tsetse fly), conservation initiatives, and development. Restricted resource access may be influencing the livelihood decisions of pastoralists living adjacent to world-renowned protected areas, which are experiencing considerable anthropogenic environmental changes. The objective of this study is to better understand how these challenges are interrelated by examining resource-use decisions of Maasai pastoralists. In particular, how have changes in access to DRAs influenced pastoralist livelihood decisions?

We address this research question by focusing on Maasai households living in communities that vary in proximity to Tarangire National Park (TNP). We hypothesize that resource access restriction due to the establishment of TNP has influenced Maasai livelihood decisions, such as where to take livestock during dry periods. In particular, we expect that households living near the park responded to the loss of access to the Tarangire River and Silalo Swamp following the establishment of TNP in 1970 by shifting resource use to a small number of remaining bottomland sites; however, we anticipate that the factors affecting decisions about where to water livestock during droughts vary with levels of village water development.

Study Area & Population

The iconic savanna landscapes of East Africa support remarkable populations of large mammals (e.g., wildebeest, elephant, lion) and a network of world-renowned protected areas. The rangelands of the Kenya/Tanzania border region receive a mean annual rainfall of about 300 to 1,200 mm (Gichohi *et al.* 1996), but this region exhibits high annual and inter-annual rainfall variability and low-rainfall years are common (Prins and Loth 1988). Annually, the climate regime is characterized by a dry season from June to October and a rainy season from November to May; the rainy season is often subdivided into the short rains (November to January) and the long rains (February to May) (Prins and Loth 1988). Maasai pastoralists, who inhabit the rangelands of northern Tanzania and southern Kenya, cope with annual and inter-annual variability through flexibility in the composition of their livestock herds, mobility, social institutions that regulate access to water and grazing resources, and household structure (Homewood and Rodgers 1991; Spear and Waller 1993).

A Maasai man, his wives, and their dependents form a unit referred to as an *enkishomi* or *olmarei*, and these household units are traditionally affiliated with other *olmarei* that are organized within a compound called an *enkang* (McCabe *et al.* 2010; O'Malley 2000). Each *olmarei* typically owns a combination of cattle, goats, and sheep, which are moved across the landscape to take advantage of seasonally productive pastures. Temporary *enkang* are sometimes established during dry seasons and droughts when livestock are moved to areas that are far from the household.

Streams and rivers are widely used water sources. When surface water is no longer available in rivers,[1] hand-dug wells are used to access water for livestock and households. Maasai communities regulate the use of specific water sources through nested access rules. Sections are social and political units that regulate access to large territories and thereby limit the use of grazing areas and water resources to people within broad geographical areas (Homewood and Rodgers 1991). Clans[2] regulate access to particular hand-dug wells, and well users establish an order of use for each day that is based on clan membership, village affiliation, and household location (Miller and Doyle 2014). Residence, age, and kinship form "circles of rights" that overlap incompletely, so if the relationship in terms of one of the circles does not establish the right needed by someone for access to a resource, one of the other circles might (Ndagala 1992). This remains true for wells in riverbeds, but the situation is changing – many people are getting access to water through boreholes, which are typically regulated by village committees. Customary institutions for managing water are thus being either replaced or supplemented through formal government institutions (Miller and Doyle 2014).

The Kenya/Tanzania border region has also undergone considerable changes in land use and availability. A historical period (1883–1902) that had substantial bearing on land use patterns is collectively referred to among Maasai as *Emutai*, meaning "to finish off (completely)" in reference to the complete destruction of their herds (Waller 1988: 74). First, an outbreak of bovine pleuropneumonia reduced livestock numbers, then rinderpest swept through sub-Saharan Africa during the 1890s, killing about 90 % of the cattle and large numbers of domestic sheep and goats (Normile 2008). As a result, an estimated two-thirds of Maasai in Tanzania died of starvation, and the famine stimulated livestock raiding between different Maasai sections. These catastrophes were concurrent with a smallpox epidemic. This decline in livestock, wild ungulate, and human populations led to a reduction in grazing and burning activities. Consequently, areas of bushland expanded, facilitating the spread of tsetse flies and trypanosomiasis, which discouraged people from returning to some areas (Homewood and Rodgers 1991; Koponen 1988). The British colonial government later implemented tsetse eradication programs, but overall, colonial rule served to further constrict the territory of Maasai pastoralists.

Postcolonial policies, international development programs, and influxes of cultivators from other areas increased pressure on available rangeland resources. Following independence in 1961, the Tanzanian government instituted the Villagization Program ("Ujamaa") – and later, more directed regional efforts that became known as "Operation Imparnati" in Maasailand – whereby people were required to resettle near village centers in permanent structures (Ndagala 1982). Since that time, international development programs (e.g., World Bank structural adjustment programs) and large-scale commercial agriculture (e.g., wheat, barley, and flowers) further reduced land and water availability (Fratkin 2001), and alienated residents from large tracts of land (Igoe and Brockington 1999; Igoe 2004). Moreover, Maasai themselves are increasingly participating in cultivation and wage-labor (Homewood *et al.* 2009; Little *et al.* 2001; McCabe *et al.* 2010; Thompson and Homewood 2002). The establishment of conservation areas by the Kenyan and Tanzanian national governments has exacerbated competition for remaining resources (Campbell *et al.* 2000) and has raised concerns about livelihood sustainability (McCabe 2003), food security (Galvin *et al.* 2004), access to and control over land and resources (Goldman 2011; 2003; Igoe 2004; Sachedina 2006), drought coping strategies (Goldman and Riosmena 2013; Western and Manzolillo-Nightingale 2004), and local perceptions of risk (Baird *et al.* 2009).

This body of work has identified and described the social impacts of conservation and development projects, and called attention to injustices and policy failures. However, questions remain as to how household herding strategies during drought have changed over time as a result of these and other factors. Such information is necessary for informing socially and environmentally responsible conservation and development initiatives. We address this research gap by focusing on the Simanjiro Plains, Tanzania, a critical wet-season dispersal zone for wildlife from TNP and home to Maasai as well as smaller numbers of people from a variety of other ethnic groups. The establishment of TNP alienated Maasai from the Tarangire River and Silalo Swamp, which have been described as two of the most reliable dry-season water and grazing sites in the ecosystem and historically important DRAs (Goldman 2003; Igoe and Brockington 1999; Igoe 2004; 2002; Sachedina 2006). We sought to understand how this dramatic change in resource access, coupled with water development efforts, has influenced the herding decisions of Maasai households. We focused on four villages in Simanjiro that vary in proximity to TNP and have different levels of water development (listed here in approximate order of increasing water infrastructure; for a more detailed summary see Baird 2014): Sukuro, Terrat, Emboreet, and Loiborsoit. This work is also informed by a limited amount of quantitative and qualitative data from the villages of Loiborsiret and Landanai (Fig. 1).

[1] We use the term "rivers" loosely to refer to rivers, streams, and korongos (i.e., seasonal waterways). The vast majority of drainages in the study area were intermittent or ephemeral.

[2] Clans are patrilineal groups which constrain marriage opportunities and access to hand-dug wells, and provide geographically dispersed social support networks (Homewood and Rodgers 1991; Spear and Waller 1993).

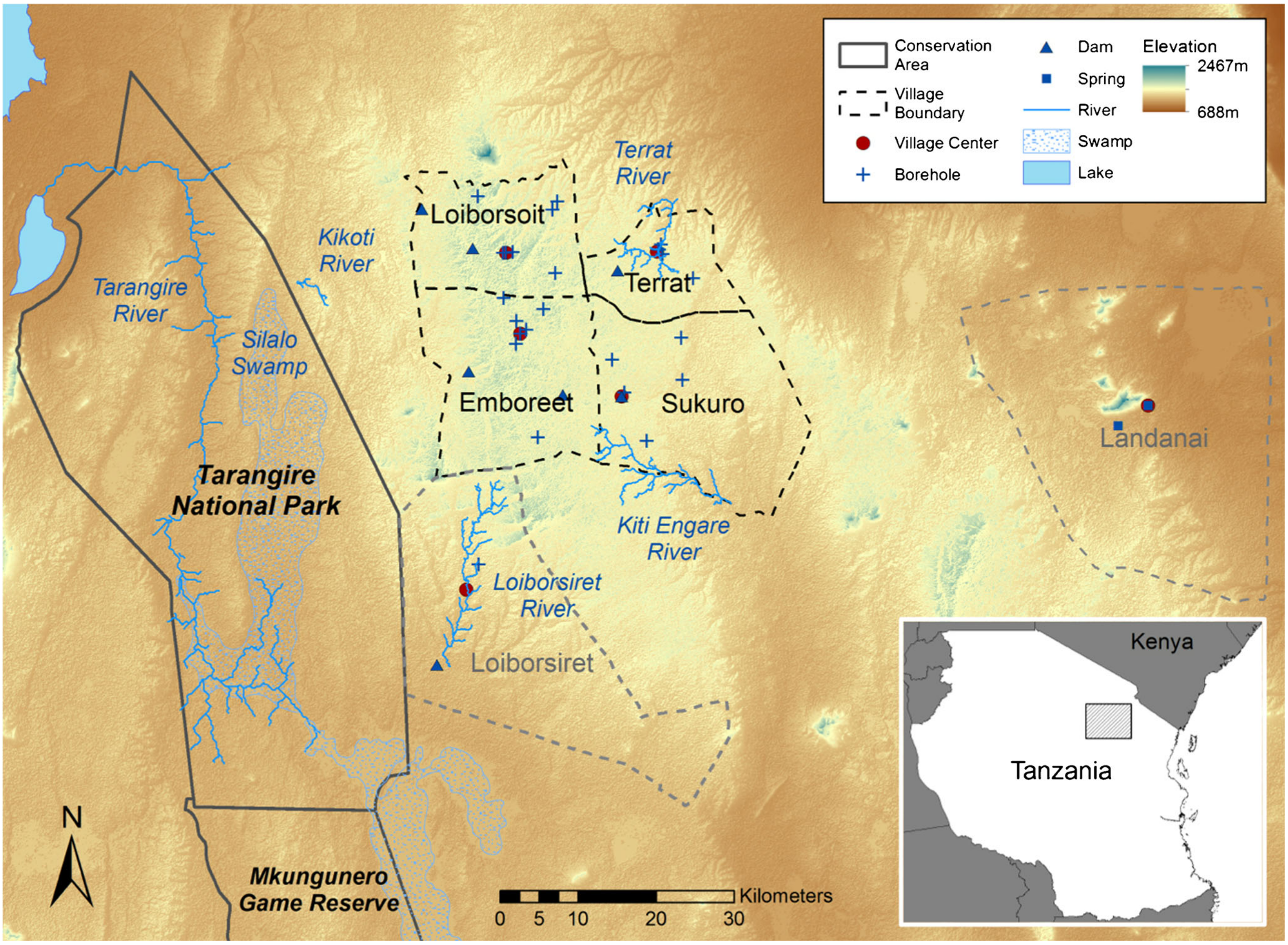


Fig. 1 Map of four main study villages (black dashed lines) and two additional study villages (grey dashed lines) in the Simanjiro Plains, Tanzania. Water sources shown on the map are not necessarily productive or functioning; rivers indicate the location of elevation-derived flow paths and may not represent active channels, and some dams and boreholes were broken at the time of data collection

Data & Methods

This research is based on 43 semi-structured group interviews and a survey of 134 male household heads in 2011, and is informed by extensive ethnographic data collection, comprising several decades of experience in the region and over 10 years of research in the study villages. Interviews and surveys were collected with the assistance of two Maasai Tanzanian field assistants who are fluent in English, Kiswahili, and Maa (the Maasai language).

First, we constructed a timeline of historical droughts and water development projects through interviews with village leaders. We used this hydrologic event calendar in combination with a chronology of social landmarks (e.g., warrior initiations) in order to improve respondents' recall of resource use patterns during past droughts. We then used ethnographic decision modeling (described by Bernard 2002) to analyze decision-making. This process entails identifying decision criteria, relating criteria to specific choices, and building decision models from these data. The decision criteria, or factors, reflect respondents' perceptions of household and resource conditions; thus, decision modeling is based on the premise that decision makers are the experts on how they make choices (Gladwin 1989).

For the first step of ethnographic decision modeling, we conducted semi-structured group interviews that addressed household responses to changing DRA availability induced by TNP, cultivation, and water development projects. These interviews concentrated on where people have taken livestock and acquired household resources during recent and historical droughts. We focused on water sources in order to streamline analysis and because it was frequently cited as the resource of greatest concern; however, the interview format allowed for the possibility that the availability or location of other resources (e.g., fodder) influenced water-use decisions. In addition to gaining a general understanding of drought resource use, the objective of these interviews was to identify decision criteria (e.g., distance to resource, labor requirements, rules/restrictions) that influenced where people obtained water during droughts. Responses from group interviews were compiled into decision-making criteria. For example, if an interviewee stated that he used a borehole during the last drought because it was the closest source of water to his household and he did not have to wait to use it, this response would have yielded proximity to household and waiting time as the criteria for resource use.

Group interviews thereby elicited an aggregated set of criteria that influenced people's decisions about resource acquisition. By necessity, these criteria were simplifications of more complex categories of factors; for instance, a range of social relationships – including acquaintances, kinship ties, and friendships – was found to influence access to water sources, and we grouped these relationships into a single "social capital" criterion in order to streamline QCA. Parameters were defined broadly in order to reflect each respondent's perceptions of a given variable (e.g., herd size, grazing availability) – which is consistent with the aforementioned premise of decision modeling – and to allow for dichotomization into Yes/No responses (discussed below).

The cultural rules and norms that regulate resource access are important and shape individual households' decisions. However, it is also likely that the complexity of the overlapping circles of rights mentioned above (Ndagala 1992) may to some degree free individuals to choose water sources based on the criteria we focus on. In other words, the choices that we modeled were likely to have been made by selecting among options that were shaped by socio-cultural norms, constraints, and obligations.

The second step of decision modeling entailed relating these criteria to actual resource use choices through survey interviews with male household heads. The survey sample (n=134) was structured to capture variation in household wealth, sub-village location (i.e., near and far from the village center), and age. The surveys that were conducted in Landanai (n=9) and Loiborsiret (n=5) were only included in the analyses of historical droughts if the respondent was living in one of the 4 focal study villages at the time of the historical drought. Otherwise, these responses were not included in the analyses due to our more limited qualitative data from these villages and related concerns about the representativeness of these small samples.

Survey interviews began with the same open-ended questions from the group interviews about where they watered livestock during the 2009 drought and during the first drought they could remember, and why they used those sites. We divided droughts in this way in order to capture the broadest possible range of drought years, while having at least one time point that could be compared across villages. Moreover, 2009 was widely agreed upon as an especially severe drought year. We then asked Yes/No questions pertaining to watering cattle that were derived from the list of decision-making criteria elicited from the group interviews. Yes/No responses were coded as 1 or 0 respectively, and the result was a table of individual resource use choices (or outcomes) and the conditions (or factors) associated with those choices.

For the final step of decision modeling we used crisp-set Qualitative Comparative Analysis (QCA) to analyze these data and evaluate resource-use decisions. QCA allows for "…systematic cross-case comparisons, while at the same time giving justice to within-case complexity, particularly in small- and intermediate-N research designs." (Rihoux and Ragin 2009: xviii) It is also useful for situations with low variation in the outcome variable or high numbers of missing values for some independent variables, which can inhibit aggregate analysis. Cases are chosen to maximize diversity in factors of interest; hence our sample of villages that vary in terms of distance from TNP, level of water development (i.e., dams and boreholes), and availability of natural water sources (i.e., rivers and swamps), and households that vary in wealth, age, and distance to village center. We used QCA to analyze survey data and identify the combinations of factors that influenced where people in each study village watered livestock during recent and historical droughts.

Group interviews suggested that the selection of livestock watering sites depends on two choices: water source type and location. We operationalized these outcomes as choosing between free and pay sources, and between local and distant sources. Pay sources were almost exclusively boreholes, but not all boreholes required payment, especially during past droughts. We coded sources as local if they were within or very near the respondent's home village boundary, and distant if they were well outside of their village or if they required multiple days of travel to reach the water source. Although this categorization was somewhat subjective, the distinction between local and distant sources was generally clear given the limited number of resource options available to households during droughts. This dichotomization was also meaningful in terms of demands on household labor, finances, and time.

QCA uses Boolean algebra to sort conditions (e.g., closest available[3] water source, well ownership) into those that are necessary and those that are sufficient to produce a given outcome (i.e., the use of a free or pay, local or distant source). In particular, we generated decision models (i.e., configurations of conditions) through an iterative process similar to the analytic induction approach used by Ryan and Bernard (2006) and recommended by Gladwin (1989). This process of iteratively improving model fit involved minimizing contradictions and remainders while at the same time maximizing coverage and consistency. Contradictions are those configurations of factors that have mixed outcomes, and remainders are configurations that are not represented in the sample.

[3] We use the term 'available' to refer to water sources that are not privately held or are otherwise inaccessible (e.g., inside a national park) and are producing water (as opposed to broken boreholes or dry dams).

Coverage is the "…number of cases following a specific path to the outcome divided by the total number of instances of the outcome," and provides an indication of the importance of a particular causal combination (Ragin 2006: 299). Consistency is "…the proportion of cases with a given cause or combination of causes that also display the outcome." (Ragin 2006: 293) For instance, if 10 out of 15 cases displaying a causal combination also display the outcome, then the consistency is 0.67. We used the *TOSMANA* software package to explore different configurations, and *fsQCA* to calculate descriptive statistics and identify necessity relations.

It is important to note that QCA identifies the different causal models (not one causal model) existing among comparable cases, which allows for different combinations of factors to yield the same result. Causality is specific to the combination of factors and context; in other words, this is not an averaging of cases, but an explicit consideration of their diversity (Rihoux and Ragin 2009).

QCA results are presented as a series of "implicants" or sets of conditions whose relationships are displayed using notation from Boolean Algebra: "*" means "and;" "+" means "or." Variable codes in capital letters represent presence (value=1), lower case letters represent absence (value=0). Below, we present complex solutions, which exclude remainders. We did not include parsimonious solutions, which include remainders for reduction, because these results often require simplifying assumptions and may exclude necessary conditions. In our efforts to reduce contradictions and thereby avoid simplifying assumptions (which can make interpretation of the results challenging), we arrived at a set of final models that do not contain contradictions (which is a common way to present results); as a consequence, the consistency for all implicants presented below is 1. For brevity, we present a subset of the outcomes and implicants that were tested. The variables considered for inclusion in implicants are listed at the bottom of the QCA results tables. We also omit villages and years with no variation in the outcome (i.e., Emboreet, 2009 source type and location; Loiborsoit, historical source type and location; and Sukuro, historical source type).

Results

Drought Resource Use

The earliest drought referenced by a respondent had been passed down through oral history and reportedly took place in 1886, and may have coincided with and exacerbated *Emutai*. The earliest drought remembered by an individual respondent occurred in the mid-1940s (approximately 1944–47). Other prominent drought years include 1952–54, '61, '74–77, '83–84, '93–94, '97, and 2009 (see Appendix I for drought timeline).

During group discussions, 2009 was often agreed upon as the most severe drought in memory, but some people believed that it only became a problem in Simanjiro because of the influx of people and livestock from other, more severely impacted areas. During that year, herders moved into Simanjiro from as far away as Longido and southern Kenya in search of water and livestock fodder, and crop failures had dire consequences for many households. The mid-1940s also saw a particularly bad drought, which was associated with "Red Bone Marrow Disease."[4]

Respondents were generally the ones responsible for making the herding decisions during the 2009 drought. During historical droughts, 50 % of respondents stated that their father made the herding decisions, with smaller proportions being represented by the respondent's brother (24 %), the respondent themselves (24 %), and other friends and family.

The mean estimated traveling time (with livestock) over all droughts from the *enkang* or temporary *enkang* to the water sources used was about one and a half hours, or roughly 3 km. However, some respondents walked up to 5 h or as far as 15 km. During droughts, herders waited anywhere from several hours to several days to water their livestock, depending on the source, but some reported no wait at all. At some river wells, people could only water a few livestock at a time and would have to wait several hours for the well to recharge before watering the next group of animals.

Roughly half of respondents used natural sources (i.e., rivers, korongos, and swamps), and half used built sources (i.e., dams or boreholes) during both historical droughts and the 2009 drought. Many of the sites used during historical droughts were also used in 2009. A variety of small drainages have remained in use, and the Terrat River has continued to serve as an important DRA. One notable difference is that no respondents used dams during the worst part of the 2009 drought, whereas this was a relatively common practice during historical droughts (25 % of respondents used dams during historical droughts). There was also an increase in the use of boreholes from 26 to 53 %.

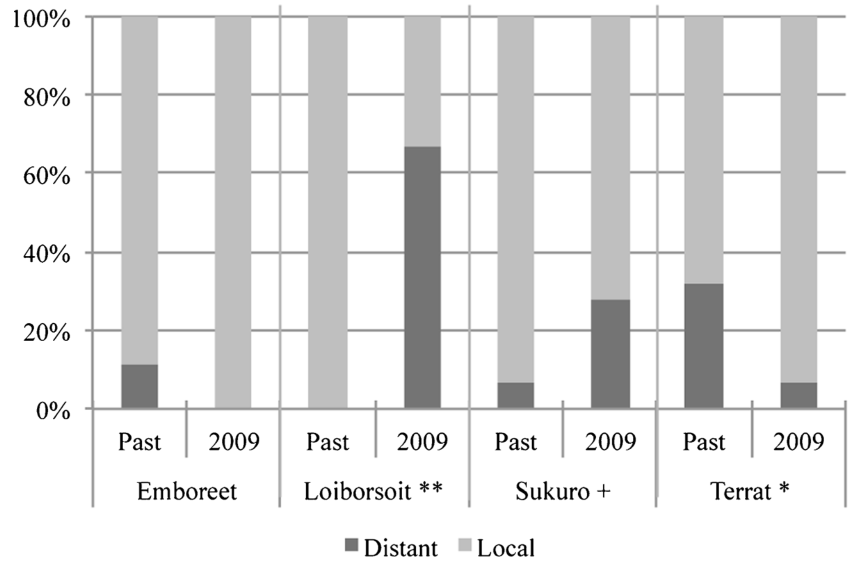
19 respondents, representing all four villages, recalled herding practices during a drought prior to the establishment of TNP in 1970. None of these respondents cited the use of Tarangire River or Silalo Swamp (now located inside TNP). Instead, these respondents cited the use of 5 rivers, 2 dams, and 2 boreholes located outside of the park. All of these individuals stated there was sufficient grazing near the watering sites they used.

There was a significant increase in the proportion of respondents who watered livestock at distant sources

[4] "Red bone marrow disease" afflicts livestock during particularly severe droughts and refers to the unusual look of the bone marrow of an animal that has died from lack of food and water, rather than an infectious disease.

Fig. 2 The proportion of respondents in each village that used local or distant water sources during the 2009 drought and historical ("past") droughts. Villages refer to the respondent's village at the time of drought.

+ $p<0.1$; * $p<0.05$; ** $p<0.01$ for Fisher's exact test of change between the two time points



(Fisher's exact test: $p<0.01$); the proportion increased from 11 % during historical droughts to 25 % during the 2009 drought. There was also a significant decline in the proportion of respondents using the nearest *available* source ($p<0.05$); 72 % of respondents used the nearest available source during historical droughts, while only 58 % of respondents used the nearest available source during the 2009 drought. The proportion of people that used distant sources varied significantly by village, both during historical droughts and during the 2009 drought ($p<0.01$). There was a significant increase in the proportion of respondents that used distant sources in Loiborsoit, and a significant but less pronounced decrease in Terrat (Fig. 2).

There was a significant increase in the use of pay sources from 14 % during historical droughts to 53 % during the 2009 drought (Fisher's exact test: $p<0.01$). The proportion of people that used pay sources also varied significantly by village, both during historical droughts and during the 2009 drought ($p<0.01$) (Fig. 3). In Sukuro, most respondents used dams in the past and boreholes in 2009. In Emboreet, nearly 90 % of respondents used boreholes during historical droughts, and people used boreholes exclusively during the 2009 drought. In Loiborsoit and Terrat the majority of respondents used rivers during both periods.

In terms of changes in individual resource use, the majority of respondents continued using the same type of source (i.e., distant or local, free or pay). Of those that changed, a greater proportion changed from using local to distant sources than vice versa, and a greater proportion changed from using free to pay sources.

Fig. 3 The proportion of respondents in each village that used free or pay water sources during the 2009 drought and historical ("past") droughts. Villages refer to the respondent's village at the time of drought.

+ $p<0.1$; * $p<0.05$; ** $p<0.01$ for Fisher's exact test of change between the two time points

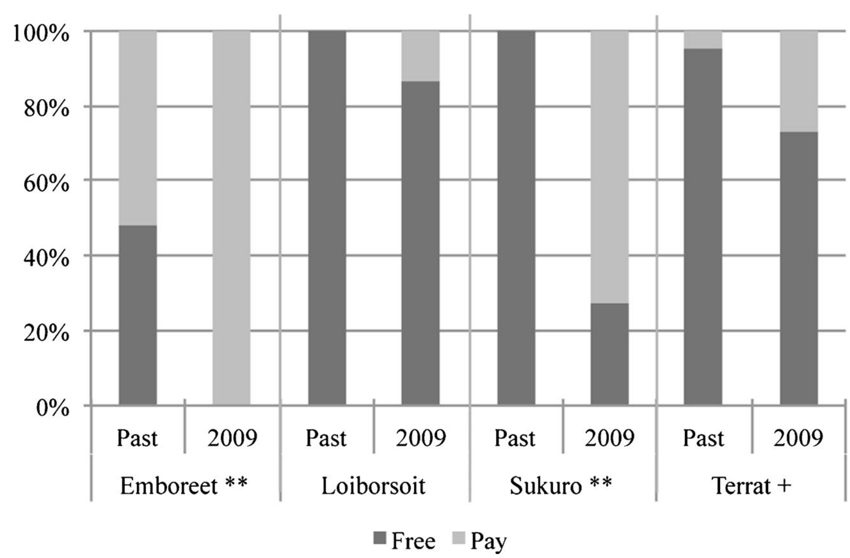


Table 1 Results of qualitative comparative analysis of the choice of free versus pay sources during the 2009 drought

Village	Outcome	Prime implicants	Coverage	Remainders
Loiborsoit	Pay (*n*=4)	**NEAREST** * ALTCAPITAL +	0.75	
		NEAREST * capital	0.50	
		Combined solution	1.0	1
	Free (*n*=26)	nearest * ALTCAPITAL +	0.615	
		CAPITAL*altcapital	0.385	
		Combined solution	1.0	1
Sukuro	Pay (*n*=21)	Grazing + capital	1.0	0
	Free (*n*=8)	GRAZING * CAPITAL	1.0	0
Terrat	Pay (*n*=8)	wait +	0.875	
		enkdist * nearest	0.250	
		Combined solution	1.0	0
	Free (*n*=22)	NEAREST * **WAIT** +	0.909	
		ENKDIST * **WAIT**	0.727	
		Combined Solution	1.0	0

Necessary conditions are highlighted in bold; "*" = "and"; "+" = "or"; lowercase letters represent the absence or opposite of a given variable (value=0)

ALTCAPITAL social capital at an alternate source, *CAPITAL* social capital at the source used, *ENKDIST enkang* located near the village center, *GRAZING* grazing at or near the source used, *NEAREST* used the nearest available source to the *enkang* or temporary *enkang*, *WAIT* long waiting times at the source used

Decision Modeling

The majority of respondents from Loiborsoit used free sources to water livestock during the 2009 drought. Taking livestock to the nearest available source was a necessary condition for the use of pay sources in Loiborsoit in 2009, and people used the nearest available borehole even if they did not know someone on the borehole committee, or if they knew someone who owned a well in the nearest river (Table 1). The majority of Sukuro respondents used pay sources in 2009, and those who used free sources reported the availability of both social capital and grazing at the site used. In Terrat, short waiting times were a sufficient but not necessary condition for the use of pay sources in 2009. There was only one respondent who used a pay source despite waiting for a long time to water his animals; he owned a large herd and reported that there was not enough water in the Terrat River and there were many people and animals using the river. This was reflected in the implicants for the use of free sources in Terrat, where long waiting times were a necessary condition (i.e., all respondents who used free sources in Terrat reported long waiting times), even for people living near the village center or using the nearest available source.

Table 2 Results of QCA of the choice of local versus distant water sources during the 2009 drought

Village	Outcome	Prime Implicants	Coverage	Remainders
Loiborsoit	Distant (*n*=20)	**CAPITAL***HERD*GRAZING +	0.350	
		CAPITAL*herd*grazing*enkdist+	0.700	
		CAPITAL*GRAZING*ENKDIST	0.050	
		Combined Solution	0.850	7
Sukuro	Distant (*n*=8)	**GRAZING** * disease * COST +	0.5	
		GRAZING * HERD * DISEASE * cost	0.125	
		Combined solution	0.625	9
Terrat	Distant (*n*=2)	GRAZING * HERD * LABOR	0.50	
		Combined solution	0.50	1

Necessary conditions are highlighted in bold; "*" = "and"; "+" = "or"; lowercase letters represent the absence or opposite of a given variable (value=0)

CAPITAL social capital at the source used, *COST* payment for water, *DISEASE* disease at the source used, *ENKDIST enkang* located near the village center, *GRAZING* grazing at or near the source used, *HERD* large herd size, *LABOR* enough labor availability

For those using distant sources during the 2009 drought, the availability of social capital at the water source was a necessary condition for Loiborsoit residents, whereas the availability of grazing was a necessary condition for Sukuro respondents (Table 2). People from Sukuro used distant sources that required payment if those sources were perceived to not have problems with livestock disease. Sukuro residents used distant sources seen as riskier for disease if the source was free and they also had a large herd. Grazing availability and large herd size were also related to long distance livestock movements for people from Terrat, but having enough labor was also a necessary condition.

During historical droughts, labor availability affected the choice of source type for residents of Emboreet (Table 3). Households that did not have enough labor used a free source if it was also the nearest available source and there were concerns about disease at alternative sources.[5] In Terrat, proximity to a water source was a sufficient, but not a necessary condition for the use of free water sources during historical droughts. Having a small herd was also associated with the use of a free source, even if it was not the nearest available source. The one household with a large herd who used a free source that was not the nearest available option expressed concern about conflict at an alternate source.

Households in Emboreet used distant sources during historical droughts if they had a large herd and concerns about disease at other locations, even if they had to wait for a long time to water their animals (Table 4). When we added variables for drought years, large herd size was the only necessary condition for using distant water sources (although this approach eliminated contradictions and increased the coverage to one, we did not include the result in Table 4 because it increased the number of remainders dramatically). In Terrat, perceptions of conflict, cultivation, disease, and waiting times affected the choice of watering location during historical droughts. Most respondents that used distant sources did not report issues with conflict and did not wait long to water their animals, but some indicated that cultivation was affecting their access to alternative water sources.[6] The respondent who reported conflict and long waiting times at a distant source that they used stated that there was disease at alternative water sources. Only two respondents from Sukuro used distant sources during historical droughts. One referred to a drought during the 1940s, and reported that the Terrat River was the nearest available source. The other respondent referred to the 1993/94 drought and stated that the dams were dry and the nearest river was crowded with many people and livestock.

The choices of water source type (i.e., free versus pay) and location (i.e., local versus distant) were influenced by different factors (Table 5 and Table 6). During the 2009 drought, proximity to a water source and the availability of social capital affected the choice of water source type in more than one village, whereas grazing availability and perceived herd size affected decisions about water source location. Grazing was a relevant factor for the choice of local versus distant sources in all villages during the 2009 drought, but not during historical droughts. Several factors were associated with resource-use decisions during historical droughts but not during the 2009 drought: conflict at the used source and other sources, cultivation around other sources, and disease at other locations.

Discussion

The significant increase in the use of pay sources across all study villages was partly due to an increase in the number of pay sites and the reduced availability of water from dams. Dams often retained water during historical droughts but many were dry during the 2009 drought. The apparent increase in the proportion of respondents from Emboreet who used pay sources was due to several boreholes switching from free to pay sources in the recent past. In Sukuro, the same pattern was likely due to the development of a new (pay) borehole within the village coupled with a lack of water in the Sukuro Dam during the 2009 drought, which did not always dry up during past droughts.

Most rivers became dry during droughts, but the availability of surface water in rivers was not significantly correlated with use. Many households moved livestock to the Kikoti River during the 2009 drought even though it did not have surface water (instead, herders extracted water from hand-dug wells in the river channel and adjacent floodplain). The significant increase in the use of distant sources by households in Loiborsoit is likely related to the use of the Kikoti River. In contrast, the observed decrease in the use of distant sources by Terrat households may be related to the development of new water sources prior to the 2009 drought. The overall increase in the proportion of respondents who used distant sources, such as Kikoti River, and the finding that fewer people were using the nearest *available* source in 2009 compared to the past suggests that something other than water availability has influenced changes in mobility. It is possible that this finding was a result of increased drought severity, but we were unable to control for drought severity because of a lack of local historical rainfall data coupled with the fact that drought severity is the product of a confluence of factors (i.e.,

[5] There were several contradictory cases (i.e., cases that had different outcomes – some people used free sources and some used pay sources – for the same combination of factors), but only because some boreholes were free and some were not during historical droughts. All of these respondents were using boreholes.

[6] The two respondents that reported issues with cultivation were referring to the relatively recent 1993/94 drought.

Table 3 Results of QCA of the choice of free versus pay water sources during historical droughts

Village	Outcome	Prime implicants	Coverage	Remainders
Emboreet	Free (*n*=14)	labor *NEAREST *DISOTHER *WAIT +	0.643	
		LABOR * nearest * WAIT +	0.143	
		LABOR * nearest * DISOTHER +	0.143	
		LABOR * NEAREST *disother * wait	0.071	
		Combined solution	0.930	7
Terrat	Free (*n*=22)	NEAREST +	0.762	
		herd * cftother +	0.333	
		HERD* CFTOTHER	0.095	
		Combined solution	0.953	1

"*" = "and"; "+" = "or"; lowercase letters represent the absence or opposite of a given variable (value=0)

CFTOTHER conflict at alternate source, *DISOTHER* disease at alternate source, *HERD* large herd size; *LABOR* enough labor availability, *NEAREST* used the nearest available source to the *enkang* or temporary *enkang*, *WAIT* long waiting times at the source used

precipitation, hydrology, land use, water demand). According to respondents, the severity of the 2009 drought in Simanjiro was exacerbated by the influx of livestock from other areas. This is consistent with the finding that the increase in the use of distant sources was largely a consequence of reduced grazing availability.

QCA results demonstrated that the choice of water source location was related to perceived herd size and grazing availability, and to a lesser extent labor, cost, disease, social capital, and household location. Grazing was a relevant factor for the choice of local versus distant sources in all villages during the 2009 drought, but not during historical droughts. This finding does not necessarily mean that grazing was not an important factor in decision-making during historical droughts, only that the availability or lack of grazing near the water source used was not a relevant factor for distinguishing between those households that used distant sources and those that used local sources during historical droughts. However, group interviews suggested that grass was generally more abundant during historical droughts, and during the 2009 drought, the influx of livestock from further north diminished grazing resources in Simanjiro. Herd size and grazing availability are closely related because having a large herd increases the amount of fodder that a herder must find for his animals. The finding that the majority of people who watered livestock at distant sources during the 2009 drought used rivers (73 %; *n*=22) may also be related to lower likelihood of finding grazing near developed sources, which are often located closer to village centers and are generally more likely to be surrounded by overgrazed pasture.

The choice of free versus pay sources during the 2009 drought was dependent on a household's proximity to the source and social capital, and to a lesser extent waiting times, household location (distance from the village center), and grazing. The increased use of boreholes during the 2009 drought coupled with differences in the governance structures of boreholes and wells indicates that the role of social capital in water use has changed over time. Respondents were more likely to report knowing a friend or family member who owned a well in a river than someone who served on a borehole committee; this was partly because there are a larger number of river wells compared to boreholes, and because clan affiliation can determine which wells a herder is able to use. Clan membership can give a herder priority access to a

Table 4 Results of QCA of the choice of local versus distant water sources during historical droughts

Village	Outcome	Prime Implicants	Coverage	Remainders
Emboreet	Distant	HERD * DISOTHER * WAIT	0.500	
	(*n*=4)	Combined solution	0.500	2
Terrat	Distant (*n*=8)	cft * CULOTHER * disother +	0.286	
		cft * culother * wait +	0.429	
		CFT * culother * DISOTHER * WAIT	0.143	
		Combined solution	0.857	8

"*" = "and"; "+" = "or"; lowercase letters represent the absence or opposite of a given variable (value=0)

CFT conflict at source used, *CULOTHER* cultivation affected access to alternate source, *DISOTHER* disease at alternate source, *HERD* large herd size, *WAIT* long waiting times at the source used

Table 5 Factors associated with decisions about water source location (L) and cost (C) during the 2009 drought

	Loiborsoit	Sukuro	Terrat
Household location	L		C
Cost		L	
Disease		L	
Grazing	L	C&L	L
Herd size	L		L
Labor			L
Nearest available	C		C
Social capital	C&L	C	
Social capital at alt. source	C		
Waiting			C

river well, but is less effective for gaining faster access to boreholes that are controlled by formal village committees, which crosscut clan and family ties. Village-based committees regulated access to most boreholes in recent droughts, but this was not always the case in the past when some boreholes had no regulatory committee or people from outside of the village operated them. These changes in borehole management and use suggest that social ties other than clan affiliation have gained importance for accessing water during droughts.

Some decision-making factors were unique to a particular village. For respondents in Terrat during the 2009 drought, labor availability was relevant to the choice of water source location, and waiting times and household location affected the choice of source type. The influence of labor availability on herding decisions in Terrat should be interpreted with caution because the implicant explained the decision of only one of two individuals who used distant water sources (i.e., small sample size). Nonetheless, it is likely that increasing children's school attendance or wage labor migration of other household members (especially young men looking for mining-related work in Mererani; Smith 2012) have affected the number of people in the household that are available to help herd during drought and non-drought periods (Goldman 2006). Of the Terrat residents who used boreholes, a greater proportion reported short waiting times compared to the other villages (Terrat=88 %; Sukuro=10 %; Loiborsoit=25 %; Emboreet=33 %). Yet even Emboreet respondents did not cite waiting times and grazing availability as major problems, despite the fact that they used boreholes almost exclusively during droughts. This could be the result of effective resource management practices, lower total demand on water and grazing resources, higher rainfall in that village, or a combination of several factors.

Table 6 Factors associated with decisions about water source location (L) and cost (C) during historical droughts

	Emboreet	Terrat
Conflict		L
Conflict at other sources		C
Cultivation at other sources		L
Disease at other locations	C&L	L
Herd size	L	C
Labor	C	
Nearest available	C	C
Waiting	C&L	L

Conflict, disease, and cultivation were factors that affected decision-making during historical droughts but not in 2009. These factors may be perceived as less of a concern in recent years because of improved access to veterinary medicine and better mediation of conflict and land use plans. However, comparing decision-model results for recent and historical droughts is problematic because of the aggregation of drought years that had different social and physical conditions.

Perhaps the most surprising finding from this study is the absence of respondents who brought cattle to sites that are now within TNP (i.e., Silalo Swamp and Tarangire River) during historical droughts. We see three possible explanations for this finding: the people most affected by this change emigrated or left the pastoral sector (and were therefore omitted from our sample), the sample of people who recalled droughts that occurred prior to TNP was not large enough to capture people who used those sites, or the utility of some areas within TNP was different than previously thought. We cannot rule out the first possibility, but the second seems unlikely given the supposed importance of these resource areas. Group interviews from the four core study villages and from Loiborsiret are consistent with the third possibility, and shed light on the possible reasons for this surprising finding.

When asked about watering cattle during droughts that occurred before the establishment of TNP, people rarely mentioned the use of the Silalo Swamp or Tarangire River. Most people relied on wells in rivers and korongos within Simanjiro. Residents of Emboreet (who live especially close to TNP) stated that most livestock used the Terrat River and some used the Loiborsiret River before the colonial government drilled two boreholes and built 2 dams in the 1950s. Similarly, respondents from Loiborsiret (also adjacent to the park boundary) cited the use of the Loiborsiret River for cattle during historical droughts.

When asked specifically about their use of Silalo Swamp, respondents often stated that it was a good grazing area for small stock (i.e., sheep and goats), but they also cited concerns about livestock disease and water availability for cattle. Silalo is dependent on rainfall for surface water and during droughts it was difficult to dig large enough wells to obtain sufficient water for cattle. Moreover, Silalo was a problem area for ticks and tick-borne livestock diseases (e.g., East Coast fever), and for tsetse flies that transmit trypanosomiasis to people and animals. These diseases have been implicated in the uneven distribution of livestock in precolonial Tanzania more broadly (Koponen 1988), and would have been of particular concern during periods with little access to cattle dips, veterinary medicine, and clinics. Historically, some people would, however, take their animals to TNP at the beginning of the rains in order to avoid bovine malignant catarrhal fever that is spread by wildebeest calving in the Simanjiro Plains during the wet season.

When asked about the Tarangire River, people cited concerns about wildlife, water quality (high salinity), and the presence of other ethnic groups. Barabaig herders were living on the far side of the Tarangire River and Silalo Swamp, so using these areas would have meant an increased risk of conflict and cattle raiding. Dorobo and Mbugwe hunters and gatherers were also living in and using the TNP area, but conflict with these groups was not expressed as a concern. Maasai and Dorobo share a variety of cultural traits but have distinct production strategies (Galaty 1993), which may have reduced competition over resources. Dorobo is a Maasai word meaning "'poor' – by inference, those without cattle." (Sutton 1993: 50) The presence of hunter-gatherers within TNP is consistent with the idea that the area was not ideal for livestock keeping due to wildlife and disease risks.

The discrepancy between our findings and our expectations may be related not only to the distinction between grazing areas for cattle versus small stock, but also to changes in perceptions about resource availability. Livestock herders now perceive sites within TNP as valuable *potential* DRAs due to increased pressure on resources outside of the park and improved access to veterinary medicines that would reduce the disease risks associated with using those sites. In other words, the perceived value of Silalo Swamp and Tarangire River as DRAs may be heightened by broader changes in resource availability in the region and in Simanjiro. Some respondents stated that grazing availability was being compromised by increases in human and livestock populations, cultivation, and other conservation areas. Agriculture is an increasingly common aspect of Maasai livelihoods, but problems with cultivation were often viewed as stemming from immigrant landowners and large-scale commercial agriculture. Private safari and hunting companies seeking to establish areas that are free of herders and livestock have also substantially impacted households in the area in recent decades and threaten to further affect access to key resource areas. The configuration of land uses is also relevant because cultivation and other land uses is disrupting access routes to both grazing and water resources in some communities.

Limitations

This research yielded a number of substantive findings, but, like all studies of complex, real-world phenomena, it suffers from several limitations. First, this research focused on male heads of household. We recognize that human-environment interactions are gendered; men and women have different environmental knowledge, rights, levels of involvement in management, and day-to-day responsibilities (Robbins 2004). Women's roles in Maasai society have often been ignored or marginalized by development initiatives (Hodgson 2001), but should be an integral part of land use planning and water development decisions. Women play a key role in making decisions about acquiring water for the household, and therefore have a substantial bearing on health and sanitation. The factors influencing women's decisions about water acquisition are likely to be distinct from the factors affecting men's livestock watering decisions, and as a result, changes in resource availability are likely to have different implications for men and women. We collected interview and survey data on women's water-gathering decisions, and we plan to explore gender differences in future work.

Second, dichotomization is not a very precise way to operationalize measures of rather complex social and environmental variables, especially considering that these variables can sometimes overlap (e.g., labor and social capital). In future studies, it would be useful to include continuous or categorical variables for measures of wealth, waiting times, and water source locations, and to analyze these data using multi-value or fuzzy set QCA. We could also account for different types of conflict. For example, conflict during the 2009 drought was generally not violent or severe; rather, arguments were arbitrated by others in the community such as elders or committee members. This is distinct from conflict that may have occurred during historical droughts involving cattle raids or violent confrontations between ethnic groups.

Third, we did not compare our findings against a separate sample of individuals because of a lack of data. Testing the predictive capacity of these models on another sample from the study villages would provide an indication of the models' internal validity, which is the typical form of validation for ethnographic decision models (Ryan and Bernard 2006). It would also be interesting to repeat this kind of analysis in other communities that may have had different histories of utilization of resources now in TNP, including villages on the west side of the park.

It is also possible that respondents in our sample were not being truthful about illegal use of TNP. Although illegal use of parks is risky for herders (who face arrest, fines, livestock confiscation, or worse if caught), it is certainly not unheard of (Butt *et al.* 2009; Goldman and Riosmena 2013). We found that some people illegally grazed their animals in grasslands on the eastern side of Tarangire, but these were mostly migrants into the area from Longido and southern Kenya who grazed their animals in the grasslands. People in our study villages generally reported that that they had enough grazing resources, although some did have to go to the park boundaries because migrant livestock had consumed all of the grasses in their village. Even allowing for the possibility that people grazed animals inside of TNP illegally during the 2009 drought, this would not detract from our finding that respondents did not report grazing cattle in Silalo and Tarangire River during droughts prior to the establishment of TNP.

Finally, there was potential for recall error, especially for droughts that were further in the past. However, we are confident in the accuracy of respondents' recollections of herding practices during historical droughts, even ones in the 1940s, because of the salience of these events and the importance of these memories for avoiding disaster during subsequent years. Droughts have severe effects on livestock mortality and calving rates, and longer-term impacts on herd demography (Dahl and Hjort 1976). Herding successes and failures during these periods are so important that they are transmitted across generations through oral history.

Conclusion

East African rangelands are undergoing considerable changes in land use and development. Water developments are having substantial positive impacts on household water security, but boreholes are prone to overcrowding and breaking, so increased dependence on developed water sources could increase vulnerability to severe droughts. Small rivers and even ephemeral streams continue to serve as critical DRAs for residents of Simanjiro as well as livestock herders from as far away as southern Kenya. Maintaining rivers and streams as accessible and productive resource areas is essential for supporting pastoralist livelihoods in the region.

Results supported our expectation that decisions regarding where to water livestock during droughts before and after TNP was established vary by village, but we cannot demonstrate that this variation was due to village proximity to TNP. On the contrary, this variation is more closely related to levels of water development and proximity to the primary natural water sources in Simanjiro. Changes in grazing availability are also central to these decisions.

The effects of the establishment of TNP on livestock herding were different than anticipated. In contrast to our expectations based upon previous studies, we did not find evidence that sites that are now within TNP (Tarangire River and Silalo Swamp) were key resource areas for cattle during historical droughts. Rather, these places were more commonly used as grazing areas for small stock and wet-season grazing areas for cattle to avoid malignant catarrhal fever carried by calving wildebeest. To some degree, the use of Silalo Swamp and the Tarangire River were limited by risks from diseases such as East Coast Fever and trypanosomiasis, insufficient water availability, and interactions with other ethnic groups. Dams, boreholes, and especially several smaller rivers and drainages nearer the study villages have been important water sources during recent and historical droughts due to a variety of social and environmental factors. These findings are consistent with the notion that pastoralist herding strategies are generally a balance of resource needs and risks (McCabe 2004).

This is not to say that TNP has not affected Maasai households; TNP has indeed influenced resource access (Goldman 2003; Igoe and Brockington 1999; Igoe 2004; 2002; Sachedina 2006), risk perception (Baird *et al.* 2009), education and water infrastructure (Baird 2014), and livelihood diversification (Baird and Leslie 2013). Our work suggests that TNP also affected small stock and wet-season cattle herding. Subsequent conservation initiatives (including community-based conservation efforts) have continued to affect local communities, including loss of ownership and control over land and resources (Goldman 2011; 2003). The effects of these conservation initiatives are especially troubling in light of concerns related to household food insecurity and changes in climatic variability in the region (Galvin *et al.* 2004).

Despite the simplification of decision-making processes that is inherent in decision modeling, this study has shown that such modeling is useful for understanding the balance of factors that affect resource-use choices. Deconstructing and analyzing resource-use decisions, instead of thinking of them as singular choices, was informative; by conceptualizing the selection of a livestock watering site as at least two choices – water source location and type – we were able to identify the different sets of factors influencing each choice. Overall, we found that resource-use decisions are complex and incorporate a variety of information beyond the size or reliability of a given resource area, including contextual factors (e.g., disease, conflict, water cost, waiting times, and grazing) and household factors (e.g., social capital, labor, herd size).

When evaluating resource-use decisions in a conservation context, it is necessary to account for the ways in which conservation and other community-level characteristics translate into specific opportunities and constraints at the household-level. In other words, it is the combination of context, household conditions, and individual perceptions that influence how people respond to changes in resource access. A better understanding of these behavioral responses to changes in resource access is needed in order to improve the social and environmental outcomes of conservation initiatives (Miller *et al.* 2012). Ethnographic decision modeling, QCA, and related methods can help meet this demand by offering a structured way to identify the factors affecting human choices and behaviors.

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Appendix I

Hydrologic event calendar; D=drought, Dis=disease outbreaks, W=water development, R=rainfall, and H=other hydrologic events; **Olengesher* is a meat eating ceremony that signifies the transition of an ageset from senior warriors to elder

Reporting Village(s)	Loiborsoit	Terrat	Terrat	Emboreet, Sukuro, Terrat	Sukuro, Loiborsoit	Emboreet	Sukuro	Emboreet, Terrat	Loiborsoit	Sukuro	Emboreet, Terrat	Loiborsoit, Emboreet, Terrat, Sukuro	Terrat	Sukuro, Terrat, Emboreet, Loiborsoit	Loiborsoit, Terrat	Loiborsoit
Event	D	Dis	D	D	W	W	D	D	R	H	D	D	W	D/Dis	D	W
Year and/or Social Landmark	1886	1894-1898 (Ituati were warriors)	1944-47 (Nderito were warriors)	1952-54 (Meshuki were warriors; Iseuri ~12 years old)	1954	1957	1961 (2 years after Meshuki finished Olengesher*; Iseuri were jr. warriors)	1964-67	1968	1968 (Seuri became warriors)	1971-72	1974-77 (Iseuri Olengesher)	1981	1982-85	1987	1990
Description	"The year that people ate donkey meat"	*Emutai;* disease epidemics and warfare	Red bone marrow disease	There was water in the Terrat River, but people moved to Loiborsiret because of rain and grass	Sukuro Dam and Loiborsoit borehole were built by the colonial government	Red Dam and Emboreet Borehole built	"The Red Grass Year;" people moved from Sukuro to Kisongo and Manyara	"The year of the sun;" people ate cow hides; some in Terrat consider this the worst drought in memory	"The year of water" good rains followed by elevated water table for several years, the Sinya River was flowing	Loiborsiret and Kiti Engare Rivers "started" flowing		People moved to Loiborsiret and beyond to Kiteto and Kondoa because of a lack of grass	Government built a borehole	Rinderpest outbreak; a lot of dead wildebeest; U.S. brought food aid		Borehole and dam built

Reporting Village(s)	Sukuro, Terrat	Loiborsoit	Emboreet, Loiborsoit, Sukuro, Terrat	Sukuro	Sukuro, Loiborsoit, Terrat, Emboreet	Emboreet, Sukuro, Terrat	Sukuro; Emboreet, Terrat	Sukuro	Sukuro, Terrat	Sukuro	Emboreet	Sukuro, Loiborsoit, Terrat	Sukuro, Emboreet, Loiborsoit, Terrat	Sukuro, Terrat	Loiborsoit, Emboreet, Terrat
Event	D	W	D	W	D	D	D	W	D	W	W	W	H, D	W	W
Year and/or Social Landmark	1990-91	1992	1993-94	1996	1997-98	1999-2000	2002-03	2003	2005-06	2007	2008	2009	2009	2010	2011
Description		People discovered water by digging wells in the Kikoti River	People moved to Sukuro from Kondoa	2 hand pumps built near the Kiti Engare river	People moved into Loiborsiret; people in Loiborsoit were using the Kikoti River wells			Windmill borehole built	People took their animals toward the park and even into the park	District govt. built dam in Loiborsiret; hunting co. built cement barriers in Kiti Engare river to collect water and attract wildlife	Dam built in Emboreet	Borehole built in Sukuro by village; windmill borehole built in Loiborsoit; borehole built in Terrat	People brought livestock to Simanjiro from across the region; first time people came from Kenya	3 boreholes built in Kiti Engare; 2 boreholes built in Terrat	4 boreholes under construction in Loiborsoit; 2 in Emboreet; 1 in Terrat

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